

Australian National University

Eliciting Plasma Illumination as a Responsive and Relational Medium within Blown Glass

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A thesis submitted for the degree of Doctor of Philosophy of
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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge, it contains no material previously published or written by another person, except where due reference is made in the text.

Harriet Schwarzrock

February 2026

Abstract

This practice-led research investigates plasma illumination within blown glass as a responsive and relational medium through creative practice. Unlike the distant spectacle of auroras or lightning, plasma illumination invites proximal engagement with these phenomena. Drawing on the dual etymology of plasma, as both the luminous fourth state of matter and a vital component of blood, the illuminated objects and installations created through this research evoke circulatory pathways as a metaphor for connection and presence.

Using a diffractive methodology, I combine techniques from glassblowing, neon fabrication, and scientific glass working to make a plasma vessel. I draw upon the tripartite process known in the neon lighting trade as “processing”, which involves: 1) glass vessel formation; 2) atmospheric manipulation; and 3) electromagnetic activation. I subject this tripartite process to a craft-intensive methodology that I describe as leaks and tangles. Subsequently, the varied interior surface of the vessel actively contributes to the plasma's behaviour, while the glass's transparency allows those behaviours to remain visible.

Informing this doctoral project are interviews with eleven international plasma illumination practitioners, documenting the language of makers alongside field research examining histories of scientific apparatus. Resonant with the relational interpretation of quantum mechanics, the principle that phenomena emerge through interactions rather than existing as isolated entities, I reframe plasma illumination as a relational medium. Through iterations of encasing plasma phenomena within glass objects and installations, the artworks demonstrate oscillatory behaviours in relation to the glass surface and the viewer's proximal engagement, revealing our otherwise unperceived interconnectedness.

Ethics

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee *(Protocol 2022/765).* The Fieldwork Approval Protocol letter is provided in the appendices.

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I acknowledge the Traditional Owners of the unceded lands of the Ngunnawal and Ngambri peoples. This is the place that I call home, where I live, make, and work. I pay profound respect to the knowledge and connections of Elders past, present, and emerging, and I recognise my First Nations colleagues.

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During donations at Lifeblood Australia, I find care and support alongside continued fascination with the dual meanings of plasma: both as bodily fluid and as illuminated

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Content warning: The artwork and exegesis contain bright light from plasma illumination and images of plasmapheresis, blood-plasma donation.

Table of Contents

Declaration i
Abstract ii
Ethics iii
Acknowledgements iv
Table of Contents vii
List of Figures xi
Chapter 1: Introduction 1
1.1 Research Questions 3
1.2 Plasma's Dual Etymology 8
1.3 Making with the Thing-ness of Light 13
1.4 Practitioner Interviews: Working with the Material of Plasma 18
1.5 Particulate Thing-ness of Light 20
1.6 Context 22
1.7 Methodology 26
1.7.1 Physical Diffraction 27
1.7.2 Diffraction as Methodological Framework 30
1.8 Plasma's Tripartite Process: My Practice of Leaks and Tangles 33
1.9 Interconnected Circulatory Process 36
1.10 Exegesis Structure 38
Chapter 2: Examining the Curious Phenomena of Plasma— From Invisible to Visible Matter 42
2.1 The Fourth State of Matter: Beyond Gas in Concert with Energy 42
2.2 Creating Low-Pressure, Altering Atmospheres 45
2.3 Early Plasma Phenomena: Barometric Light and Static Electricity 47
2.4 Electromagnetic Activation: From Coils to Transformers 49
2.5 Luminous Gas-Discharge Tubes: Geissler 50
2.6 Scientific Craft, Visualising the Invisible, Magnetism and Electrons 56

2.7 Tripartite Glass Manipulation 59
2.8 Invisible Made Visible: Non-Reactive, Rare, Inert, or Noble Gases..... 62
2.9 Sensing an Aurora 68
2.10 My Community of Contemporary Plasma Practitioners 70
2.11 Contemporary Art Practice with Plasma..... 77
2.12 Darkness as Collaborator 81
2.13 Wonder as a Catalyst 83
2.14 Touching but Not Touching 85
2.15 Excitation: Light Production 86
2.16 Reflections: Toward a Relational Understanding of Plasma 91
Chapter 3: *Intra/twined* and *Chambered Vessels*—Exploring Plasma's Responsive Nature within Blown-Glass Vessels 93
3.1 From Haptic to Proximal Interaction: *Between Movement and Stillness* 95
3.2 Tripartite Process: Blown-Glass Vessel Formation..... 98
3.2.1 Coloured Glass Applications 102
3.3 Tripartite Process: Atmospheric Manipulation and Electrode Attachment 106
3.3.1 Atmospheric Manipulation—Manifold as Connector..... 113
3.3.2 Connecting the Vessels to the Manifold 117
3.3.3 Testing for Leaks 118
3.3.4 Removing Atmospheric Impurities: Cleaning the Vessel 124
3.3.5 Playful Plasma Colour Testing and Luminous Effects 125
3.3.6 Sealing and separating 132
3.4 Tripartite Process: Electromagnetic Activation 134
3.4.1 Gas-Specific Behaviours and Interactions..... 138
3.5 Paired Systems*: Intra/twined* Vessels 141
3.6 Chambered Vessels: Internal Architecture Illuminated 144
3.7 Outcomes and Reflections 157
Chapter 4: *Entangled Vessels*—Manifold and Capacitance as sites of Circulation, Containment and Connectivity..... 160
4.1 Tubular Forms: From Vessel to Connecting Conduit 163

4.2 Plasmapheresis; Plasma, Blood, Content Warning 166
4.3 Manifold as a Flexible System: Ed Kirshner's Method 167
4.4 Borosilicate Tubing and Texture with Peter Minson 170
4.5 Bridging Techniques with Steven Cole: Creating Three-Dimensional Conduits 173
4.6 Masterclass at Strattman Design and Corning residency 178
4.7 Manifold as Conduit 182
4.8 Capacitive Illumination and Voltage Differential 186
4.9 Fields of Potential 189
4.10 Reflections 196
Chapter 5: Properties of Plasma—From Responsiveness to Relationality 198
5.1 Testing Plasma's Responsiveness in My Home Studio 201
5.2 Makers Forum: Participant-Driven Engagement 203
5.3 Generous Encounters: Speculative Objects at Suki & Hugh Gallery 206
5.4 Canberra Museum and Gallery Installation: *Nearly Barely There* 214
5.5 Classics Museum: Spiralling Symbiotic Objects 224
5.6 Plasma Behaviours: Observation, Documentation, and Presentation 233
5.7 Reflections 239
Chapter 6: Conclusion 241
6.1 Historical Context 241
6.2 Methodology 243
6.3 Findings in Relation to the Research Questions 244
6.4 Contributions to Knowledge 249
6.5 Impact and Significance 250
6.6 Limitations and Future Directions 251
Bibliography 253
Appendices 271
Fieldwork Approval Protocol 271
Interview Transcripts 273
1 Tate McAluney 273

2 Steven Cole 284
3 Daniel Davis 293
4 Percy Echols II 329
5 Jeff Feigen 338
6 Mundy Hepburn 352
7 Ed Kirshner 362
8 Amy Lemaire 383
9 Aaron Ristau 392
10 Kamila Mróz 413
11 Wayne Strattman 417

List of Figures

All images not otherwise attributed are of the author's own work.

Figure 1 Detail of plasma illumination, blown glass, transformer, ionised gases, 2022. Photo Mark Mohell. 1

Figure 2 The image shows Geissler tubes from the mid-1800s, illuminated using a Tesla coil, held by Rïse Peacock. The electrical spark from the Tesla coil provides the energy to ionise the low-level gas contents within this tube into their light-emitting plasma state. From the Corning Museum of Glass Historic gas discharge illumination, educational collection. 7

Figure 3 Kacie Lees, diagram titled "Atomic Excitation in a Luminous Gas Lamp," in *Neon Primer: Handbook on Light Construction,* 69. 10

Figure 4 Wayne Strattman, *Art of Plasma*, 137. Diagram describes energy pathways and capacitive coupling of the plasma globe from power-supply to ground. Illustration by Cary Rapaport 12

Figure 5 : The perforated line exemplifies the "leaks and tangles" metaphor I use to describe the tripartite process for the studio production for eliciting plasma illumination, 2025. 15

Figure 6 Thomas Young, 1807 illustration presented in a lecture in 1807, showing his famous two-slit diffraction experiment for water in a ripple tank. Thomas Young's sketch of wave diffraction. Wave sources A and B produce distinctive interference phases at points C, D, E, and F. Source: Thomas Young/Wikimedia Commons. 27

Figure 7 Laser beam diffraction pattern. Wisky, licensed under CC BY-SA 3.0, via Wikimedia Commons. 28

Figure 8 Double slits produce two coherent sources of waves that interfere. (a) Light spreads out (diffracts) from each slit because the slits are narrow. These waves overlap and interfere constructively (bright lines) and destructively (dark regions). We can only see this if the light falls onto a screen and is scattered into our eyes. (b) Double-slit interference pattern for water waves is nearly identical to that for light. Wave action is greatest in regions of constructive interference and least in regions of destructive interference. (c) When light that has passed through double slits falls on a screen, we see a pattern such as this. Credit: PASCO. 28

(L) Figure 9 Helen Klus, *Newton's Theory of Light*, The Star Garden, http://www.thestargarden.co.uk/Newtons-theory-of-light.html, licensed under CC BY-NC-SA 4.0. 29

(R) Figure 10 Detail of a plasma vessel viewed through a diffraction grating, revealing its constituent rainbow of spectral lines, 2023. 29

Figure 11 *Chambered Vessel,* 2024, plasma-illuminated blown glass vessel. This image evidences diffraction, showing how the luminous radiation squeezes through a small aperture, spilling wave-like into a larger volume, creating intersecting patterns of light. 30

Figure 12 Percy Echols II, “Elements of Plasma Diagram,” *Taming Lightning*, https://taminglightning.net/blog/elements-of-plasma-visual-diagram-2nd-edition-expanded. 34

Figure 13 Diagram of “leaks and tangles”, indicating the non-linearity of this practice, 2025. 36

Figure 14 Scott Riddell, “Scheme of Circulation,” 1913, from *A Manual of Ambulance*, Wellcome Collection. 37

Figure 15 Ink and watercolour sketch, 2024, showing vein-capillary-artery system, based on a diagram from *Encyclopædia Britannica*. 38

Figure 16 “The Evolution of Atomic Theory, as Illustrated by Models of the Oxygen Atom,” from “2.4: The Structure of Atoms,” Chemistry LibreTexts, licensed under CC BY-NC-SA. 44

Figure 17 *Torr Concept Sketch*, 2025. 46

Figure 18 Neon-filled tendril excited by static electricity, 2024. The blur is the artist's hand twisting one tube. 48

(L) Figure 19 Michael Faraday's electromagnetic coils, Royal Institution, London. Samples of coils Faraday made and used in his experiments. 49

(R) Figure 20 Example of Faraday's coils, wound wires around a metal core, demonstrating material configuration that induced electrical phenomena. 49

Figure 21 Examples of Geissler tubes from the glassblowing laboratory headed by Sally Prasch at the University of Massachusetts Amherst, USA, during field research in 2023. 51

Figure 22 Video still from GeeksforGeeks, “Discovery of Electrons,” 2022, visualising the circuit of a discharge tube with cathode and anode. 53

Figure 23 An electric glow discharge (Crookes tube) showing the different glowing regions in the gas that appear when a high DC voltage is applied between the electrodes. 54

Figure 24 Julius Plücker diagrams illustrating variations of striations produced by the glass vessel's architecture and the distance between positive and negative electrodes. Plücker, “XIV. On the Action of the Magnet upon the Electrical Discharge in Rarefied Gases,” 123. 55

Figure 25 William Crookes's cathode ray tube, blown glass, possibly with tungsten wires, approximately 25 cm. Description from Royal Institution wall text. 56

Figure 26 Carmel Azzopardi, "Maltese Cross.Avi," YouTube video stills, Magnet changing shadow shape on tube wall. Video still (timestamp 0:35, 1:05) https://www.youtube.com/watch?v=IzcApoeuG-s 57

Figure 27 Glassblower at work, Cavendish Laboratory, Cambridge University, ca. 1897, Whipple Museum of the History of Science. Photograph from the period of J. J. Thomson's electron discovery. Glassblower unidentified..... 59

Figure 28 Deirdre Feeney, *Hollow Lens*, 2017–19, glass, water, electronic pump, steel, laser-cut acrylic, plastic tubing, Raspberry Pi, 3D-printed PLA, LCD screen, LED, and driver. 60

Figure 29 Glass ingot samples produced by Michael Faraday. Royal Institution, London. 61

Figure 30 Modern periodic table showing Group 18, the noble gases (in white). *Encyclopædia Britannica*. 63

Figure 31 William Ramsay as the personification of chemistry. Leslie Ward, chromolithograph, *Vanity Fair*, 1908. Edgar Fahs Smith Memorial Collection, University of Pennsylvania. 63

Figure 32 Diagram showing noble gases (Group 18) with stable outer electron shell configurations. Radon is radioactive. Technology UK, https://www.technologyuk.net/. 64

Figure 33 Emission spectral lines for elements in the periodic table. Atomic Spectra, Untitled [Interactive Atomic Table.] n.d. 65

Figure 34 Colour chart of noble gases ionised as plasma. Hg = mercury; argon with mercury produces high UV for phosphor-coated tubes. Strattman Studio, photographed during field research, 2023. 66

Figure 35 Aurora australis over Kunanyi/Mt. Wellington (palawa kani: Kunanyi), Hobart, Tasmania, August 2024. 68

Figure 36 Diagram of visible light spectrum. National Institute of Standards and Technology (NIST), “What Is Spectroscopy?,” n.d. 70

Figure 37 Wayne Strattman, *Emergent no. 1: Growth*, flameworked borosilicate glass, inert gas, electricity, 51 x 36 x 71 cm. 72

Figure 38 Ed Kirshner, *Dancing Mushrooms* (detail). From “Aurora Sculpt,” artist's website, accessed October 1, 2025, https://www.aurorasculpture.com/. 73

Figure 39 Percy Echols II, *Atupa, Aurora Purple*, 2024, furnace-blown and engraved glass, h. 15.5 in. (39.4 cm). Photo by Allison Burrell. 75

Figure 40 Percy Echols II, *Atupa, Aurora Purple,* Illuminated*,* 2024, furnace-blown and engraved glass, h. 15.5 in. (39.4 cm). Photo by Allison Burrell..... 75

Figure 41 Kamila Mróz, *Intrinsic Bond Energy II* (installation detail), 2023. Photo by Zuzanna Czech. 76

(L) Figure 42 Catherine Richards, *L'intrus*, 2012, interactive glass heart with electromagnetic properties. Artist's website. 78

(R) Figure 43 Catherine Richards, *L'intrus*, 2012, illuminated, when handled by spectators, the jar and glass heart excite, phosphoresce, and beat. 78

Figure 44 Tavares Strachan, *Robert*, 2018, blue neon, purple neon, Pyrex, transformers, MDF box, dimensions variable. Installed at 58th International Art Exhibition, La Biennale di Venezia, *May You Live in Interesting Times*, 2019. Photo by Andrea D'Altoè/Neonlauro, courtesy of the artist. 79

Figure 45 Haines & Hinterding, *Encounter with the Halo Field*, 2016, video, 5:23 min. MCA Australia. Installation views, *Extraction, Extinction and Post-Carbon Futures*, UQ Art Museum, 2023. 80

Figure 46 Anthony McCall, *Line Describing a Cone*, 1973. Installation view, Tate, London, September 2024. 82

Figure 47 Kacie Lees, orbital ring diagram showing the excitation of helium, *Neon Primer: A Handbook on Light Construction*, 69. 87

Figure 48 Emission of light by hydrogen. NASA, "Spectroscopy 101 – How Absorption and Emission Spectra Work," n.d. 88

Figure 49 Video still from "Understanding Electric Discharges," See the Pattern, YouTube, posted 9 August 2023, https://www.youtube.com/watch?v=0Pl5qBajPLk. 90

Figure 50 *Intra/twined (uranium)*, 2023, blown glass, ionised gases, paired plasma forms sharing a single transformer, 30 x 40 x 16 cm. Photo by Suki & Hugh Gallery. 93

Figure 51 *Between Movement and Stillness*, 2018, blown glass, transformer, ionised gases. Installation view (detail), Canberra Glassworks. Photo by Suki & Hugh Gallery. 95

Figure 52 Rear view of wall-mounted system: Neoniser 21 driver (black rubber-dipped unit) and Meanwell 120–240-volt power supply (silver unit) connected to mains power, 2020. 97

Figure 53 Glassblowing demonstration showing inflation of glass bubble through hollow blowpipe, Canberra Glassworks, Canberra, ACT, 2023. Video still courtesy of WEFT Production. ... 99

Figure 54 Glassblowing demonstration showing shaping of molten glass bubble using tweezers, Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production. 100

Figure 55 Glassblowing demonstration: transferring bubble from blowing pipe to punty, transitioning from bubble to vessel. Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production. 100

Figure 56 Glassblowing demonstration showing tweezing and changing the diameter of a puntied Chambered Vessel, Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production. 101

Figure 57 Glassblowing demonstration showing a puntied Chambered Vessel. Pulling the heated material changes the diameter of the opening, which later becomes the attachment point for an electrode. Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production. 102

Figure 58 Interactive Colour System. Lisa Cianci, screenshot from "Additive [L] and Subtractive [R] Colour Systems," 2023. Licenced by Creative Commons 4.0. 103

Figure 59 Plasma vessel detail showing colour variation at point of touch, 2021: ruby veneer (L), ruby pink over uranium with electrode displaying fluorescence (R). 105

Figure 60 Geissler tubes from Spark Museum Collection displayed under ultraviolet light, illustrating fluorescence of liquids and uranium oxides in glass, Spark Museum of Electrical Invention, Bellingham, Washington, 2023. 105

Figure 61 *Chambered Vessel* (work in progress), 2022, blown clear glass with ruby red veneer. Studio view in natural daylight..... 106

Figure 62 *Chambered Vessel* (detail), 2023, blown glass with pink veneer, ionised gas. Under plasma illumination, the pink veneer appears blue 106

Figure 63 Soft-glass electrodes showing blow hose attachment system for glass tubulation. Image shows tubulated electrodes oriented upwards, with one connected to orange blow hose.. 107

Figure 64..... 108

Figure 65 Percy Echols II and Ben Orozco, “Taming Lightning × GEEX” Electrode application, 2021. 110

Figure 66 Electrode attachment process, film still, 2024. Video documentation by WEFT Production. 111

Figure 67 Heating electrode for attachment to glass vessel, film still, 2025. Video documentation by WEFT Production. 112

Figure 68 Joining electrode to glass vessel, film still, 2024. Video documentation by WEFT Production. 112

Figure 69 Sketch of manifold, iteration 3, 2023, showing vacuum pump, gas bottles, valves, and blow hose. The work within the kiln would be connected to the right of the sketch. 114

Figure 70 Manifold 1, 2020, depicting connecting pipes with valves, CGA 580 fittings for gas bottle connections, and vacuum pump (grey) on lower shelf. 115

Figure 71 Manifold 1, 2020, showing connection of disposable (lecture) gas bottles (white) to CGA fittings during vacuum draw. Valve to blow hose (red) is closed; valve to DVR2 gauge (blue) is open, reading atmospheric pressure within manifold at 0 Torr..... 115

Figure 72 Manifold 2, 2022, showing improvements including orange blow hose, flexible stainless-steel bellows for manifold pipes (particularly to DVR2 atmospheric gauge), and D-type gas bottles attached with T100 fittings..... 116

Figure 73 Manifold 3, iteration X, 2023, T100 fittings for gas bottles with variety of gauges being tested to measure pressure below 1 Torr within manifold. 116

(L): Figure 74 Capacitance manometer replacing DVR gauge (blue), 2024, for precision readings in 0–1 Torr range. Display shows 2.3×10^{-3} Torr, indicating a low molecular density in manifold... 117

(R): Figure 75 Swagelok compression fittings for connecting flexible stainless-steel bellows or glass on manifold, 2024. Swagelok, “Ultra-Torr Vacuum Fittings,” https://products.swagelok.com/en/all-products/fittings/ultra-torr-vacuum-fittings/c/169 117

Figure 76 Atmospheric manipulation, 2023. Showing the manifold connection between the *Intra/twined* vessels and the branching tubular manifold extension. The transformer visible in foreground ionises and excites the low-pressure atmosphere within the tubes, exciting a pink light, indicative of the oxygen and nitrogen in our atmosphere. 119

Figure 77 Tesla coil, spark tester. 122

Figure 78 Tesla-coil spark crawling into partial vacuum within glass form, 2024. Pink hue of ionising atmosphere appears where vacuum is stronger. Tubing at left remains clear as pressure is insufficient to ionise atmosphere due to leak. 124

Figure 79 Neon discharge exhibiting variable behaviours depending on volumes and distance from transformer, 2024. 126

Figure 80 Low-pressure neon fill test, *Intra/twined*, 2023. 127

Figure 81 Krypton and neon sprinklers, video still from Peachey and Mosig, 2024. 128

Figure 82 Xenon and neon, video still from *Peachey and Mosig*, 2024. 129

Figure 83 Dendritic xenon tendrils, video still from *Peachey and Mosig*, 2024. 129

Figure 84 Red phosphor powder dusted on back interior surface, 2023, demonstrating colour variation in xenon and neon discharge. Discharge appears pink-red against phosphor, blue against clear glass front. 130

Figure 85 Spectral variations in discharge tube with anode and cathode. From Coyne, *Laboratory Companion*, 449. 132

Figure 86 Separating filled glass piece from manifold, 2024. Video still by WEFT Production. 133

Figure 87 Detail of sealing process: nipping off soft-glass piece from manifold, 2024. Video still by WEFT Production. 133

Figure 88 Testing body as conductor with *Chambered Vessel*, 2024. 136

Figure 89 Comparison of transformer effects (left to right: Neoniser 21, Hepburn transformer, Tech 22 Midget), 2024, neon-xenon fill, 180 Torr, pale, blue-tinted glass with uranium veneer. 137

Figure 90 *Intra/twined* (work in progress), 2023, blown glass, ionised gas, electrode and transformer in base. 141

Figure 91 *Intra/twined* (work in progress), 2023: viewer-participant proximity draws more current into closest object. 143

Figure 92 *Chambered Vessel Pair,* 2024, installation view, Canberra Museum and Gallery. Photo by Brenton McGeachie. 144

Figure 93 Harriet Schwarzrock and Matthew Curtis preparing, heating, and measuring individual forms to be pressed together into one object, Australian National University, 2023. Video still by author. 146

Figure 94 Testing connection of glass forms, Australian National University, 2023. 146

Figure 95 Joining of blown glass forms, Australian National University, 2023. 147

Figure 96 Separating blown glass form from blowpipe, Australian National University, 2023. 147

Figure 97 Adapted *Incalmo* technique showing attachment to punty before annealing, Australian National University, 2023. 148

Figure 98 Sally Prasch displaying an original Geissler tube at the glassblowing laboratory, University of Massachusetts, Amherst, 2023. 149

Figure 99 *Chambered Pair* (work in progress), 2023, blown glass. 151

Figure 100 *Chambered Pair* (work in progress), after cold-working punty removal, 2023, blown glass. 151

Figure 101 Vessels connected within kiln for bake-out, 2024. 152

Figure 102 *Chambered Vessel Pair* (detail), 2024, plasma illumination, ionised gases within two interconnected blown glass chambers, transformer, base, 24 x 36 x 25 cm. 153

Figure 103 *Chambered Vessel Pair* (detail), 2024, plasma illumination ionised gases within two interconnected blown glass chambers, transformer, base, 23 x 44 x 13 cm. 154

Figure 104 *Chambered Vessel Pair*, 2024, two interconnected blown glass chambers with ionised gases, transformer, base, installation view at Canberra Museum and Gallery. Photo by Brenton McGeachie. 155

Figure 105 *Chambered Vessel Pair*, 2024, two interconnected blown glass chambers with ionised gases, transformer, base, installation view at Canberra Museum and Gallery. Photo by Brenton McGeachie. 156

Figure 106 Testing for illumination, vessels connected within kiln for bake-out, 2024. 157

Figure 107 *Chambered Vessel* (work in progress, studio), 2024, blown glass, ionised gas. Photo by Cassie Abrahams. 157

Figure 108 *En/tangled* (detail), 2024, neon and argon plasma in borosilicate tubing. Photo by Cassie Abrahams. 160

Figure 109 Vessels connected within kiln for bake-out, 2024. 161

(L): Figure 110 Illuminated manifold extension during atmospheric manipulation, 2023. 162

(R): Figure 111 Manifold extension after atmospheric manipulation of the glass vessels, 2023. 162

Figure 112 Watercolour Drawing by J.C. Whishaw, The Circulatory System: Diagram Showing the Heart, Arteries, Lungs and Major Organs, with a Cartoon-Style Face and Hands (ca. 1853). 163

Figure 113 Watercolour Drawing by J.C. Whishaw, Circulatory Systems: Seven Diagrams, Indicating the Heart and Circulatory Systems of Mammals, Birds, Reptiles, Lobsters, Fish and Arachnids (1852/1854) 163

Figure 114 *Transparent Woman* (detail), Wellcome Collection, London, 2024, displayed in their permanent *Being Human* exhibition. 165

Figure 115 Plasmapheresis Lifeblood, 2023. My blood being filtered before its return into my body, Canberra 167

Figure 116 Plasmapheresis donation, 2023 Apple juice coloured plasma dripping into the donation bag. Lifeblood, Canberra 167

Figure 117 *Faraday Cage*. Video Still: visualising distribution of electric charge (+-) influenced by a conducting shell or Faraday cage, or kiln. UNSW physics video, time stamp 1:50 169

Figure 118 Ed Kirshner with Bernd Weinmayer and Jaime Guerrero, *Vase with a Bowl of Chaos* (detail), n.d. constructed blown glass, ionised gases, transformer. 169

(L) Figure 119 Peter Minson demonstrates techniques to thicken and alter the glass walls while ensuring no folds or undercuts, 2023. Binalong Australia. 172

(R) Figure 120 Detail of sections of uneven thicknesses in an inflated borosilicate tube. 172

Figure 121 Neon fill (25 Torr) 2023 inside of blue borosilicate glass tubing manipulated by heat. .. 173

Figure 122 Borosilicate tubing organic bridging welds, 2022. 173

(L): Figure 123 Bernt Weinmeyer and Iris van Herpen collaboration, *dimensionsim*, 2020–2021, 80 x 90 x 80 cm. Photo by David Uzochukw..... 175

(R): Figure 124 Eric Franklin, *An Anatomical Study of the Human Body Considering the Mind and Body as One Entity*, 2006–2008, flameworked borosilicate glass, krypton, wood, 198.12 x 91.44 x 60.96 cm, Roberts Family Fine Art Collection. Photo by Brad Carlile. 175

(L): Figure 125 Softening borosilicate tubing, 2024. Photo by Cassie Abrahams. 176

(R): Figure 126 Bending borosilicate tubing, 2024 video still WEFT Productions. 176

(L): Figure 127 1&2 Cole's diagrams for preparing join by blowing out bubbles, 2023. 177

(R): Figure 128 Sketch of working with Cole to refine branching and bridging joins, 2023. 177

Figure 129 Steven Cole, 2023. Showing a tubular constriction (to the left) allows for the removal of electrode after atmospheric manipulation and testing for light. The narrower sections of tubing can then be heated to remove the electrode from the component. 178

(L): Figure 130 Feigen in Strattman's workshop 9-12 February 2023. standing manipulation of a glass tube, using a hand-held torch, during masterclass. 180

(R): Figure 131 Welding a join with specialised miniature propane and oxygen (Smith Little) torch for precision heating, 2024. Photo by Cassie Abrahams. 180

Figure 132 Corning Artist residency work in progress, red borosilicate glass melted into the surface of the manipulated glass tubing, 2023. 181

(L): Figure 133 Borosilicate glass mobius (work in progress), Corning Museum of Glass Studio, 2023. 182

(R): Figure 134 Borosilicate work in progress at the Corning Museum of Glass Studio, 2023. Photo by Allison Burrell. 182

Figure 135 Manifold iteration number two, 2023; with borosilicate glass welded onto the manifold extension inside the kiln, connected via a hole that perforates the side of the kiln. (The kiln door is wide open out of the image on right.) 183

Figure 136 Preparing to remove objects from the manifold, with Pearl, 2024. 184

Figure 137 Video stills of capacitive illumination demonstration at Strattman's studio, 2023, featuring his artwork series *Emergent*. Bringing the neon element into the electromagnetic field (generated by the transformer and extended by the powered piece) elicits plasma excitation in the capacitively coupled or symbiotic component. 186

Figure 138 A Strattman assisted sketch (2023) during workshop. 188

Figure 139 Emily Morandini. Concept sketch of the atmospheric electric field distorting over an earthed conductor. Illustration inspired by Richard Feynman's Lectures in Physics, Vol 2., 196 ... 190

Figure 140 Richard Box, *Field,* 2004. Video stills from documentation of the 2004 installation of this work. 191

Figure 141 Testing capacitive symbiotic tangles of neon, suspended above a blown glass plasma vessel, 2024. 191

Figure 142 Capacitive studio test, 2024. Photo by Cassie Abrahams. 192

Figure 143 Borosilicate glass, xenon, neon, transformer, 2024. Although xenon has a lower ionisation potential, is a more resistive gas and requires a more powerful transformer to excite the plasma through the length of the tube. 194

(L): Figure 144 *Sinuous Möbius Pair* Detail ,2023. Borosilicate glass, electricity to ionise gases using direct electrode connection and capacitive illumination, (2023) photo Suki and Hugh. 195

(R): Figure 145 Detail *Nearly, Barely, There,* 2024. Long exposure image of direct and capacitive illumination. 195

Figure 146 *Intra/Pendant Looped Möbius*, 2024, borosilicate glass, neon plasma capacitive illumination, transformer mounted within wall shelf, 40 x 35 x 11 cm. Photo by Suki & Hugh Gallery. 198

Figure 147 *Möbius*, 2023, borosilicate glass, electrodes, ionised gas, high voltage transformer, 43 x 39 x 20 cm. Photo Suki & Hugh Gallery. 206

Figure 148 *Sinuous mobius pair II*, 2023 borosilicate glass, electrodes, ionised gas, high voltage transformer, 44 x 35 x 35 cm, variable. Photo Suki & Hugh Gallery. 208

Figure 149 *em/brace entwine*, 2023, flameworked borosilicate glass, electrodes, ionised gas, high-voltage transformer, nylon thread, 72 x 48 x 15 cm (variable). Photo by Suki & Hugh Gallery. 209

Figure 150 *em/brace oblique* (2023) borosilicate glass, electrode, ionised gas, high voltage transformer, nylon thread. 70 x 60 x 17 cm dims. variable. Photo Suki & Hugh Gallery. 210

Figure 151 *em/brace bridging* 2023 borosilicate glass, electrodes, ionised gas, high voltage transformer, nylon thread, approx. 58 x 58 x 20 cm. Photo Suki & Hugh Gallery. 211

Figure 152 *A Frenetic Stillness,* 2023, borosilicate glass, electrodes, ionised gas, high voltage transformer, nylon thread, approx. 230 x 120 x 11 cm. Suki & Hugh Gallery. 212

Figure 153 *Nearly Barely There* [1-7] 2024, bent, spliced and flame-worked borosilicate glass tubing. neon, argon, krypton, xenon, electrodes, transformers, ionised inert gas, metal frame, nylon thread, 240 x 150 x150 cm dims. variable. Home studio test hang, photo Cassie Abrahams. 214

Figure 154 *Nearly Barely There* (detail), 2024 bent, spliced and flame-worked borosilicate glass tubing (neon, argon, krypton, xenon), electrodes, transformers, ionised inert gas, nylon thread, home studio test hang. Photo by Cassie Abrahams. 216

Figure 155 *Nearly Barely There*, 2024. Installation at Canberra Museum and Gallery, photo Brenton McGeachie. 217

Figure 156 *Lightly Tethered,* 2026, bent, spliced and flame-worked borosilicate glass tubing, electrode, transformer, high voltage cable, ionised neon gas, nylon thread, home studio test hang. 221

Figure 157 *Lightly Tethered* 2026, bent, spliced and flame-worked borosilicate glass tubing, electrode, transformer, high voltage cable, ionised neon gas, nylon thread, home studio test hang. 222

Figure 158 *Lightly Tethered* 2026 detail. 223

(L): Figure 159 Handling the object, 2024, photo Julian Laffan. 225

(R): Figure 160 Eighth-century bronze spiral brooch, accessioned 1980.12 Classics Museum ANU. 225

Figure 161 *Spiralling Symbiotic Object* (detail), 2024, laboratory glass tubing, ionised neon gas, electrical potential from high-voltage transformer. 226

Figure 162 Possibly German, Possibly French *Geissler Tube,* about 1890-1910, Lampworked glass. https://glasscollection.cmog.org/search/geissler%20scientific%20 Corning Museum of Glass. 228

Figure 163 Handing a Geissler tube, 24 March 2023, Massachusetts Amherst Scientific glassblowing Laboratory. 229

Figure 164 *Spiralling Symbiotic* sketch, visualising the larger potential gradient of a taller object.. 230

Figure 165 *Spiralling Symbiotic Object,* 2024, borosilicate glass, ionised neon gas, capacitive transformer base. Detail shows voltage gradient and colour change from vibrant neon red to pink indicative of unclean glass. 231

Figure 166 *Spiralling Symbiotic Object,* 2024, borosilicate glass, ionised neon gas, capacitive transformer base. Detail shows symbiotic participatory capacitive objects influencing each other. 232

Figure 167 *Entangled* detail, 2024, borosilicate glass, ionised neon gas, transformer. Detail on left shows spectral line of xenon, blue-white, the neon red-orange glows capacitively in the background. 234

Figure 168 *Entangled* detail, 2024, borosilicate glass, ionised neon gas, transformer. Under differing conditions detail on left shows spectral continuous green plasma sheaths possibly Bremsstrahlung, around the xenon ionising, the neon red-orange glows capacitively in the background. 234

Figure 169 Krypton beads of light, and its reflection within a tube in the kiln. (2024) 236

Figure 170 Dendritic branching lines forming, in Xenon and neon tube. Video still Peachy & Mosig 2024. 236

Chapter 1: Introduction



Figure 1 Detail of plasma illumination, blown glass, transformer, ionised gases, 2022. Photo Mark Mohell.

In a darkened corner of my studio, I approach a luminous form; its softly curved blown-glass surfaces encase a flickering, pulsing light. This form of illumination appears to respond directly to my touch, as meandering points of light are drawn towards my hand (Figure 1). Furthermore, my proximity influences the quality of the oscillating luminosity elicited within the form; changes appear even before touch. Interacting with this object,

piqued by wonder, I feel a sense of connection and curiosity. This exegesis investigates the production of plasma illumination as an artist, through making and conceptualising plasmas' material properties encased within blown glass, I explore plasma as a medium capable of making visible the viewer's proximity and presence.

By examining historical artefacts of plasma illumination, also known as gas-discharge illumination, often located in science museums, alongside examples of contemporary artworks that harness these luminous phenomena, I develop my studio-based practice, investigating the responsive and, ultimately, relational potential of this medium. Initially, I understood *responsive* to describe the conditions of cause and effect, where one object or experience affects another. Yet as this project progressed, I came to understand *relational* as a more nuanced and encompassing descriptor, denoting the continuity of mutual influence, in which phenomena arise through interactions through a multiplicity of contributing factors.

Plasma illumination relies on applying electrical energy to a gaseous medium encased within a glass envelope, eliciting invisible subatomic interactions that we may experience as visible light.[1] From the perspective of an artist with a glass-making practice, this exegesis charts my understanding of these invisible drivers through a methodological approach I call my practice of "leaks and tangles". This approach acknowledges the procedural and tangled material complexities of producing gas discharge illumination. This practice emerged from the practical necessity of dismantling and reassembling processes to understand and articulate them: to demonstrate an understanding of the nuanced, even particulate components that contribute to plasma illumination. I physically and conceptually "un-craft" both the material practices and physical processes involved, from examining the sub-atomic

[1] Plasma practitioner and artist Mundy Hepburn introduced me to the term "envelope" of glass during mentorship at his studio in 2019.

actions that drive luminosity, enabling deeper understanding and a hybridised approach to making artwork.[2] The density of technical and scientific detail that follows is intentional: this research departs from conventional studio glass practice into the sub-atomic conditions that make plasma illumination possible, and a more nuanced understanding of those conditions is necessary to justify the making decisions that underpin it. I employ processes derived from the neon signage trade, required to achieve vacuum-tight, precisely calibrated below-atmospheric pressures within glass vessels. By conducting interviews with contemporary plasma practitioners, I identify and document hybrid glass-making approaches to producing plasma illumination discussed outside academia.

Concurrently, through making and exhibiting objects and installations, my practice-based research demonstrates how viewers' proximity affects these forms of illuminated, radiating phenomena. This exegesis frames plasma illumination as a relational medium, in which glass vessels, plasma's luminosity and viewer-participants' presence contribute to oscillating plasma behaviours, as evidenced in the artworks. This research makes small technical and practical contributions to the specific field of illuminated glass practice, whilst gathering tacit knowledge from practitioners and contextualising that knowledge as an artist within a framework of relationality.

1.1 Research Questions

The artworks and this exegesis serve to answer the following questions:

- How might novel glass blowing techniques affect plasma's luminosity?

[2] Martin Murer et al., "Un-Crafting: Exploring Tangible Practices for Deconstruction in Interactive System Design," *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (New York, NY, USA), TEI '15, Association for Computing Machinery, January 15, 2015, 470.

- What role does proximity play in influencing the behaviours of plasma illumination within creative practice?
- In what ways can plasma be conceptualised as a medium that reveals ongoing relational dynamics that emerge between viewers and artworks?

Guided by these questions, I initially examined plasma as a responsive medium that makes cause and effect visible. Throughout this exegesis, I describe the participant, viewer, observer, mentor and maker collectively as the viewer-participant, recognising how their influence and agential presence affect these objects. My approach includes contemplating historical examples of gas-discharge illumination for how they revealed scientific insights into the dynamics of electromagnetic phenomena. The manifold processes, vacuum technology, and plasma physics described in these chapters are not incidental to the practice but constitute the very conditions through which the relational phenomena are made possible. By interrogating these insights and integrating them into my contemporary practice, this research contributes to an emerging field of studio glass practice harnessing plasma illumination. The outcomes of this project present possibilities for creating artworks that make visible the typically imperceptible connections between bodies and objects.

The terms *responsive* and *relational* function as catalysts throughout the making and my conceptualisation of the phenomena that contribute to, and are elicited by, these objects, their exhibition, and their documentation in this exegesis. While *responsive* and *relational* are connected terms within this research, they are not interchangeable, and this distinction is made explicit here before either concept is developed in depth. *Responsive* describes a more direct, observable correlation between cause and effect, for example the perceptible reaction of light-emitting plasma, contained within the vessel, responsive with the direct touch of the viewer-participant.

Relational offers a more nuanced and contextual descriptor, a term that resonates with the relational interpretation of quantum mechanics, in which phenomena arise not from a single cause but through interaction with a multiplicity of contributing factors. In the context of plasma illumination, I draw a correlation between how the material properties of the glass and its making, the behaviour of the ionised gases, and the electromagnetic conditions arising from the transformer, together influence the particulate gaseous matter eliciting its varying luminosity. I consider that this confluence of contributing factors is readily comprehensible to a maker: objects are not passive recipients of process but are continuously informed by the conditions of their making and activation.

Within contemporary art scholarship French curator and philosopher Nicolas Bourriaud describes:

> Relational (art) [as] A set of artistic practices which take as their theoretical and practical point of departure the whole of human relations and their social context, rather than an independent and private space.[3]

Rather than the psycho-social conditions Bourriaud expounds in relational art practices of the 1990s, I consider the relationality at work in this project to be fundamentally material: matter changing with the application of energy. The plasma-illuminated objects and installations I examine are affected by proximal encounters, in which the presence of the viewer-participant, as a body in space, elicits material changes to objects luminosity. It is through subtle material encounters, and the differences elicited within plasma-illuminated objects, that the relationality I observe aligns more closely with the conjectures of sub-atomic action than with the social turn of relational aesthetics.

[3] p. 113

This exegesis documents the development, iterations, and creation of three ongoing series of luminous artworks that investigate plasma's qualities within vascular glass vessels: *Chambered Vessels*, *Entangled Vessels*, and *Symbiotic Objects*. Through objects and installations, I have experimented with how vessel geometry, gas composition, and altered electromagnetic fields influence plasma illumination's behaviour in relation to the viewer-participant.

When I engage with plasma illumination, my perception oscillates between fleeting sensory understanding and wonder, where we might "stare and widen our eyes", struck with astonishment.[4] Similarly, during interviews with practitioners about technical innovations and processes, "wonder" is acknowledged as a means of assessing the success of a plasma object. This duality of experience was also evident when investigating historic examples of gas-discharge illumination from the late 1800s (Figure 2). These objects served dual purposes, both as analytical tools and as curiosities displayed in salons to the delight of viewers. For natural philosophers, the scientists or physicists of the time, these gas-discharge tubes, with their ethereal glow, began to illustrate the fundamental relationship between matter and electric charge.

[4] Jesse Prinz, "Why Wonder Is the Most Human of All Emotions," *Aeon Essays*, 2012, https://aeon.co/essays/why-wonder-is-the-most-human-of-all-emotions.



Figure 2 The image shows Geissler tubes from the mid-1800s, illuminated using a Tesla coil, held by Rïse Peacock. The electrical spark from the Tesla coil provides the energy to ionise the low-level gas contents within this tube into their light-emitting plasma state. From the Corning Museum of Glass Historic gas discharge illumination, educational collection. [5]

Innovator, fabricator, author, artist and educator Dr Wayne Strattman explains that "All the subsequent technologies required to make plasma devices—vacuum science, electricity, and techniques in glassblowing—developed in parallel starting early in the 17th century." [6] This tripartite process involves creating the exacting conditions to elicit a responsive, or kinetic, form of light within a glass vessel. [7] I refer to my implementation (and experience) of this tripartite process to elicit plasma illumination as my practice of leaks and tangles, involving the intersecting methods of 1) glass vessel formation; 2) atmospheric manipulation; and 3) electromagnetic activation.

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[5] *Masterpiece in a Minute | Rïse Peacock*.

[6] Wayne Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity.* Strattman Design, n.d. Accessed April 10, 2022. https://store.neonmona.org/products/catalog-the-art-of-plasma. 11

[7] Wayne Strattman, interview with the author, February 8, 2023, a full transcript is available in Appendix 11. Here Strattman rephrased my question to use the term kinetic rather than responsive.

These are discussed in Chapters 3 and 4 in relation to my studio experiments and the making of artworks.

1.2 Plasma's Dual Etymology

To contextualise plasma's centrality to this research, its dual etymology is instructive. [9] My understanding is synthesised from a variety of sources. [10] I am not a scientist; equations are a foreign language to me and, as such, I rely on descriptions gleaned from experts across the arts, trades, physics and popular science. Plasma is often described as the fourth state of matter, after solids, liquids and gases.[11] Physicist Irving Langmuir coined the term "plasma" in 1928, when a green glow was observed inside laboratory glassware during his experiments with vacuums and electromagnetic fields.[12] This phenomenon was named after the Greek *plassein* ("to mould") because the luminous green glow hugged the shape of the glass vessels and apparatus. [13] Anecdotally, Langmuir also drew parallels to blood plasma, noting how both circulate invisible particles within a system.[14] Throughout this project, I draw on my experience donating blood plasma and employ circulation as a central metaphor to examine connection within my arts practice. Implicitly, plasma's dual etymology informs this practice-led enquiry.

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[9] "Plasma, n. Meanings, Etymology and More." *Oxford English Dictionary*.
[10] "BBC Radio 4 - In Our Time, States of Matter." "Melvyn Bragg and his guests discuss the science of matter and the states in which it can exist.
[11] von Keudell and Schulz-von der Gathen, "Foundations of Low-Temperature Plasma Physics—an Introduction."
[12] Irving Langmuir "Oscillations in Ionized Gases." Proceedings of the National Academy of Sciences of the United States of America 14, no. 8 (1928): 627–37.192
[13] *Etymonline,* "Plasma | Etymology of Plasma by Etymonline," accessed November 30, 2023. https://www.etymonline.com/word/plasma.
[14] "Irving Langmuir," Plasma-Universe.com, accessed July 26, 2022, https://www.plasma-universe.com/irving-langmuir/ Blood plasma is the transparent fluid component of blood that transports blood cells, nutrients, hormones, proteins, vitamins and minerals throughout our circulatory system, and thus our bodies.

Plasma illumination involves generating visible light within glass vessels. This practice begins with invisible materials: gases at sub-atmospheric pressure, less dense than air, contained and energised within a vessel. In our built environment, examples include neon lighting and fluorescent light bulbs. Although most of the light we see in the night sky is in the plasma state, it is not straightforward to conceptualise or work with.[15] Chapter 2 traces experimental, scientific, and artistic methods for eliciting plasma illumination. Glass, as an ideal transparent material for plasma containment, features throughout this practice-led research, enabling viewer-participants to closely encounter these phenomena.

In the neon signage trade, transformers ionise inert gases enclosed within bent glass tubes, exciting them into a plasma state that produces visible light.[16] This interconnected circuit involves a high-voltage electrical transformer with two wires, each connecting to an electrode (a sealed glass-and-metal component) at either end. These electrodes are seamlessly joined to the glass tube and are in contact with the enclosed gas (Figure 3).[17] When excited by high-voltage electricity, the gases are ionised into a plasma state, powering subatomic processes that in turn radiate visible light.[18]

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[15] MIT Plasma Science and Fusion Center. "What Is Plasma?" Accessed November 12, 2024, https://www.psfc.mit.edu/vision/what_is_plasma. Exceptions are luminous bodies such as the moon, where we perceive reflected rather than radiating light.

[16] Samuel Miller and Wayne Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*, 4th edition, ed. Wayne Strattman (ST Media Group International Inc., 1997), particularly pages 44–61.

[17] Kacie Lees, *Neon Primer: A Handbook on Light Construction* (Plazma Press, 2022), 98. Although neon signage practice is a form of glassblowing it is often referred to as bending, here Lees describes the "key moves" in neon bending.

[18] L. R. P. Butler, K. Laqua, and A. Strasheim, "Nomenclature, Symbols, Units and Their Usage in Spectrochemical Analysis - V: Radiation Sources (Recommendations 1985)," *Pure and Applied Chemistry* 57, no. 10 (January 1, 1985): 1456, https://doi.org/10.1351/pac198557101453. Butler et al. delineate that the "term radiation source is preferred to light source as the word light is understood to refer to the spectral region to which the human eye is sensitive." Throughout this research project, it has been important for me to consider this specificity, as I am producing a radiating form of visible light.

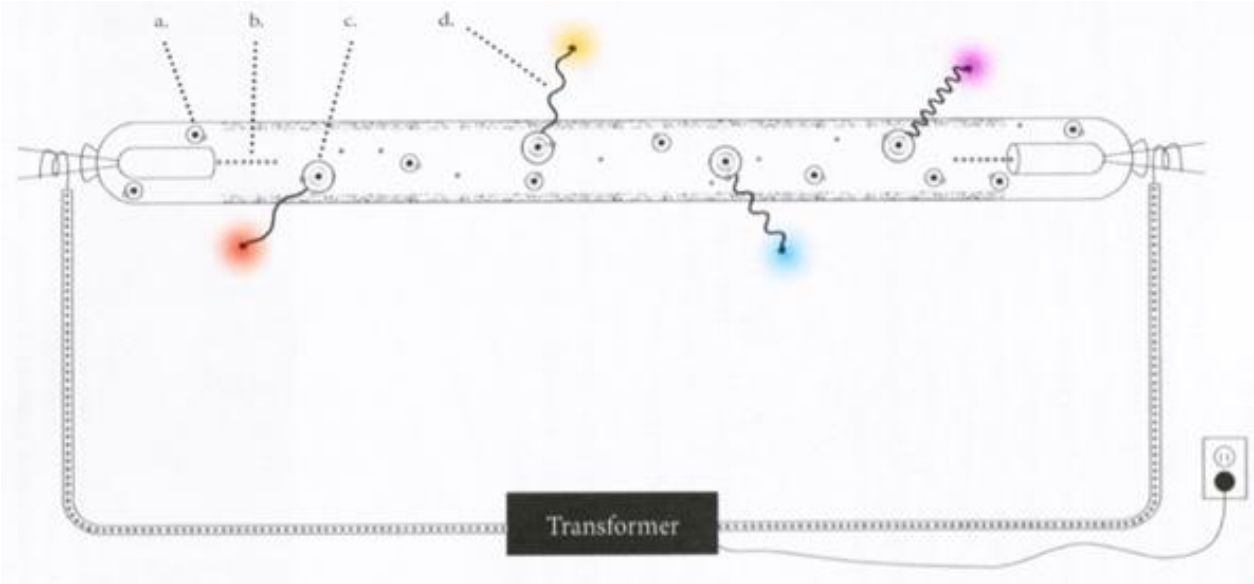


Figure 3 Kacie Lees, diagram titled "Atomic Excitation in a Luminous Gas Lamp," in *Neon Primer: Handbook on Light Construction,* 69.

Neon bender, artist, and author Kacie Lees describes and depicts the production of light in a neon lamp (Figure 3) as:

a. *Neutral atom in a unit;*
b. *A stream of electrons is introduced*; [Atoms are ionised by energy introduced through electrical potential from the transformer. Because electrons are smaller than the remaining ions, they stream and move through the plasma more readily in response to the current.]
c. *The neutral atoms become excited (gain energy) by the electron stream;*
d. *Excitement is released from the atoms in the form of photons of electromagnetic radiation (light).*[19]

Once ionised and excited, plasma becomes a charge-carrying, potentially glowing medium within the glass vessel (expanded on in Chapter 1). Excitation and light production vary with gas composition, pressure, vessel geometry, and transformer specifications. At low pressures, excitation produces a soft glow discharge, whereas at higher pressures it produces meandering, lightning-like lines of light.

[19] Lees, "Construction," in *Neon Primer: Handbook on Light Construction*, 69.

Subtly distinct from neon signage, where a transformer creates a closed circuit that distributes charge (through two high-voltage leads, two electrodes, and the plasma itself, Figure 3), plasma vessels require specialised transformers, due in part because as the vessels often have only one electrode. These transformers create a circuit that is not as easily visualised as a circular or interconnected. Innovator and artist Aaron Ristau described the configuration of a plasma transformer as changing or "breaking" the traditional circuit to include the surrounding environment.[21] These plasma drivers in conjunction with a power supply, create a radiating field in which the vessel, environment, and observer collectively form an extended electrical system, responsive to external influences. Within this configuration, even our electrically conductive bodies facilitate drawing more current while simultaneously grounding the system.[22] As viewer-participants approach these gas-discharge or plasma illuminated objects, electromagnetic field changes make our presence visible, we effectively couple with the vessel (Figure 4). Varying the plasma's luminous behaviours: glow discharge may

[21] Aaron Ristau, interview with the author, December 4, 2023, full transcript available in Appendix 9. Aaron describes the open configuration of the transformer configuration for plasma as "breaking the circuit."
[22] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 120.

brighten, while dendritic or arcing plasma responsively meanders toward the point of touch.

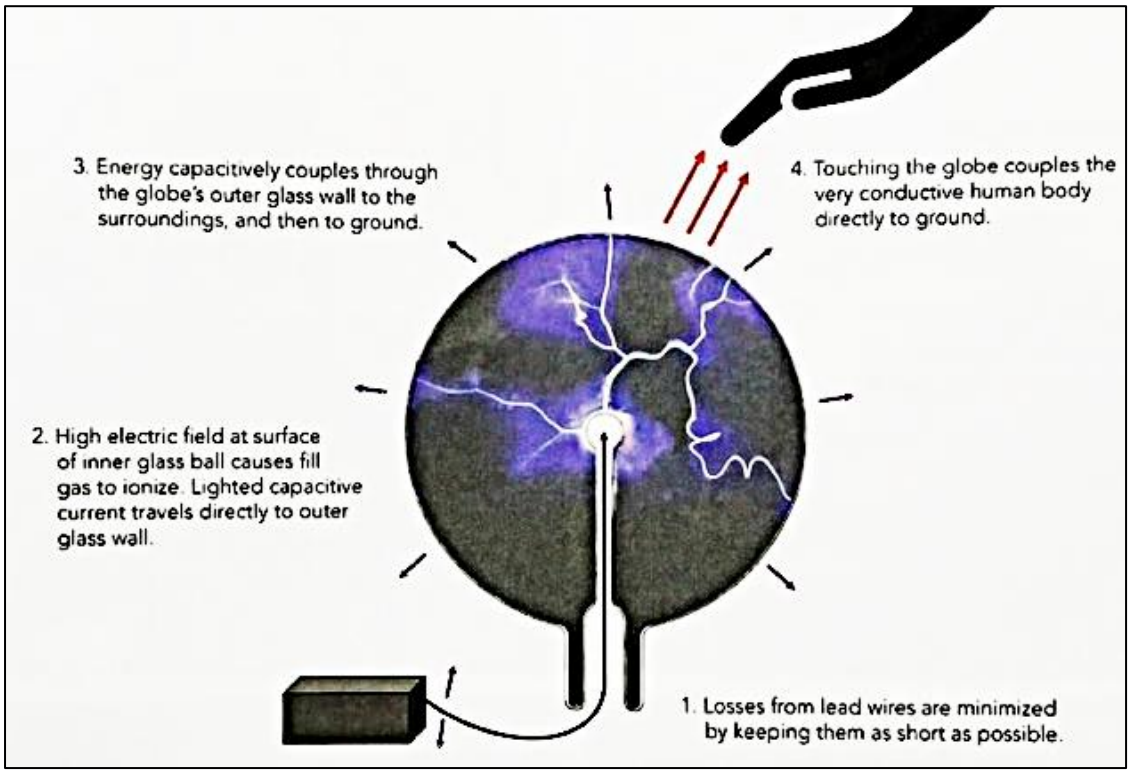


Figure 4 Wayne Strattman, *Art of Plasma*, 137. Diagram describes energy pathways and capacitive coupling of the plasma globe from power-supply to ground. Illustration by Cary Rapaport.

Strattman uses the electrical term capacitance to describe how electromagnetic energy couples capacitively through the plasma vessel to be transferred and distributed through the viewer-participant and to the electrical earth or ground (Figure 4). Alternatively, a plasma vessel may have no electrode, requiring a specialised capacitive configuration. These luminous configurations, without direct wiring, are discussed in Chapter 4. I have come to visualise capacitive coupling via touch and proximity as material conduits through which currents can flow from regions of higher to lower charge.[23] Strattman describes:

[23] Kleynhans, *Unit 1*. "Capacitance exists wherever conductive material is separated by insulating material. Capacitors can store energy as an electric field."

> Capacitance (C) refers to the ability of empty space or a dielectric, an insulating material, to store energy in the form of an electric field. This field is typically established between two conductors separated by a dielectric, such as glass or empty space. The chief property of a capacitor is that for alternating current, energy can pass through it even though, because of the insulating barrier, no actual charge flows through the capacitor. Electrons build up on one side of the capacitor and other electrons are simultaneously pushed away from the other side. When the voltage reverses, the same thing happens in the opposite direction. This back-and-forth flow of charge translates to other parts of the circuit and amounts to an [alternating current] AC displacement current. It is no less real than other currents and produces the effects we see as lightning, energized even through highly effective insulators like glass or air surrounding the sculpture.

Capacitive coupling therefore alters the distribution of charge, in turn affecting the discharge behaviours within plasma-illuminated objects.[24]

1.3 Making with the Thing-ness of Light

The artist James Turrell, described as the "master of light" and a seminal figure in the Light and Space movement, creates work that operates through the entanglement of perception and luminosity.[25] Turrell speaks of the physicality or "thing-ness" of light as the core material of his practice.[26] Similarly, I engage with visualising the material and particulate nature of light, as discussed in Chapter 2, engaging with plasma as a responsive medium within creative practice.

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[24] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 120
[25] Kirkland, "Optics in Art." 28
[26] James Turrell Exhib. Website, "James Turrell Exhibition Website." In this interview Turrell speaks.... "I look at light as a material. It is physical. It is photons. Yes, it exhibits wave behavior, but it is a thing. And I've always wanted to accord to light its thing-ness. That was very important to me to do."

My artworks are made luminous using techniques derived from historic gas-discharge practices, which experimentally revealed light to be particulate. Examining historical exemplars of gas-discharge illumination offers perspectives on contemporary studio-based methods of production, while providing insights into the material nature of plasma and how these constituents might be visualised.27 The methods of generating plasma illumination were refined in the neon signage trade, where the term "processing" refers to the preparation of glass tubes using exacting techniques so that their internal atmosphere serves as a light-emitting conduit.[28] Rather than harnessing neon's even glow (calibrated for its brilliant lines of light within glass tubes), plasma vessels elicit luminous discharges that pulse, flicker, and meander within larger volumes of bespoke glass. As viewer-participants engage with this form of illumination, we experience different expressions of plasma's oscillations, material and energetic alterations, as our proximity changes the luminosity we experince.

As an artist, maker, and glassblower, I employ craft and trade-based techniques to realise these luminous objects. Through this project, I prioritise glassmaking methods to heighten plasma's luminous behaviours. I refer to my implementation of the tripartite process for plasma illumination as my practice of leaks and tangles, indicative of the convolutions and intricate interdependencies required to elicit these phenomena (Figure 5). Similarly, literature from varied sources supports and is woven throughout this exegesis, articulating my leaky and tangled methodology for implementing and comprehending the complexities of plasma illumination.

[27] Oakes, "Atoms, Molecules and Enzymes."53 Oakes demonstrates the difficulty in visualising atomic structures and scale.
[28] Iterations of the techniques and tripartite process will be discussed throughout this exegesis; excellent references include but are not limited to Lees, *Neon Primer: A Handbook on Light Construction*, 122; Crook & Fishman, *The Neon Engineers Notebook*, 21; Mason, *Neon*; Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*, 12.

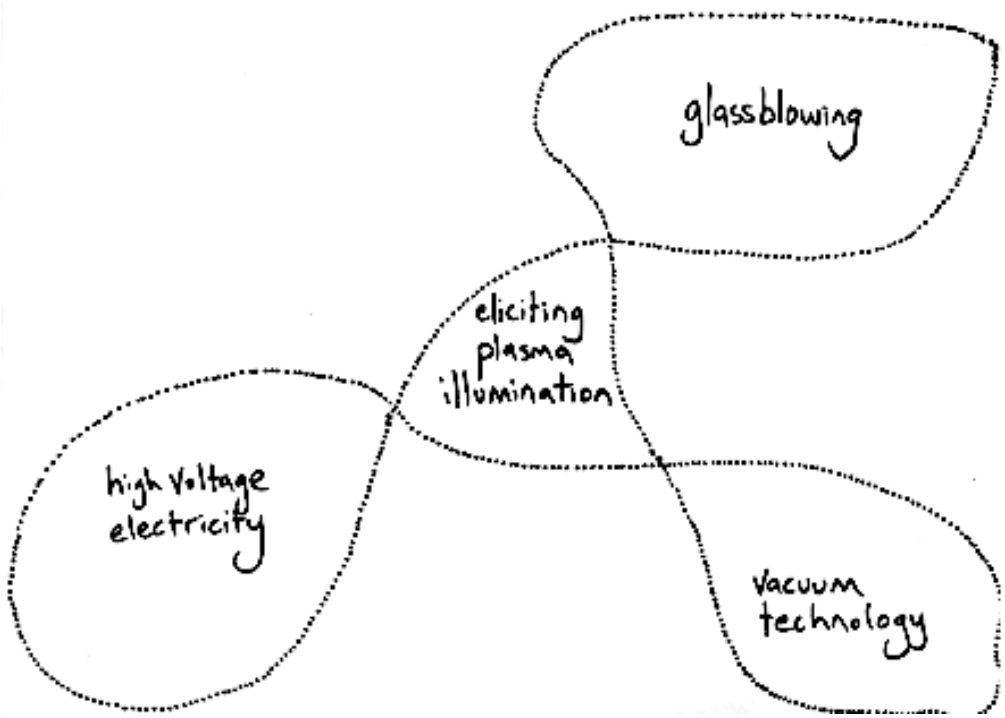


Figure 5 : The perforated line exemplifies the “leaks and tangles” metaphor I use to describe the tripartite process for the studio production for eliciting plasma illumination, 2025.

My key research questions are material, examining how novel glass-blowing techniques affect plasma's luminosity and how this might influence the viewer’s sensorial engagement. My methods involve experimenting with and adapting the tripartite process to elicit plasma within glass vessels. Initially, this pattern of studio-based production, informed by curiosity and research, prompted me to investigate plasma’s responsiveness through its subatomic interactions.

The relationships among constituent components are integral to what physics terms “physical systems”: interconnected entities with emergent properties that their individual parts cannot achieve alone. The following description from the International Council on Systems Engineering assists to articulate how each part of the tripartite process, as well as the engagement of the viewer-participant and the environment, contributes to the quality of plasma illumination:

> The behaviour of physical systems manifests itself as flows and exchanges of matter, energy and information, and interaction through force fields. The emergent property by which physical systems can be identified is that they perform processes to transform matter, energy and information in ways that their individual parts cannot. [29]

Throughout this exegesis, I use various terms to describe the physical systems of gas-discharge and plasma illumination, with particular focus on their constituent glass components. For historical and contemporary examples, I use the terms; artefacts and apparatus, objects, vessels, components, and installations. These physical systems are realised through the complex relationships among materials, energy supplies processes, and knowledge.

Sociologist and craft studies expert Dr Erin O'Connor argues that embodied actions in the world are how we accrue practical knowledge. [30] O'Connor has conducted research by immersing herself in developing glassblowing skills. Her work aligns with the phenomenology of French philosopher Maurice Merleau-Ponty, who proposed that "the body is our general means of having a world." [31] This perspective suggests that knowledge and skill development emerge not through abstract understanding but through a body that is primed and adept at working with materials, tools, and thoughts. This embodied model of knowledge can be extended through Bruno Latour's actor-network theory, which reframes the maker's body as one node within a broader network of human and non-human actors.[32] For Latour, tools, materials, and even the material's own resistances are not passive instruments awaiting human intention; they are

[29] INCOSE, "Physical and Conceptual." "The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization founded to develop and disseminate the transdisciplinary principles and practices that enable the realization of successful systems."
[30] Erin O'Connor, "Embodied Knowledge in Glassblowing: The Experience of Meaning and the Struggle towards Proficiency," *The Sociological Review* 55, no. 1_suppl (2007): 127.
[31] Maurice Merleau-Ponty, *Phenomenology of Perception*, trans. Donald A. Landes (London: Routledge, 2012), 147.
[32] Institut d'Etudes Politiques de Paris (Sciences Po) and Latour, "On Actor-Network Theory. A Few Clarifications, Plus More Than a Few Complications."p.2

actants, entities that exert influence and help constitute the outcome of an action. Applied to glassblowing, this means the torch, the glass, the gather, and the shifting viscosity of the material itself all participate in shaping what the maker can know and do in each moment. Skill, in this framing, is not a capacity residing solely within the maker's body, but an emergent property of the exchange between body, mentor and material, distributed across the network of actors and materials involved in the making process. Autor and artist Paul Carter describes this confluence of creative practice as bearing "witness to the multiplicity of histories it incorporates".[33] This positions the glassblower not as a sole author exerting will over inert matter, but as one among many, responsive to and co-constituted by the materials and tools they work with, a framing that resonates directly with the relational qualities this research identifies in plasma illumination itself.

The interplay between processes, materials and bodies exemplifies what Emeritus Professor of Social Anthropology Tim Ingold describes as flux.[34] I experience working in the molten glass studio as a practice of ever-shifting potential. My studio methods resonate with Ingold's description of material and making practices, in which flux and flow can arise during the creative process. Ingold illustrates the animacy that occurs between the "kite", the "kite-flyer," and the "air", or the potential that arises between the "potter", the "wheel," and the "clay".[35] In my practice, I experience how repetition of techniques, mentorship in new skills, and subsequent experimentation results in sensorial integration, refined skills and a more nuanced understanding of the materials.

[33] Carter, *Material Thinking*. p.179
[34] Tim Ingold, *Bringing Things Back to Life: Creative Entanglements in a World of Materials. Working Paper*. Realities / Morgan Centre, University of Manchester, 2010, 8, http://www.manchester.ac.uk/realities/publications/workingpapers/.
[35] Tim Ingold, Making: Anthropology, Archaeology, Art and Architecture (Taylor & Francis Group, 2013), 100.

For the purposes of this exegesis, I refer broadly to these material practices of trade-based and crafting skills as “making”. [36]

1.4 Practitioner Interviews: Working with the Material of Plasma

Even within the repository of the Corning Museum of Glass Rakow Research Library, literature on plasma illumination in creative practice primarily addresses the technical concerns of neon, leaving the medium's inherent responsiveness and its potential within creative practice underarticulated. As part of this research, I conducted qualitative interviews with eleven international members of the Plasma Art Alliance: Steven Cole, Dr Daniel Davis, Percy Echols II, Dr Jeffrey Feigen, Mundy Hepburn, Ed Kirshner, Amy Lemaire, Tate McAluney, Dr Kamila Mróz, Aaron Ristau, and Dr Wayne Strattman. [37] By gathering perspectives from these practitioners, I developed a substantive discussion of plasma's responsive potential, and the full interview transcripts are included in the appendix to this exegesis.

Motivated by my research questions, I asked open-ended questions about technical processes, conceptual frameworks, and plasma's responsive nature. [38] Each maker has developed specific methodologies and techniques, using various glass types, gas mixtures, and power supplies to enhance their work. Throughout this project, my technical and theoretical engagement with the difficult-to-conceptualise physical

[36] *Etymonline*, “Make - Etymology, Origin & Meaning.” Old English *macian* ”to give being to, give form or character to, bring into existence; construct, do, be the author of, produce; prepare, arrange, cause; behave, fare, transform,” from West Germanic **makōjanan* ”to fashion, fit” (source also of Old Saxon *makon*, Old Frisian *makia* ”to build, make,” Middle Dutch and Dutch *maken*, Old High German *mahhon* ”to construct, make,” German *machen* ”to make”)…”

[37] PAA, “PLASMA ART ALLIANCE Plasma Art Alliance - Plasma Art and Glass Art.”

[38] The questions I asked were: Are there particular techniques you employ [or have devised] that expand upon plasma illumination’s artistic application and inherent responsiveness?
How do you experience responsiveness within your plasma practice?
How do you envisage the viewer/participant engaging with your work?
How do you describe responsiveness within this form of illuminated practice?

properties of plasma illumination has been put into practice and informed by insights from colleagues and mentors.

Throughout this exegesis, excerpts from practitioner interviews support and extend the published body of work on the responsive, ultimately relational nature of plasma illumination. The practitioners' responses echo philosopher Bruno Latour's assertion that science's certainty gives way to the "warm" and "risky" uncertainty of research.[39] All practitioners described iterative, experimental processes aligned with scientific enquiry, while embracing delight, curiosity, and play as conceptual drivers.

These experts shared their knowledge and terminology, revealing methods that range from precise techniques to intuitive explorations, describing the phenomena as "wonderous", "magical", or "alive".[40] During her interview, Dr Kamilla Mróz referred to the medium as

> ...a kind of magic. Although I see myself as a very rational person who strongly believes in science and understands the laws of physics that control plasma discharges, the responsiveness of plasma discharges is still hypnotizing and magical. So maybe I'm not so rational after all![41]

These perspectives support and inform my studio practice. Furthermore, interviewing my colleagues reflected what I instinctively knew: that peering into this practice yields insights and perspectives that are constantly shifting, seeming to oscillate or ripple,

[39]Latour, "From the World of Science to the World of Research?" *Science* 280, no. 5361 (1998), 208.
[40] See, for example, Mundy Hepburn's interview with the author, 23 May 2023, full transcript in Appendix 6.
[41] Kamila Mróz, interview with the author, 25 February 2025, full transcript in Appendix 10. Practitioner Mróz uses the term magic to describe her wonderous or less-than-logical moments of engagement with this work.

much like the phenomena in the work itself.[42] Through learning, making, and bringing practitioner perspectives to light, I contribute to this field of practice.

1.5 Particulate Thing-ness of Light

The tripartite process towards Eliciting Plasma Illumination rarely follows the cause-and-effect trajectories of classical physics. Inherently entangled in this practice are unpredictable yet probabilistic outcomes arising from subatomic particles interacting to produce these luminous phenomena.[43] Niels Bohr (1885–1962) and Werner Heisenberg (1901–1976) are arguably the founders of quantum mechanics, contemplating this new subatomic frontier.[44] Though I cannot interpret the complex equations underlying their work or the fundamental interactions that govern plasma luminosity, their conceptual insights inform my understanding. Engaging with these concepts is challenging. Throughout this exegesis, I will retain the popular-science references that served as catalysts for investigating peer-reviewed research. I listened to relevant scientific discussions (repeatedly) while working in the studio "on the tools", deepening how I conceptualise states of matter, physics, and quantum mechanics.[45] These subjects listened to though podcasts, provided a scaffold for this project and are discussed in Chapter 2.

[42] Kirshner, interview with the author. During Kirshner's interview, he spoke of his practice with plasma as an expression of chaos theory, informed by his previous interest in video feedback. Just as fractals emerge from chaotic systems, mesmerising patterns emerge in Kirshner's exacting plasma artworks.
[43] Caves and Schack, "Unpredictability, Information, and Chaos.",4 Caves and Schack focus on "unpredictability in physics" initially through the "measurement problem." "The obvious place to look is quantum mechanics, which in our present understanding provides the framework in which fundamental physical laws are formulated. In a quantum mechanical description, even if one has maximal information about a physical system, i.e., knows its quantum state exactly, one nonetheless cannot predict the results of most measurements."
[44] Rovelli, *Seven Brief Lessons on Physics*. 34
[45] I spent many hours "on the tools" as my maker friend Jono Everett would say, listening to BBC Radio 4 In Our Time Science podcasts, where Melvin Bragg and three esteemed guests discuss topics in intricate details, contextualising incredible topics that I selected as relevant to my topic.

Two humanities-based texts have also supported me navigate quantum-mechanical concepts, informing my understanding of matter and in turn my making practice. The first is Karen Barad's 2007 book Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning, in which Barad, a professor of Feminist Studies, Philosophy, and History of Consciousness, draws on Niels Bohr's work to develop their theory of "agential realism".[46] The second is Professor of Theoretical Physics Carlo Rovelli's 2020 publication, Helgoland: The Strange and Beautiful Story of Quantum Physics.[47] This book assists me to contextualise quantum insights elucidated by Heisenberg and further developed by Rovelli in his "relational interpretation" of quantum mechanics.[48] Like Barad's work, Rovelli's writing functions as a shifting lens, or a rippling rockpool, through which I can peer, offering quantum perspectives that alter my understanding of matter, making, energy, and observation. I carefully considered his relational interpretation of quantum mechanics while investigating the materiality of plasma and its light-emitting effects. This led to a model of practice in which plasma emerges not as a fixed medium but as ongoing relational processes among materials, energies, and observers. Both Barad's and Rovelli's quantum-focused frameworks have allowed me to consider how luminous behaviours arise through dynamic interactions rather than as inherent properties.

Through this project, I built on my initial experience with plasma illumination's responsiveness to investigate relationality through three bodies of work, which are discussed in Chapters 3 and 4: *Chambered Vessels*, *Entangled Vessels*, and *Symbiotic*

[46] Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Duke University Press, 2007), 138. Barad reflects upon the incredible shift in thinking that Niels Bohr's 1913 quantum mechanical insights initiated.
[47] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics*. 13
[48] Rovelli, Carlo. "Relational Quantum Mechanics." In The Stanford Encyclopedia of Philosophy, Spring 2025, edited by Edward N. Zalta and Uri Nodelman. Metaphysics Research Lab, Stanford University, 2025. https://plato.stanford.edu/archives/spr2025/entries/qm-relational/.

Objects. Following this, Chapter 5 examines the related exhibition, presentation, and viewer-participant interactions in greater detail.

1.6 Context

Plasma illumination occupies a unique intersection between artistic practice, craft knowledge, and electromagnetic phenomena. While Light and Space movement pioneers Dan Flavin, James Turrell and Cerith Wyn Evans are clearly precedents for using light as a primary medium for sculptural installation, my focus remains specifically on plasma's oscillating behaviours within a glass vessel.[49]

Within the broader multidisciplinary field of art, science, and technology, the history of relational and systems-based art precedes and informs much contemporary art practice today. This lineage extends from the systems-based thinking of seminal figures such as László Moholy-Nagy, whose *Light Prop for an Electric Stage (Light-Space Modulator)* (1930) remains a touchstone for kinetic and light-based practice. On a field trip to Boston, I encountered this shiny sculpture by Bauhaus meister László Moholy-Nagy.[51] On the day I visited, a rare activation of the work allowed me to experience this early kinetic sculpture in motion.[52] With its rotating screws and metal plates motorised, simultaneously folding and fracturing the surrounding space with their rotating mechanically generated reflections, a machine for distributing light, a work that championed moving objects as art.

[49] John Perrault describes Flavins practice as situational, rather than an installation practice.
Natl. Gallery Aust., "National Gallery's James Turrell Within Without 2010." "Cerith Wyn Evans .... in Light of the Visible | MCA Australia." I experienced this exhibition on 07 06 2025.
[51] Harvard, "Light Prop for an Electric Stage (Light-Space Modulator) | Harvard Art Museums." The Harvard Art Museum holds a replica on exhibition, constructed in 2006 through the courtesy of Hattula Moholy-Nagy.
[52] Harvard, "Gallery Talk."

Relational art in turn, broadly describes practices in which human interactions and social relations, rather than discrete objects are the intension. Theorised most influentially by Nicolas Bourriaud in *Relational Aesthetics*, he describes the artist's role as one of producing relations: "The artist's practice, and his behaviour as producer, determines the relationship that will be struck up with his work. In other words, what he produces, first and foremost, is relations between people and the world, by way of aesthetic objects." Robert Barry's ethereal performance *Inert Gas Series/Helium, Neon, Argon, Krypton, Xenon/From a Measured Volume to Indefinite Expansion*. 1969. Is a precedent to this genre relational aesthetics. Described by the Museum of Modern Art as "Testing the limits of materiality…The work was the release, …, of five measured volumes of odorless, colorless, noble gasses into the atmosphere… where they would diffuse and expand naturally into infinity." [53] Although substantially invisible Bourriaud writes of this work as one that has "summoned the public to observe a specific phenomena." [54] This performance exemplifies relational aesthetics through social encounter, whereas my project is concerned with making the invisible visible: rendering the sub-atomic interactions of matter luminous and perceptible to the viewer-participant. Furthermore, as I work with fractionally distilled inert gases drawn from air, I find myself pondering whether the very atoms I handle were present in Barry's performance, an invisible tethering across time, a non-temporal moment of connection between practices separated by decades.

Bourriaud's methodological framing gives rise to immersive contemporary participatory environments, such as those of Olafur Eliasson, among others, whose practice privileges objects of perception as sculptural devices within an expanded field. Visiting Eliasson's exhibition *Presence* (Brisbane, QAGOMA 2025) I was struck by the early work *Beauty* (1993), which generates a rainbow in a veil of mist, into the vast spatial

[53] "Robert Barry. Inert Gas Series/Helium, Neon, Argon, Krypton, Xenon/From a Measured Volume to Indefinite Expansion. 1969 | MoMA."
[54] Bourriaud, *Relational Aesthetics*. p.29

installation. Eliasson speaks of his work addressing a notion of “we” where perspectives shift as we meet the work through our senses and body.[55] Chris Saines writes of this exhibition “Each work exists uniquely in our gaze, recreated anew from every angle and incident of our movement into and through space. In accepting to co-create our experience of his work, we respond to Eliasson’s provocations about the very nature of the world itself.” [56] Encountering *Beauty* in a darkened space, enveloped in refracted light, we see our own rainbow, a profoundly emotional, entirely immersive yet intimately affecting experience.

While Professor Claire Bishop argues that genuinely productive relational art should generate antagonism and disruption rather than social ease, insisting that the quality of the relationship established between viewer and work is politically and ethically consequential. [57] The term relational throughout the exegesis is not in Bourriaud's primarily social sense, but to describe a physical and material condition: one in which phenomena arise through interactions among plasma, glass, electromagnetic charge, and the viewer-participant's proximate body. This understanding draws more directly on the interdisciplinary field of art-science-technology and resonates with Bruno Latour's actor-network theory, in which agency is the network, the “filaments” connecting human and non-human actors alike.[58] Clarifying this distinction is important: while the work participates in the broader relational turn in contemporary art, its specific knowledge contribution concerns plasma illumination as a responsive physical system, made relational through the conditions of its material and spatial encounter.

[55] Qld. Art Gallery Gallery Mod. Art, “Olafur Eliasson”; “Presence • Artwork • Studio Olafur Eliasson.” Gallery visit with artist Kirstie Rea
[56] “Presence • Artwork • Studio Olafur Eliasson.”
[57] Bishop, “Art of the Encounter.” p.32-35
[58] Institut d’Etudes Politiques de Paris (Sciences Po) and Latour, “On Actor-Network Theory. A Few Clarifications, Plus More Than a Few Complications.” p.4

My making practice is materially grounded in the studio glass movement, which positions skilfully made glass objects and vessels as sculpture. Many contemporary artists working with glass harness its transparency, recognising it as an active agent in perception. Canadian artist and professor of art at California State University Katherine Gray's use of iridescent blown glass investigates perception through the material's visibility and invisibility.[59] Venetian artist Laura de Santillana's (1955–2019) sculptures exploit closed vessels to capture an ephemeral "chromatic transience."[60] Although these practices expand glass's conceptual horizons, my research focuses on glass for its ability to encase plasma illumination.

Contemporary glass artists such as Sarah Blood, Jeremy Bert, and the She Bends Collective, who work with neon light rather than signage, bridge commercial and artistic neon applications. In Australia, Indigenous artists Brook Andrews and Aidan Hartshorn, alongside non-Indigenous practitioners Neil Roberts (1954–2002), Emma Kate Hart, Steven Cole, Brendan van Hek, Cobi Cockburn, Emeirely Nucifora-Ryan, Meagan Streader, and others, develop distinctive sculptural approaches. However, these practices remain outside this research's scope because, although a form of plasma illumination, neon signage traditions rely on plasma illumination to maximise lumens for consistently bright lines of light.[61]

The Plasma Art Alliance (PAA), established in 2017, is my primary point of reference; it provides essential specialised community development through exhibitions, symposia, generous technical mentoring, and creative cultivation. While many plasma artists document their practices online, published documentation remains scarce.

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[59] "Katherine Gray."
[60] *Financial Times, 8 July 2015 | Laura de Santillana*.
[61] Crook & Fishman, *The Neon Engineers Notebook*. 162 Lees, *Neon Primer: A Handbook on Light Construction*.128 Mason, *Neon*.12. [61] Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 82

Strattman's book The Art of Plasma offers comprehensive historical and technical foundations and insights into working with this medium, while Mróz's recent thesis *Interactive Light – the Use of Plasma Discharge in Noble Gases as a Medium of Applied Art* addresses plasma's interactive potential within creative practice, developing frameworks for vessels as mediating “skins”. Their research contributes to a growing field, illuminating the complexities of creative practice, and this is primarily where I situate my practice.

1.7 Methodology

As plasma illumination involves waves of light, I have contemplated and engaged with the phenomenon of diffraction, and resonant with this I consider that my practice-led research employs a diffractive methodological framework. This approach allows me to untangle historical knowledge, scientific principles, and artistic experimentation without privileging any single perspective. By investigating plasma illumination through these means, I develop a relational understanding of this state of matter, and its use as a medium within creative practice. Through studio experimentation with the tripartite process for plasma illumination, (my practice of leaks and tangles), field research, interviews, and mentoring, I shift my focus between making objects to conceptualising the subatomic drivers of plasma illumination. Through this approach I became increasingly aware that our presence and proximity contribute to the visible effects, within this practice. A diffractive methodology enables me to frame plasma illumination as fundamentally relational, where invisible forces are made visible, with the artworks evidencing this understanding. Below, I will briefly discuss physical diffraction, as this is a relevant concept when working with light, before considering diffraction as a methodological framework.

1.7.1 Physical Diffraction

Physical diffraction describes the interference of waves caused by obstacles. Thomas Young's famous 1807 double-slit experiment initially demonstrated diffraction patterns using water in a ripple tank (Figure 6).[64] Later, Young adapted his experiment by using light, passing it through two small slits in a screen; the resulting bands of light (captured on another screen) revealed light's wave-like behaviour as it spread beyond those points of interference (the slits).[65] When a light source passes through a single hole, it creates characteristic circular wave patterns, similar to those formed when a single pebble is thrown into a pond, producing peaks and troughs (Figure 6 and Figure 7). The interference of these peaks and troughs, in water or light, may appear as ripples on the surface.

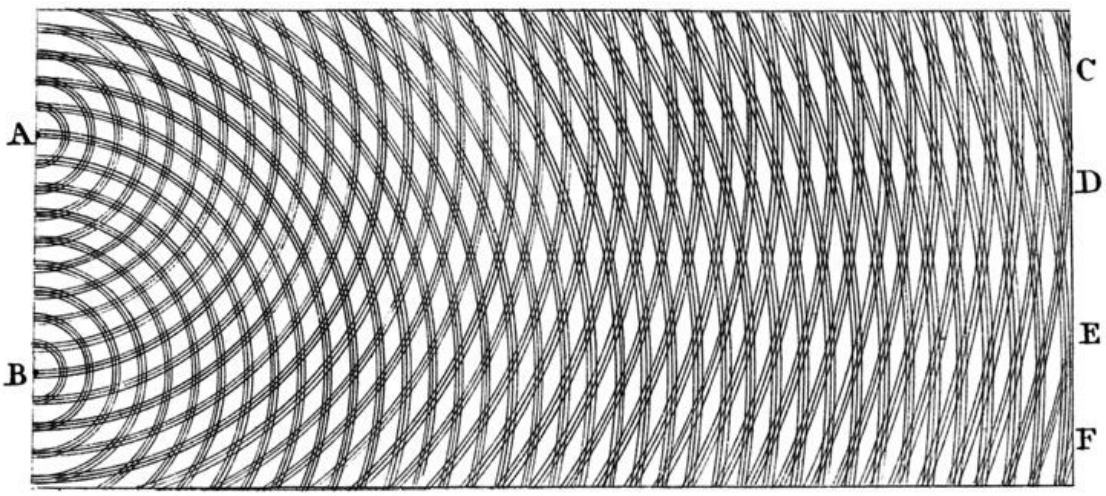


Figure 6 Thomas Young, 1807 illustration presented in a lecture in 1807, showing his famous two-slit diffraction experiment for water in a ripple tank. Thomas Young's sketch of wave diffraction. Wave sources A and B produce distinctive interference phases at points C, D, E, and F. Source: Thomas Young/Wikimedia Commons.[66]

[64] BBC, "BBC Radio 4 - In Our Time, Radiation." Melvin Bragg, and guests discuss Thomas Young's double slit experiment conducted in ripple tanks with water, later replicated with light, this was called Young's double-slit interferometer, revealing wave-like nature of light.
[65] Kim and Ham, "Revisiting Self-Interference in Young's Double-Slit Experiments."
[66] Loeffler, "What Is the Double-Slit Experiment, and Why Is It so Important?"



Figure 7 Laser beam diffraction pattern. Wisky, licensed under CC BY-SA 3.0, via Wikimedia Commons.

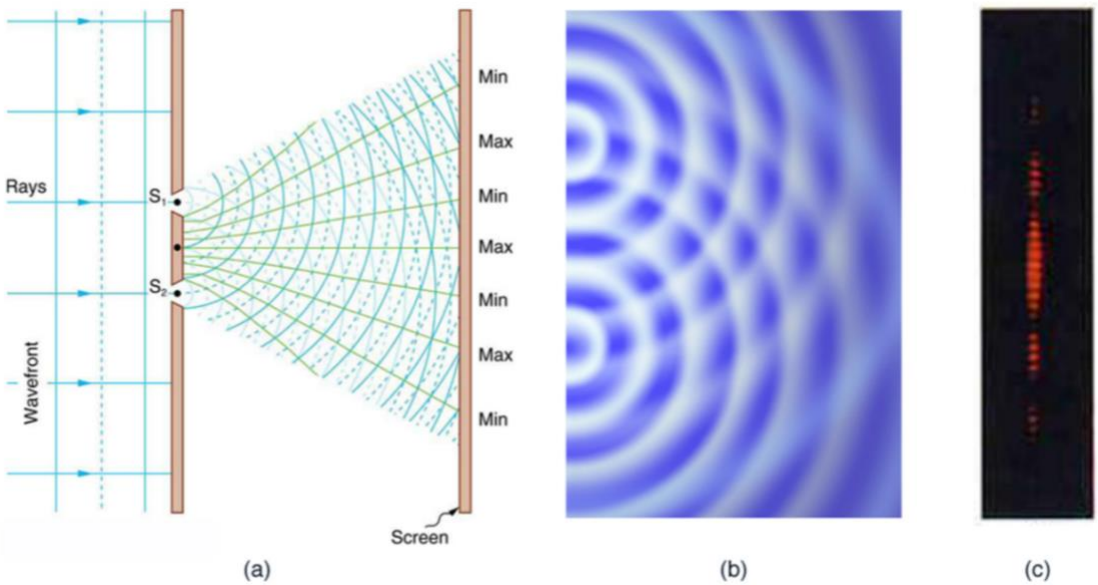
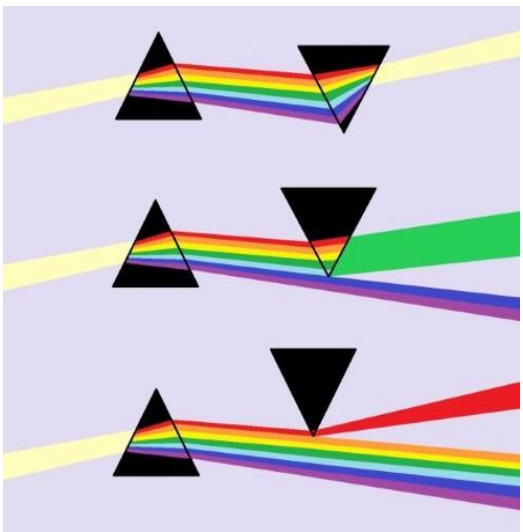
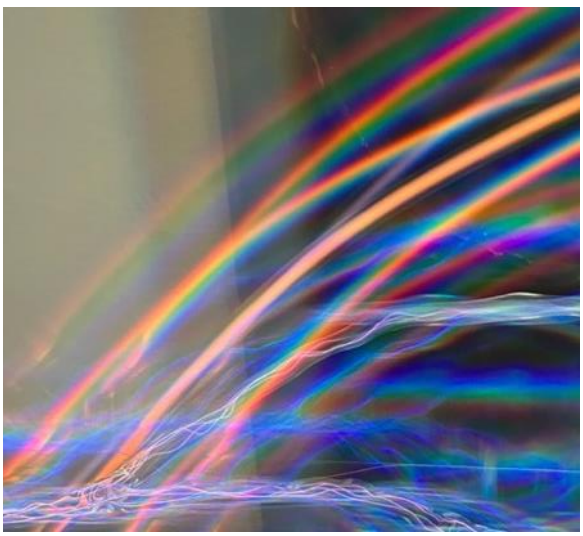


Figure 8 Double slits produce two coherent sources of waves that interfere. (a) Light spreads out (diffracts) from each slit because the slits are narrow. These waves overlap and interfere constructively (bright lines) and destructively (dark regions). We can only see this if the light falls onto a screen and is scattered into our eyes. (b) Double-slit interference pattern for water waves is nearly identical to that for light. Wave action is greatest in regions of constructive interference and least in regions of destructive interference. (c) When light that has passed through double slits falls on a screen, we see a pattern such as this. Credit: PASCO.

These diffractive models enabled me to gain a more nuanced understanding of plasma illumination within my practice. Consider the classic Newtonian prism experiment conducted in 1666, where Sir Isaac Newton separated sunlight through a prism, revealing the rainbow-coloured spectrum of sunlight. This process, when reversed, with a second prism, recombines the split rainbow back into sunlight (Figure 8 and (L) Figure 9).[68] Similarly, using a diffraction grating helps discern light's spectrum and its additive nature, as discussed further in Chapter 2 (Figure 7 and 8).[69] Using a diffraction grating in my studio (a transparent lens with tiny, ridged prisms), I can view the spectral lines of the plasma illumination within illuminated objects ((R) Figure 10).





(L) Figure 9 Helen Klus, *Newton's Theory of Light*, The Star Garden, http://www.thestargarden.co.uk/Newtons-theory-of-light.html, licensed under CC BY-NC-SA 4.0.

(R) Figure 10 Detail of a plasma vessel viewed through a diffraction grating, revealing its constituent rainbow of spectral lines, 2023.

[68] Star Gard., "Newton's Theory of Light." Dr Helen Klus provides an account of "Newton's crucial experiment" in her chapter on Newton's theory of light.
[69] "Young's Double Slit Experiment | Physics."

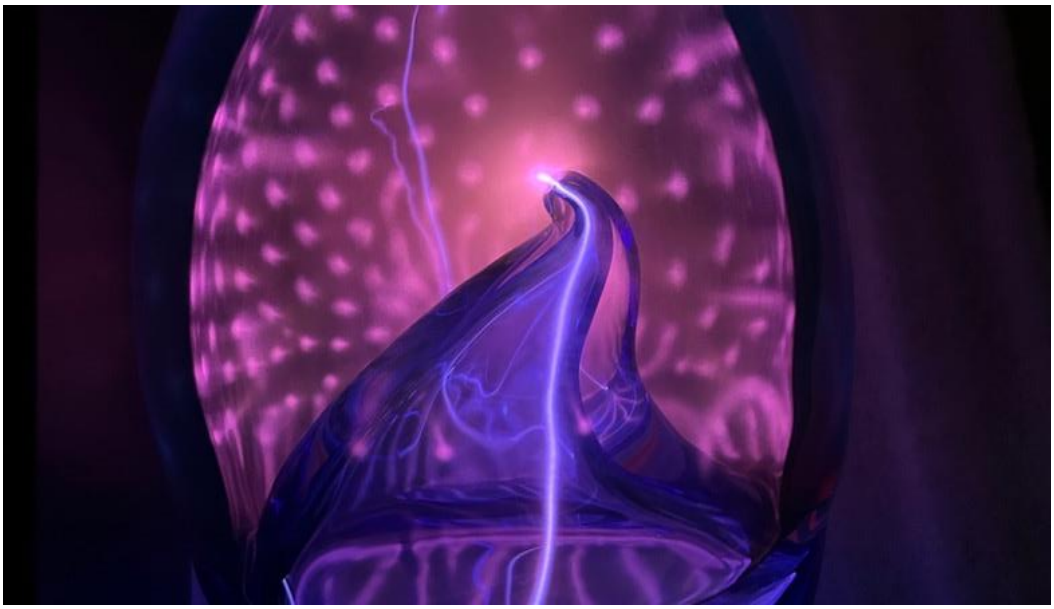


Figure 11 *Chambered Vessel,* 2024, plasma-illuminated blown glass vessel. This image evidences diffraction, showing how the luminous radiation squeezes through a small aperture, spilling wave-like into a larger volume, creating intersecting patterns of light.

Within the *Chambered Vessel* series discussed in Chapter 3, I observe plasma illumination passing through constrictions between interconnected chambers. When squeezed through a small aperture into a larger volume, a bright spot of light expands into the larger space. As the physical effects of diffractive interference describe waves of matter (either light or fluid) intersecting, I wonder whether the luminous behaviour of oscillating waves of light and the material properties of plasma within plasma-illuminated vessels constitute an example of physical diffraction made visible in a three-dimensional object (Figure 11).

1.7.2 Diffraction as Methodological Framework

Although there are examples of physical diffraction evident in plasma illumination, diffraction as a conceptual framework offers a methodology for investigating the minutiae of phenomena and practice and then celebrating their recombination. Much like peering through a diffraction grating, where white light reveals its constituent rainbow, so methodological diffraction allows me to investigate individual elements of

this practice in detail. Recombining material perspectives, techniques, histories, and their influences productively inform my practice. Dr Martin Murer from the University of Salzburg and co-authors write about the tangible disassembly of "computational things," they "believe there are significant qualities to be found in extending the mundane 'taking things apart' into an elaborate practice of un-crafting."[70] This conference presentation and paper resonate with many of my own experiences, in how deepening knowledge of objects and physical systems takes place through taking things apart. Within my project, this has involved, (both physically and conceptually) the imagined un-making or "un-crafting" of historic artefacts and their production methods, along with the physical dismantling of my own equipment to better understand their constitutive elements.

Rather than considering the physical properties of light-waves, feminist scholar and cultural critic Donna Haraway's framing of a diffractive methodology involves concepts emerging through collaborative processes. As she explains in an interview with Thyrza Goodeve, "I'm interested in the way diffraction patterns record the history of interaction, interference, reinforcement, difference."[72] Similarly, my investigation reveals the essential impact of distinct materials, matter, and energy combining and affecting each other.

Barad also discusses diffraction as methodology, noting that inheritance and indebtedness go to the core of untangling phenomena.[73] In light of this, I view my

[70] See Martin Murer et al., "Un-Crafting: Exploring Tangible Practices for Deconstruction in Interactive System Design," *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (New York, NY, USA), TEI '15, Association for Computing Machinery, January 15, 2015, 470.
[72] Routledge CRC Press, "How Like a Leaf." 102 During an interview between Donna Haraway and Thyrza Goodeve; *Diffraction as Critical Consciousness*.
[73] Juelskjær and Schwennesen, "Intra-Active Entanglements." 12 An Interview with Karen Barad, By Malou Juelskjær and Nete Schwennesen. Diffraction is also spoken about in Tuin and Dolphijn, *New Materialism*. 50 Barad "Diffractive readings bring inventive provocations; they are good to think with. They are respectful, detailed, ethical engagements."

mentors, colleagues, and the practitioners I interviewed as part of a lineage of making and eliciting the phenomena of plasma illumination.[74] The shared experience of mentorship and masterclasses within this demanding field catalyses skill development and material understanding. Mentorship does not privilege an apprenticeship model of learning, where skills are learned by rote with fixed outcomes; rather, it celebrates methods, minds and materials, and is aimed toward understanding the tripartite process required for plasma illumination.

Acknowledging that techniques and material understanding cannot be fully articulated through technical documentation alone, I have found mentorship to be a key method in my acquisition and integration of new knowledge. Research fellow Alvise Mattozzi and Laura Parolin assert aesthetic practices in the creation of artefacts as actions of exchange and translation, proposing "that such dialogue can be developed further by regarding 'aesthetic practices' as ones that encompass bodies translating bodies."[75] In this way, creative practice with plasma illumination benefits from shared knowledge, description and demonstration, particularly as the medium is affected by and composed of invisible constituents.

By integrating historical knowledge, scientific principles, and artistic experimentation while recognising the entangled nature of theory and practice, I have created experimental physical systems to make tangible interactivity and interconnection. I use a diffractive methodology, which deliberately refuses neat resolution or linear progression. Instead, it values discovery and productive uncertainty rather than predetermined outcomes.

[74] I acknowledge that practitioners Steven Cole, Peter Minson, Wayne Strattman have generously mentored me during this research, with their insights documented in Chapter 4.
[75] Mattozzi and Parolin, "Bodies Translating Bodies." 19

1.8 Plasma's Tripartite Process: My Practice of Leaks and Tangles

My studio work involves blowing glass vessels, modifying equipment to attain partial vacuums, and working with non-reactive gases at below-atmospheric pressures. Once encased within a glass vessel, these low-pressure gases are then excited into plasma by electricity. I experience the tripartite process as leaky and entangled, acknowledging this work's complex nature. Throughout this exegesis, I interrogate the material insights offered by producing and engaging with plasma illumination.

As an artist and glassblower working to elicit plasma illumination, I consider the first of the tripartite concerns to be glass vessel formation, and my career as a glassblower directly informs my methods.[76] In the diagram reproduced below, artist, educator, and podcaster Percy Echols II has visualised many of the overlapping studio-based concerns I have navigated (Figure 12), many of which are touched upon in Chapter 2.[77]

[76] My partner Matthew Curtis and I have a home studio, producing objects ranging from blown-glass tableware to sculptures, public artworks, and installations exhibited nationally and internationally.
[77] "Taming Lightning x GEEX." This Venn Diagram was developed as web content for Echol's Taming Lightning podcast. Recently re-published with the Glass Education Exchange (GEEX) "an online platform that serves glass education through community-building programming and resource-sharing." https://geex.glass/about/

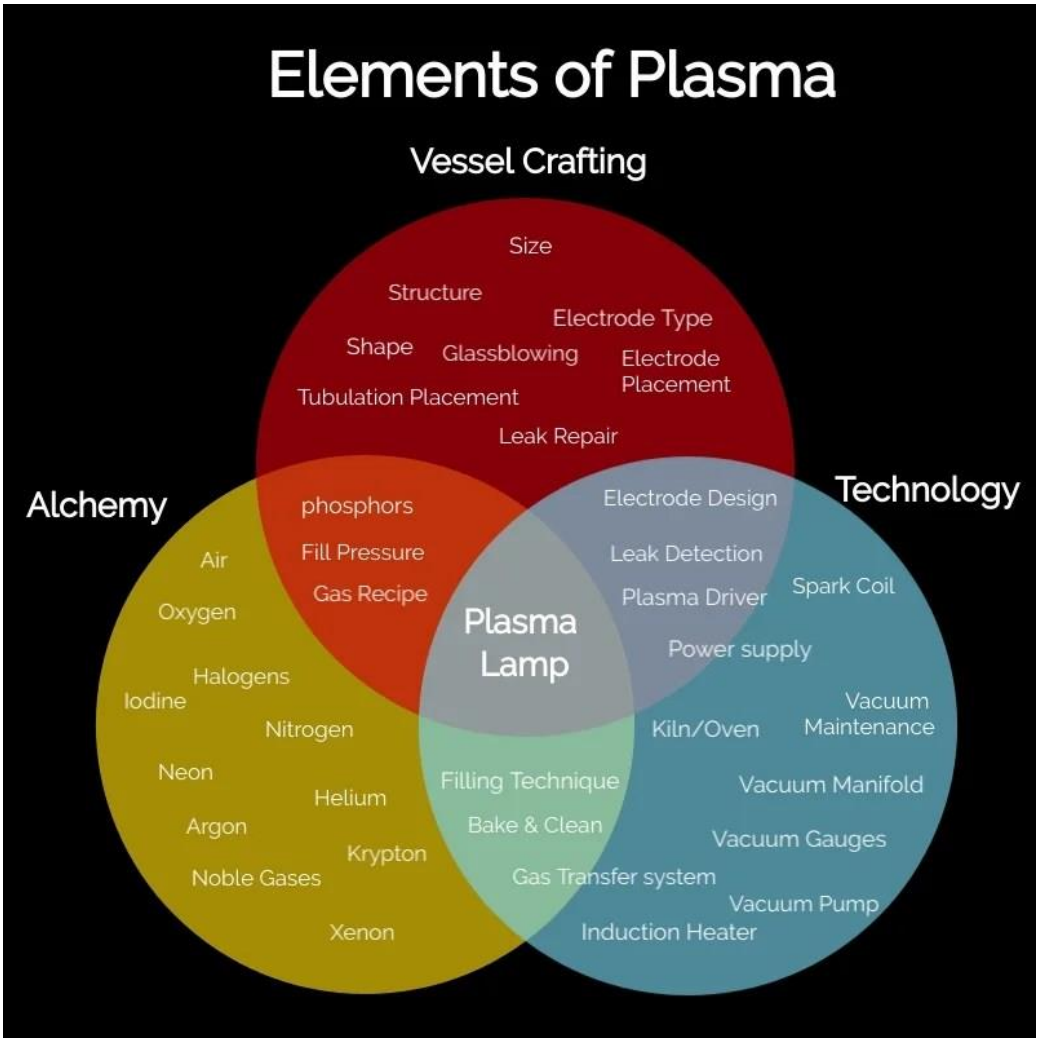


Figure 12 Percy Echols II, "Elements of Plasma Diagram," *Taming Lightning*, https://taminglightning.net/blog/elements-of-plasma-visual-diagram-2nd-edition-expanded.

After producing glass vessel in my studio, I work toward achieving specialised low-pressure conditions within that vessel. During this atmospheric manipulation, non-reactive gases (also referred to as noble, rare or inert gases) are inserted in small quantities and then encased within the vessel.[78] Later, with the application of high-

[78] Selig et al., "The Chemistry of the Noble Gases." 66 reference for non-reactive gases. Lees, *Neon Primer: A Handbook on Light Construction*. 68 reference for rare gases.

voltage electrical energy, the invisible gases may then become luminous, producing visible light through frenzied subatomic interactions.

The second part of the tripartite process unfolds at the site of the manifold, a multi-branched tubular apparatus, composed of vacuum-tight sealable inlets, outlets, and gauges to measure pressures. Using a connected vacuum pump, the manifold can evacuate the connected vessel's atmosphere. Furthermore, heating the glass in a kiln increases the molecular movement of the gases within the vessel, this assists to remove atmospheric impurities by the pump. Achieving a clean low-pressure environment within the vessel is essential. The manifold facilitates small quantities of invisible, non-reactive gases to be inserted, these inert or noble gases can also flush and purge impurities from the vessels.[79] These atmospheric alterations are then sealed inside the glass. Altering the internal atmosphere within the manifold (and vessel) is an exercise in moving atoms and molecules from space to space, a practice of displacing, replacing, purifying, inserting, testing and then sealing the glass to encase this changed atmosphere within the vessel. In Chapter 3, I discuss using blown-glass techniques to create the *Chambered Vessels*, while in Chapter 4 I discuss using laboratory glass skills, which informed the development of my *Entangled Vessels*. As will be seen, I conceptualise my work as an extension of the manifold.

The third part of the process, excitation, is the most difficult to understand, yet the most satisfying to elicit. This is the point at which the low-pressure, non-reactive gas atoms, encased within the glass are changed into their plasma state, transformed from a low-level gas into luminosity through the application of high-voltage electricity. Excitation or visible light production is contingent upon specialised low atmospheric

[79] Selig et al., "The Chemistry of the Noble Gases." 70 detailing the nuanced atomic structure of the "noble gases" I use within my work.

conditions within the vessel combined with the use of specialised transformers, necessary to elicit this interactive form of illumination within a glass vessel.

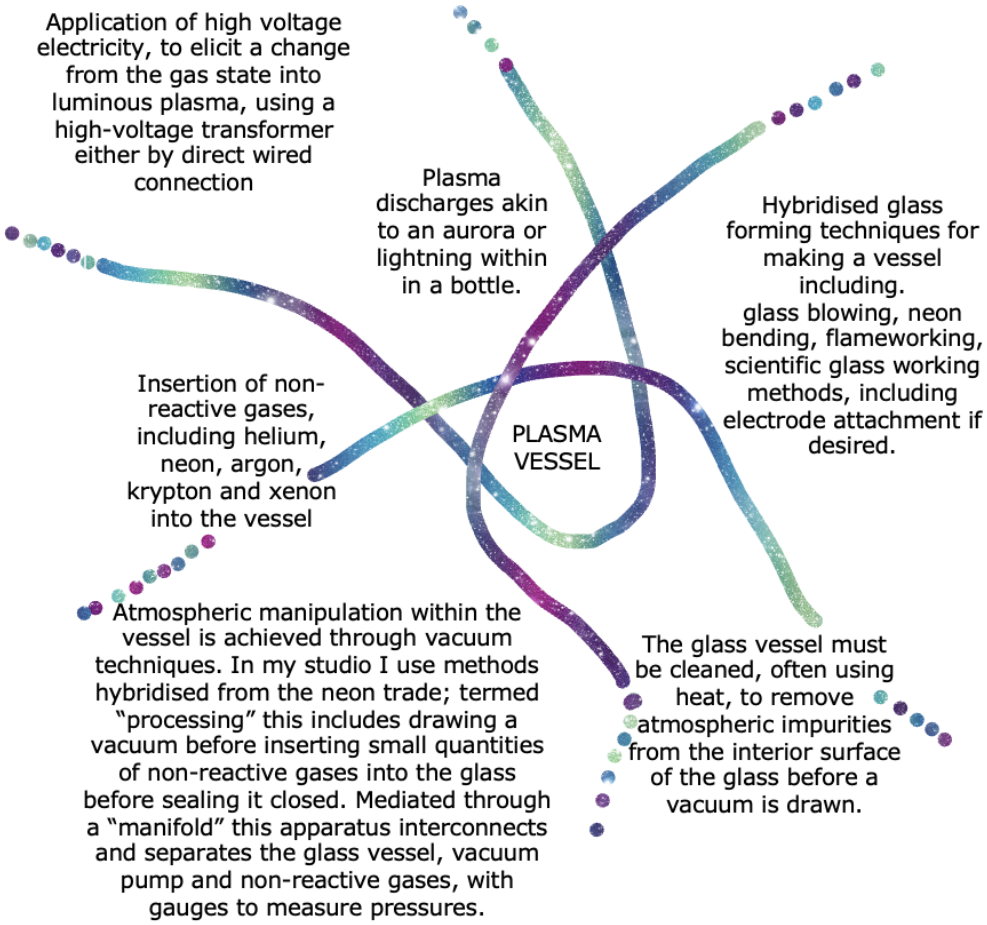


Figure 13 Diagram of "leaks and tangles", indicating the non-linearity of this practice, 2025.

1.9 Interconnected Circulatory Process

Vascular themes permeate this research, as meandering paths of circulation inform a comparison between plasma flow in the body and the flow of plasma contained in these luminous vessels. Scott Riddell's *Scheme of Circulation* (1913) likens the circulatory system, including the heart chambers and the capillaried networks of organ

tissues, to bulging regions within a singular flowing loop (Figure 14).[80] Each node in this ring appears contained, yet is composed of vein-to-capillary-to-artery connections, with their tangled networks describing a pulsing interconnectivity (Figure 15).[81] These interconnected sites of separation and connection are reflective of the themes and processes that influence each other, informing each of the four following chapters.

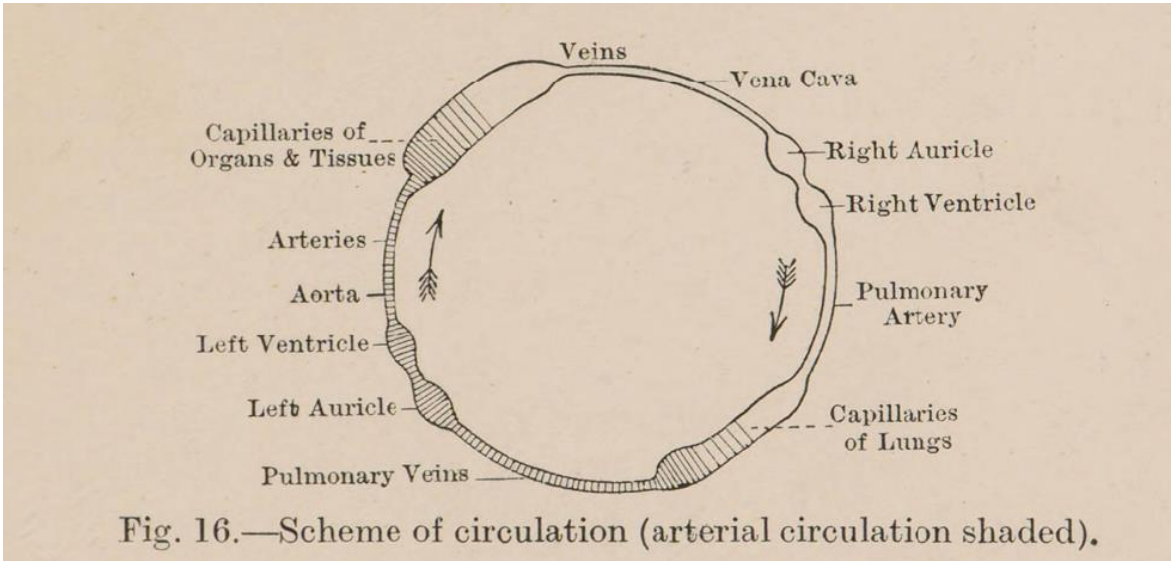


Figure 14 Scott Riddell, "Scheme of Circulation," 1913, from *A Manual of Ambulance*, Wellcome Collection.

[80] Wellcome Collect, "A Manual of Ambulance / by J. Scott Riddell." 14 "In a tabular form the order of circulation is- Left ventricle. Aorta. Arteries and capillaries. Veins. Venea cavae. Right auricle. Right ventricle. Pulmonary artery. Capillaries of lungs. Pulmonary veins. Left auricle. Left ventricle. Aorta." I consider that capilliaried could be a verb to describe that tangled action of connection that connects our organs and extremities to our circulation.
[81] "Blood Vessel | Definition, Anatomy, Function, & Types | Britannica." My sketch (*Fig.* 1.7) references the Britannica diagram.



Figure 15 Ink and watercolour sketch, 2024, showing vein-capillary-artery system, based on a diagram from *Encyclopædia Britannica*.

1.10 Exegesis Structure

The following chapter (Chapter 2: Radiant Matter—Examining the Curious Phenomena of Plasma, from Invisible to Visible Matter) provides a contextual review of plasma's physical properties and the conditions required to elicit luminous phenomena within glass vessels. The chapter examines how gas-discharge objects in the late 1800s served dual purposes: as scientific instruments revealing relationships between electricity and magnetism and as aesthetic objects delighting European salon patrons. Drawing attention to the glass vessels and their makers, I discuss how early gas-discharge experiments (c. 1850) inform modern neon signage and contemporary luminous art practices, including my own.

While scientific histories, including foundational insights into matter's subatomic structure and the cultural relevance of the neon trade, have been well documented, interest in plasma illumination medium within creative practice remains underexplored. My research addresses this gap by investigating plasma illumination's potential as a responsive and relational medium. Throughout Chapters 3 and 4, I expand upon adapting the tripartite process to elicit the conditions for illumination within distinct series of luminous vascular plasma vessels.

In Chapter 3: *Intra/twined* and *Chambered Vessels*—Exploring Plasma's Responsive Nature within Blown-Glass Vessels, I examine the iterative development of my illuminated blown-glass objects, positioning them in a dialogue between historic gas-discharge objects (particularly Geissler tubes) and contemporary glassblowing practice. Drawing on Ingold's concept of maker, process, and matter being in constant "flux", I describe relationships between materials and histories in creating novel chambered forms. I demonstrate making as a method for creating the conditions for better understanding the relationship between matter and energy. This chapter provides evidence that every aspect of the tripartite process affects the outcomes of the objects and installations.

Chapter 4: Entangled Vessels—Manifold and Capacitance as Sites of Circulation, Containment, and Connectivity, examines the adaptation of neon bending techniques hybridised with scientific glassblowing to produce interconnected tubular conduits for plasma installations. Key moments of mentorship enabled me to experiment with laboratory glass, informing developments within my work. I was able to extend metaphors of circulation as a conduit for connections through manipulating this more robust laboratory glass.

Resonant with Barad's concepts of “intra-action” and discussions of the agency of an apparatus, I explore how contemplating the plasma manifold informed shifts in my practice. The chapter also discusses physical processes for eliciting capacitively luminous objects, with no wires or electrodes. Suspending moveable components enabled me to explore object and installation strategies, examining how proximity between objects and viewers affects illumination quality.

In Chapter 5: Properties of Plasma—From Responsiveness to Relationality, I focus on the influences and reception of exhibited plasma objects and installations. Viewer interaction alters plasma behaviours: glow discharge brightens, arcing discharge moves toward contact, revealing relationality. What became evident was that illumination quality within these objects is constantly influenced by multiple factors, that the tripartite process of production, the environment, and viewer-participant proximity, or what Rovelli describes as “a dense web of interactions”.[82]

As I shifted focus, I began to consider the wonder of these interactions at the subatomic scale, and the more subtle opportunities that capacitive illumination offers. I began to elicit plasma at the edge of luminosity, where plasma behaviours shift and coloured lights within the vessels change in response to external influences. This edge is alive with wonder, illuminating the blurred boundary between craft and research, tool and science, trade and theory, revealing plasma as both a phenomenon and medium for exploring our interconnectivity with the energetic world. This exegesis frames plasma illumination as fundamentally relational, rendering invisible forces visible.

The significance of this research lies in its small but considered technical contributions to glassmaking, alongside documenting the nuanced insights gathered through conversations with established plasma practitioners. Through making and

[82] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics*. 68

experimenting, it addresses fundamental questions about how plasma illumination can function as a relational physical system, revealing viewer-participant presence and proximity through changing qualities of luminosity. The research offers diffractive models for interactive studio glass practice, inviting direct material engagement rather than passive viewing, and contributing to broader discussions about materiality, presence, and connection in contemporary art practice.

Chapter 2: Examining the Curious Phenomena of Plasma—From Invisible to Visible Matter

This chapter contextualises plasma as radiating luminous phenomena and investigates the interconnected relationship between matter and energy. Employing a diffractive methodology, I examine how physical principles, scientific methods, and studio techniques intertwine with carefully crafted glass apparatus to elicit these phenomena. These constituent approaches to eliciting plasma illumination overlap and influence each other non-linearly.

Examining nineteenth-century gas-discharge apparatus offers insights that can be applied to plasma's use in contemporary artistic practice. These apparatus were used as tools to investigate electrical phenomena, making visible the relationship between electricity and magnetism. Complex glass apparatus became sites of experimentation, revealing the invisible particulate nature of light. Untangling luminous phenomena and developing this tripartite process relied upon the combination of theoretical experimentation and apparatus produced through skilled glassmaking techniques.

2.1 The Fourth State of Matter: Beyond Gas in Concert with Energy

In 1879, after observing the radiant matter being elicited within the luminous gas-discharge vessels of the mid-1800s, English natural philosopher Michael Faraday proposed another state of matter beyond solids, liquids, and gases. He stated:

> If we conceive a change as far beyond vaporisation as that is above fluidity and then take into account also the proportional increased extent of alteration as the changes rise, we shall perhaps, if we can form any conception at all, not fall far short of radiant matter.[83]

Now known as plasma, this state is structurally distinct from gases, which contemporary researchers refer to as an "electric fluid".[84] It is said to make up over 95% of the visible universe, and is manifested in auroras, lightning, and light radiating from stars.[85]

Comprehending the structure and behaviours of this state of matter informs and shapes my practice. To conceptualise the thing-ness of plasma, I began by considering the structure of an atom, as this luminosity is contingent upon subatomic actions.

[83] Crookes, On Radiant Matter. 1 Faraday's lecture is referenced by English chemist and physicist William Crookes in his book of the same name. Crookes attributes this phrase to Faraday.
[84] Physics and director.physics@anu.edu.au, "Dr Matt Thompson Profile." Dr Matt Thompson uttered the delightful description "electric fluid" during a laboratory visit to view the equipment within an experiment (2023).
[85] "What Is Plasma? | MIT Plasma Science and Fusion Center."

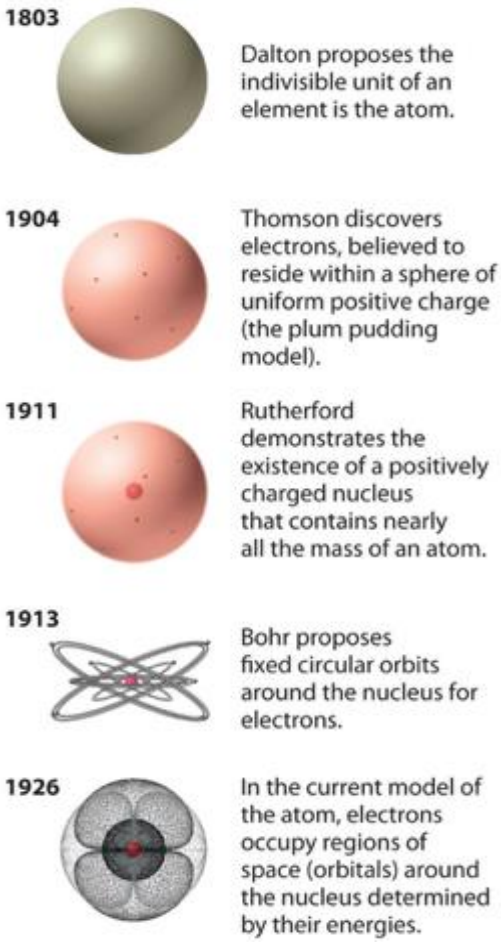


Figure 16 "The Evolution of Atomic Theory, as Illustrated by Models of the Oxygen Atom," from "2.4: The Structure of Atoms," Chemistry LibreTexts, licensed under CC BY-NC-SA.

Current atomic models reveal a balancing act: minute negatively charged electrons orbit their heavier atomic nucleus, perfectly balancing its positive charge (Figure 16).[86] Atoms can be changed from a gas state into a plasma state when thermal or high-voltage electrical energy is applied. Ionisation describes subatomic processes that alter a previously neutral atom or molecule, allowing it to carry a charge.[87] With increasing energy application, matter can be transformed from one state to another. When sufficient energy is applied to gas, ionisation occurs as electrons are "ripped"

[86] Chem. Libr., "2.4." Image 1.1 is also from this lecture series; The Structure of Atoms." Image used with Permission (CC BY-SA-NC).

[87] Electrons are referred to subatomic particles, referred to as "elementary" as they cannot be broken into smaller units.

from their atomic orbits, creating positively charged ions.[88] Plasma contains both ions and freed electrons, which allows the plasma to conduct electricity and respond to electromagnetic forces.[89] Beyond ionisation, the emission of visible light is essential to a plasma illumination practice and is described by the physical process of excitation.[90] These phenomena were revealed through experimentation with gas-discharge illumination and are discussed in this chapter and the ones that follow.

2.2 Creating Low-Pressure, Altering Atmospheres

The production of plasma illumination involves creating and then cleaning a glass vessel. Atmospheric contents are evacuated through a manifold, which consists of interconnecting tube, valves and specially calibrated gauges. The manifold connects to a vacuum pump, which removes atmospheric gas molecules, lowering pressure within the vessel. I measure pressures within the manifold on gauges using increments of Torr, which is,

> a measurement system developed by Evangelista Torricelli, a student of Galileo's, in the early 1600s. Torricelli experimented with mercury in glass tubes, postulating that we "live submerged at the bottom of an ocean of the element air, which by unquestioned experiments is known to have weight.[91]

[88] "THE ART OF PLASMA, Museum of Neon Art." A Group Exhibition Featuring Works by 32 Artists. In the catalogue essay Kline and Kirshner describe plasma as: "Electrons are ripped from the tight hold of the nucleus and roam freely amidst the chaos of other vibrating atoms. These free electrons allow the plasma to conduct an electric current. As electrons vibrate in this plasma they are continually departing from and returning to the nest of the atom. They take the energy from the applied voltage to leave and must give up that energy as heat and light at discrete frequencies to return. This is the process that yields the color within the plasma."
[89] Burm, "Plasma." 407 I use the terms state and phase, although Karel Burm presents the argument that the fourth phase or state are misleading terms, as "[t]he transition from gas to plasma occurs differently from other transitions, which are first-order phase transitions."
[90] "BBC Radio 4 - In Our Time, Plasma." Audio 09:00 Melvyn Bragg and guests discuss plasma, the fourth state of matter after solid, liquid and gas.
[91] West, "Torricelli and the Ocean of Air." 66-73.

These experiments established methods to read air pressure (Figure 17).

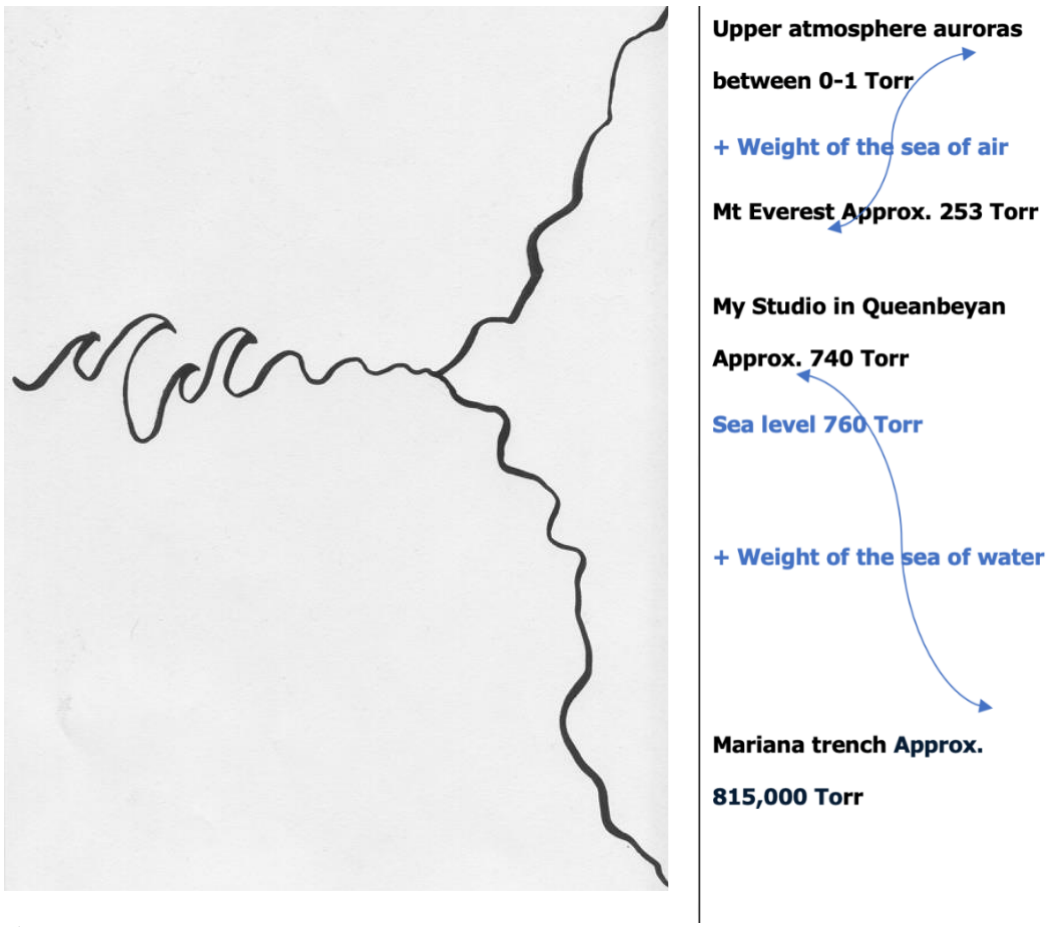


Figure 17 *Torr Concept Sketch*, 2025.

The relevance of pressure to a plasma vessel is that lower pressures require relatively less energy to excite gas into its luminous plasma state.[92] Pressure and volume affect the quality of luminosity, changing the appearance of ionised gases.[93]

[92] "BBC Radio 4 - In Our Time, Kinetic Theory." (23.05.2019) Audio 21:09 Ted Forgan, Emeritus Professor of Physics at the University of Birmingham discusses the mean free path in gases.
Melvyn Bragg and guests Steven Bramwell, Professor of Physics at University College London. Isobel Falconer, Reader in History of Mathematics at the University of St Andrews and, Producer: Simon Tillotson

[93] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 102

2.3 Early Plasma Phenomena: Barometric Light and Static Electricity

Glass vessels at low pressure that contained mercury provided early glimpses of plasma illumination activated by electrostatic phenomena. In 1675, Jean Picard documented a mysterious glow in mercury barometers, later called barometric light. When moving a mercury-filled glass tube at night, observers noticed a pale bluish glow within the vessel.[94] As mercury moves, freed electrons interact with mercury vapour, producing visible light through excitation. Barometric light reveals that plasma phenomena emerge more easily at low atmospheric pressures. This exemplifies a link between scientific instrumentation and unexpected phenomena being revealed.

Here static electricity powers the invisible yet charged subatomic principles underlying plasma excitation. Early electrostatic phenomena are traced to the ancient Greek philosopher Thales of Miletus (died c. 548–545 BCE), who reportedly noticed that certain materials possess attractive and repulsive forces capable of moving small objects.[95] Amber, or *elektron* as it was known in ancient Greece, was renowned for attracting small objects.[96]

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[94] Kikunaga, K., and Terasaki, N. "Demonstration of Static Electricity Induced Luminescence," 1. Roller, "Francis Hauksbee." 64

[95] Iversen and Lacks, "A Life of Its Own." https://doi-org.virtual.anu.edu.au/10.1016/j.elstat.2012.03.002 These phenomena are tenuously ascribed to the Greek natural philosopher Thales of Miletus (600 BCE), noticing that certain materials possess attractive and repulsive forces, moving small objects.

[96] Getty Museum. "Ancient Names for Amber." N.d. Accessed September 21, 2025. https://www.getty.edu/publications/ambers/intro/7/; Etymonline, "Electron - Etymology, Origin & Meaning."



Figure 18 Neon-filled tendril excited by static electricity, 2024. The blur is the artist's hand twisting one tube.

One cold, dry winter night, I witnessed the phenomenon of static electricity as the driver for plasma illumination. Walking around in my studio, in a woollen jumper and sheepskin boots, I sensed the familiar crackling static of my clothing turn into an unexpected light show. As I twisted a glass tube containing low-pressure neon gas, the voltage differential excited a ghostly neon glow within the tube (Figure 18). This wondrous experience demonstrated to me plasma's responsive potential to make the invisible visible.

2.4 Electromagnetic Activation: From Coils to Transformers

Electric transformers are essential to the tripartite process of plasma practice, as they supply the high voltages necessary for electromagnetic activation. In contemporary studio practice, specialised transformers can be plugged into our alternating current (AC) electrical grid, transforming Australian 240 volts (or other voltages in other countries) into 9,000–12,000 volts.[97] Transformers rely upon winding coils of wire to induce electricity, reminiscent of earliest experiments in electromagnetic induction.



(L) Figure 19 Michael Faraday's electromagnetic coils, Royal Institution, London. Samples of coils Faraday made and used in his experiments.

(R) Figure 20 Example of Faraday's coils, wound wires around a metal core, demonstrating material configuration that induced electrical phenomena.

During the nineteenth century, electrical phenomena were systematically investigated through experimentation with static or direct current (DC) electricity. This involved winding wire coils around magnets to create electromagnetic induction, the process in which a wire and magnet can generate electrical currents ((L) Figure 19 and (R) Figure 20). In 1832, Michael Faraday proposed the connection between electricity and magnetism. It laid the groundwork for the field theory that conceptualises space as

[97] Lees, *Neon Primer: A Handbook on Light Construction*. 126

fields capable of transmitting forces through electromagnetic waves.[98] James Clerk Maxwell's concurrent mathematical unification of electricity and magnetism substantiated these concepts.[99]

Early researchers relied upon Leiden jars (essentially a battery) for storing static electricity in specialised glass vessels.[100] Experimentation with the induction and distribution of static electricity later led to direct current (DC) circuits, technologies for which Thomas Edison became famous around 1882.[101] Concurrently, Nikola Tesla and George Westinghouse introduced alternating current (AC) in 1882, establishing the foundation of contemporary electrical power grids.[102] This is now the electrical system that powers the specialised transformers I use to elicit excitation within my work.

2.5 Luminous Gas-Discharge Tubes: Geissler

During the 1850s, German glass instrument maker Heinrich Geissler produced countless specialised glass apparatus for experiments.[103] [104] [105] Geissler's refinement of vacuum technologies enabled the creation of well-exhausted gas-discharge tubes through which electricity could be sent.[106] Although various tubes were created by multiple glassworkers across Europe, they are commonly referred to as Geissler

[98] Faraday, “V. Experimental Researches in Electricity.” 125
[99] BBC, “BBC Radio 4 - In Our Time, Maxwell.”
[100] “BBC Radio 4 - In Our Time, Electrickery.”
[101] Schiffer et al., *Draw the Lightning Down*. 228, 229
[102] BBC, “BBC Radio 4 - In Our Time, Nikola Tesla.”
[103] N., “Heinrich Geissler.”
[104] Dörfel, “Der Meister Und Seine Schule — Zur Biographie Und Wirkung Des Instrumentenbauers Heinrich Geißler.”
[105] Sella, “Geissler’s Glassware.”
[106] Reif-Acherman, “Heinrich Geissler.” 1675

tubes.[107] Increasingly, rarefied gases were re-inserted into these vessels resulting in colourful luminous effects, when subjected to electrical charges (Figure 21).[108]



Figure 21 Examples of Geissler tubes from the glassblowing laboratory headed by Sally Prasch at the University of Massachusetts Amherst, USA, during field research in 2023.

I first held a Geissler tube in the glassblowing laboratory at the University of Massachusetts Amherst, which is headed by scientific glassblower and artist Sally Prasch (Figure 21).[109] Examining the varied architectures and discussing their making with Prasch informed the development of my *Chambered Vessel* series discussed in Chapter 3. Historian Falk Müller describes how Geissler carried "some tubes through which no current had previously passed (virgin tube[s] he called them), which present most beautiful phenomena lost for ever after to brief a period."[110] This appreciation of ephemeral luminosity informed my own installation strategies (discussed in Chapter 5), as I began to embrace plasma's transient, shifting, responsive nature rather than

[107] "Glassblowers."
[108] Müller, "Johann Wilhelm Hittorf and the Material Culture of Nineteenth-Century Gas Discharge Research."
[109] Dijkstra, "Heinrich Geissler | Vacuum Tubes, Physics, Inventions |."
These delicate artifacts, gifted to Prasch, offered tangible connections to the legacy of scientific glassblowing. Sally Prasch glassblowing laboratory at Massachusetts Amhurst University ...These examples were gifted to her when a local neon shop closed.
[110] Müller, "Johann Wilhelm Hittorf and the Material Culture of Nineteenth-Century Gas Discharge Research." 213

seeking fixed luminosity. The development of gas-discharge technologies, from early experiments with direct current electricity being passed through Geissler's tubes, to ongoing developments in contemporary transformers, provides crucial context for understanding the technical and conceptual foundations that contemporary plasma practitioners continue to build upon.

During the 1800's gas-discharge tubes enabled experimenters such as Faraday to send electricity through evacuated glass vessels, rather than wires, to witness the effects of electrical phenomena.[111] These tubes were produced with two metallic connectors sealed into the glass. In many of these examples, an anode connects to the positive port of a power source, while the cathode connects to the negative port, using DC electricity (Figure 22). When activated, the polarisation of charge drives electrons toward the anode and ions toward the cathode. This movement dislodges further electrons, and the ionisation cascade, or "avalanche", continues.[112]

[111] Schiffer et al., *Draw the Lightning Down*. 77
[112] "BBC Radio 4 - In Our Time, Plasma." Interview with Bill Graham

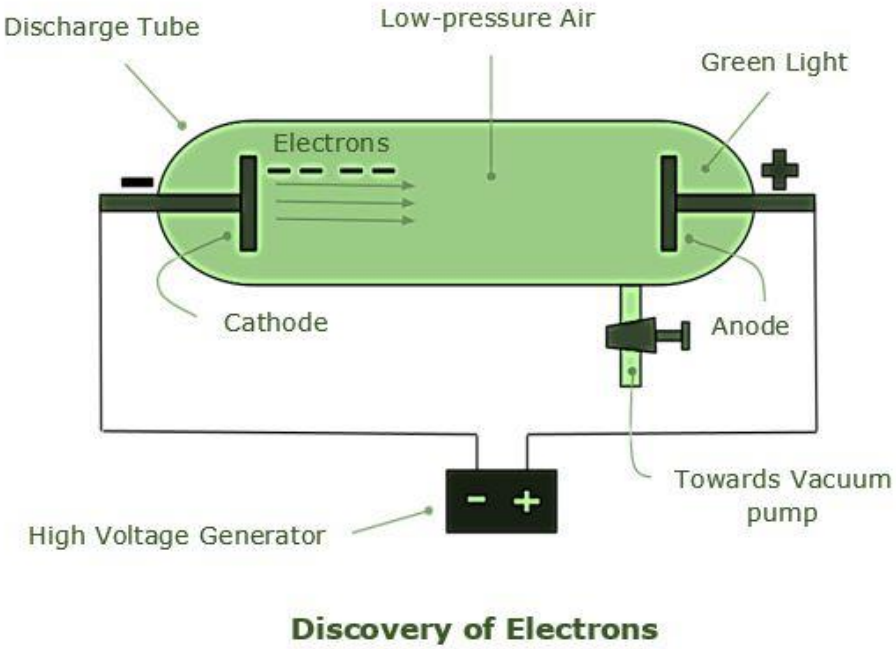


Figure 22 Video still from GeeksforGeeks, "Discovery of Electrons," 2022, visualising the circuit of a discharge tube with cathode and anode.

Within gas discharge tubes operating with this anode and cathode polarity, I visualise this circuit like a battery powering a torch.[113] Differences in the internal pressures, glass vessel architecture, and connection to the transformer all affect the quality of luminosity.

Once the vessel is evacuated by a pump, as (Figure 22) and the stopcock closed to keep the lowered pressure within, applying wires to the terminals ionises the low-level gases, and this charge-carrying plasma completes the circuit. Striations and distinctive plasma phenomena can occur at the opposing electrical terminals, revealing dark spaces and oscillating bands of colour at these DC polarities (Figure 23). Variances in appearance are attributed to how the subatomic ions and electrons are attracted to or repulsed by the polarities (anode or cathode) due to their distinct (- +) charges and

[113] GeeksforGeeks, "Discovery of Electrons." This educational resource has excellent diagrams.

relative weights. Descriptions of phenomena in vacuum tubes include areas named the "Faraday dark space" or "Crookes dark space", crediting these natural philosophers and scientists with their discoveries within the vocabulary of plasma science.[115] Contemporary alternating current (AC) transformers create wired connections to electrodes, metallic components sealed within a glass sleeve, which accommodate the constantly switching polarity.[116]

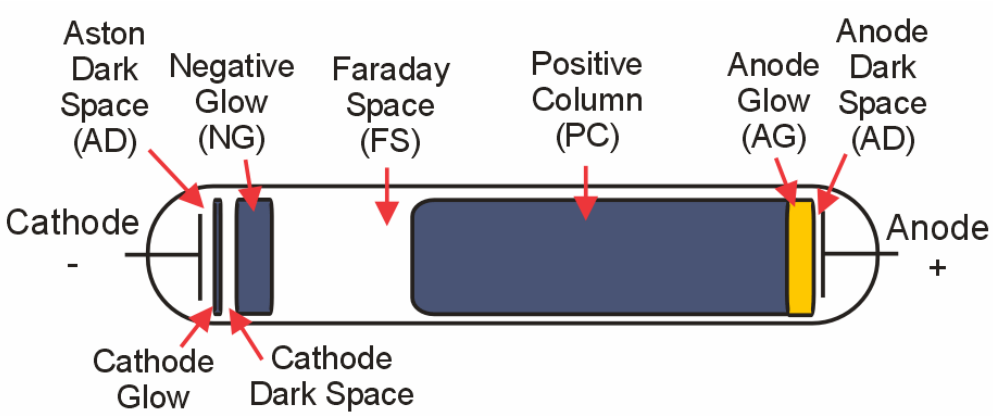


Figure 23 An electric glow discharge (Crookes tube) showing the different glowing regions in the gas that appear when a high DC voltage is applied between the electrodes.

[115] Langmuir and Compton, "Electrical Discharges in Gases Part II. Fundamental Phenomena in Electrical Discharges."
Figure 23 https://en.wikipedia.org/wiki/User:Iantresman
[116] Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 8
Wayne Strattman, Anders Mikkelsen email communication Nov 15, 2023.
As I predominantly work with single-electrode configurations, I sought clarification, Plasma Art Alliance colleagues Wayne Strattman and Anders Mikkelsen described how anode and cathode terminals attract oppositely charged particles.
Anders: "…in a single electrode lamp, or any lamp run by AC, the roles of the cathode and anode will swap twice on every cycle of the AC waveform. Since the electrode(s) serve as both anode and cathode, I'd just call them "electrodes."
Wayne: "… Using the term anode or cathode implies polarity whereas the term electrode is universal. A capacitive electrode will by virtue of how it works be alternating polarity so using the term electrode definitely makes sense. Wayne"

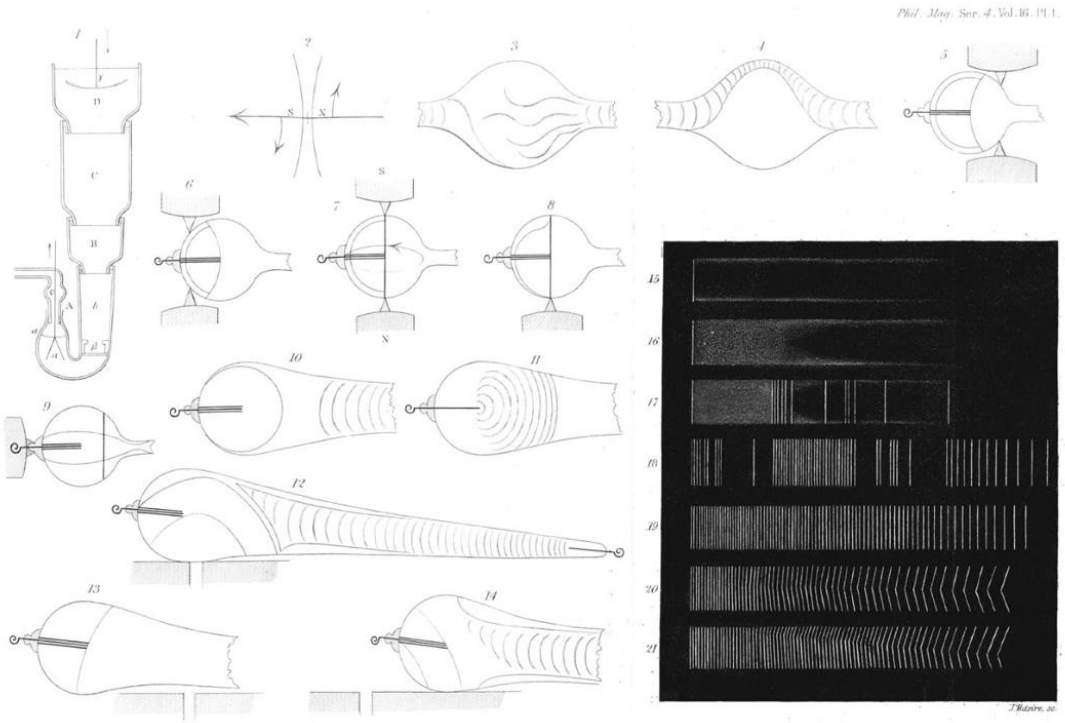


Figure 24 Julius Plücker diagrams illustrating variations of striations produced by the glass vessel's architecture and the distance between positive and negative electrodes. Plücker, "XIV. On the Action of the Magnet upon the Electrical Discharge in Rarefied Gases," 123.

Heinrich Geissler's collaboration with Julius Plücker extended beyond purely scientific objectives, encompassing aesthetic considerations.[117] Fascinated by the visual appearance of discharges, Plücker frequently described them as *schön* (meaning beautiful), writing that "this remarkable light will occupy our special attention."[118] His investigation into the visual appearance of bands and beads of light, or striations, evidenced in some of his specialised tubes, illustrate how vessel formation affects plasma behaviour. Plücker's diagrams from 1858 document the variations of the striations he observed (Figure 24).[119] These delicate renditions enable me to conceptualise the actions of light moving and interacting within these tubes. Swiss-

[117] HathiTrust, "On the Spectra of Ignited Gases & Vapours, with Especial Regard to the Different Spectra of the Same Elementary Gaseous Substance / By Dr. J. Plücker ...& ..."
[118] Julius Plücker, "XIV. On the Action of the Magnet upon the Electrical Discharge in Rarefied Gases," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, August 1, 1858, 123.
[119] Plücker, "XIV. On the Action of the Magnet upon the Electrical Discharge in Rarefied Gases," 123.

born American physicist Leonard Loeb postulated in 1939 that striations are “caused by nodes and loops set up by invisible plasma oscillations.”[120] This description aligned with my observations of fluid patterns in contemporary plasma vessels, allowing me to associate interference patterns with luminous diffraction phenomena.

2.6 Scientific Craft, Visualising the Invisible, Magnetism and Electrons

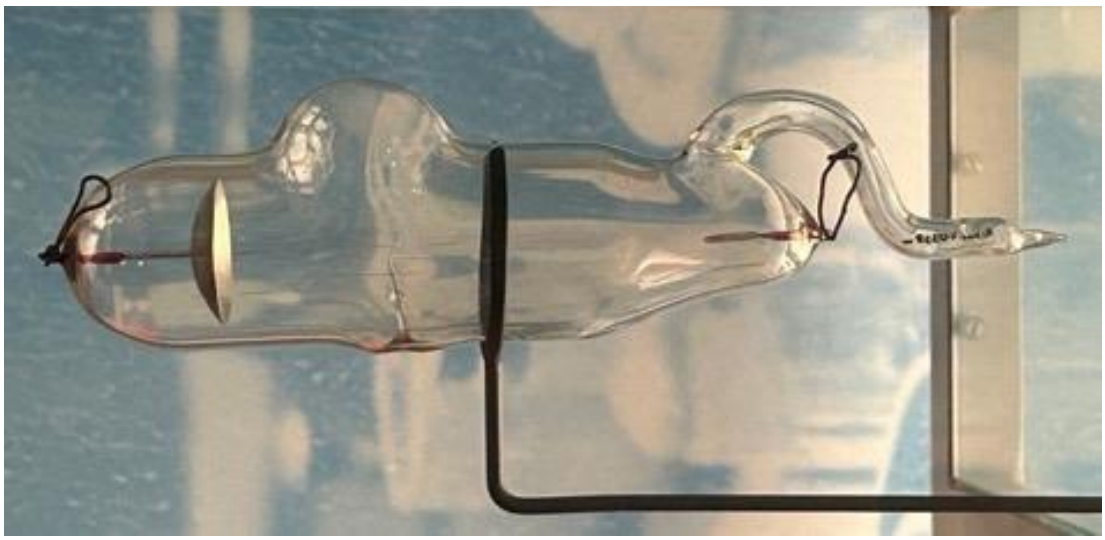


Figure 25 William Crookes's cathode ray tube, blown glass, possibly with tungsten wires, approximately 25 cm. Description from Royal Institution wall text.

In the 1880s, William Crookes's pioneering work demonstrated the streaming behaviour of rays within evacuated glass vessels.[121] These vessels were not merely containers; instead, they were active components in visualising phenomena that would otherwise remain imperceptible. The increasing complexity of the glass apparatus, from simple tubes to organ-like shapes with intricate internal metallic components, contributed to many experimental outcomes (Figure 25).

[120] Leonard B. Loeb, Fundamental Processes Of Electrical Discharge In Gases. 574
[121] Crookes, On Radiant Matter. 3

Crookes observed that at the anode end of some tubes, a green glow would appear. The curious aurora elicited by Crookes within his glass tubes required careful preparation of the material and atmospheric conditions.[122] Metallic internal structures were bled or wetted into the glass envelope to create seamless, vacuum-tight seals before atmospheric alteration.[123] Once illuminated, the internal structure can cast a corresponding shadow onto the far interior walls of the vessel. This streaming effect and its shadow demonstrated that cathode rays travelled in straight lines.



Figure 26 Carmel Azzopardi, "Maltese Cross.Avi," YouTube video stills, Magnet changing shadow shape on tube wall. Video still (timestamp 0:35, 1:05) https://www.youtube.com/watch?v=IzcApoeuG-s..

The intrinsic relationship between electricity and magnetism was demonstrated in Crookes's experiments, using magnets to alter the streaming trajectory of the cathode rays (now understood to be streams of electrons) (Figure 26).[124] Within contemporary plasma physics research, this electromagnetic relationship demands that incredibly high-temperature plasmas are contained within metallic toroidal structures

[122] Gary S. Coyne *The Laboratory Companion A Practical Guide To Materials, Equipment, And Technique Wiley Interscience (2005)*.
[123] Jeff Feigen, interview with the author, 08 December 2023, full transcript available in Appendix 5. Wetting is a term which describes making the surface conditions of the metallic component of the electrode/cathode or anode, capable of making a seamless join onto the glass.
[124] Carmel Azzopardi, "Maltese Cross.Avi," YouTube video, posted November 1, 2011, accessed January 27, 2026. https://www.youtube.com/watch?v=IzcApoeuG-s.

(tokamaks), where strong magnets further shape the plasma, this disallows the plasma from touching the metallic walls.[125] This physical and magnetic containment prevents the energetic plasma from touching the vessel/tokamak walls, as contact would destroy the inner surfaces, damaging the container.[126]

The collaborative relationship between English physicist J. J. Thomson and master glassblower Ebenezer Everett at Cambridge University's Cavendish Laboratory in the late 1800s revolutionised our understanding of atomic structure. Thomson's discoveries culminated in the identification of the electron as sub atomic in 1897, earning him the Nobel Prize and establishing the subatomic nature of matter that would become a foundation of quantum mechanics.[127] These early experiments led Thomson to propose his plum pudding model of the atom, conceptualising the invisible structure of matter from observable phenomena made visible within specialised glass vessels.

[125] Energy.Gov, "DOE Explains...Tokamaks."
[126] V.N. Tsytovich, *Lectures on Non-Linear Plasma Kinetics*, with D. Terhaar, Springer Series on Atoms + Plasmas 17 (Springer, 1995), 13.
[127] The earlier experiments with Geissler tubes were instrumental in J.J. Thomson's identification of the electron (1897) as a subatomic particle. This breakthrough earned him the Nobel Prize. J.J. Thomson's experiments revealed these lighter subatomic particles or 'corpuscles', lighter than any known atoms. These particles adopted the term 'electron', previously described by G. Johnstone Stoney as a unit of electrical charge.
[127] This subatomic nature of electrons was foundational to the development of theories of quantum mechanics.



Figure 27 Glassblower at work, Cavendish Laboratory, Cambridge University, ca. 1897, Whipple Museum of the History of Science. Photograph from the period of J. J. Thomson's electron discovery. Glassblower unidentified.

Anecdotes reveal Thomson as famously clumsy, often relegated to the far end of the laboratory to prevent damage to the fragile tubes, and actively discouraged from approaching the delicate glass apparatus Everett created for these experiments (Figure 27).[128] This combination of theoretical knowledge (Thomson) with practical expertise (Everett) exemplifies how specialised craft knowledge and making practices were essential to scientific discovery. This dynamic continues in many contemporary plasma practices where artists collaborate with specialised fabricators.[129]

2.7 Tripartite Glass Manipulation

As I am a glassblower, vessel making represents the area of plasma illumination's tripartite process that I can most directly influence. Glass has played a vital role in scientific experimentation, with glassmakers described as a “forgotten link” in

[128] BBC, “BBC Radio 4 - In Our Time, The Electron.” There is a delightful anecdote where Harry Cliff from the University of Cambridge sets the scene of Thompsons clumsiness.

[129] In contemporary arts practice, skilled fabricators in glass or plasma often produce work for artists. During my interview with Lemaire, an educator, artist, and fabricator, I considered the historic resonances of her multiple roles within this collaborative tradition.

countless scientific endeavours.[130] Material scientist and author Professor Mark Miodownik considers glass a necessary condition for producing scientific apparatus; it is seemingly "featureless and invisible," refined and developed in the pursuit of new knowledge.[131] Scientists, makers, and artists manipulate glass to enhance or distort vision, creating liminal membranes that hold, reflect, refract, scatter, and fluoresce with light.[132]

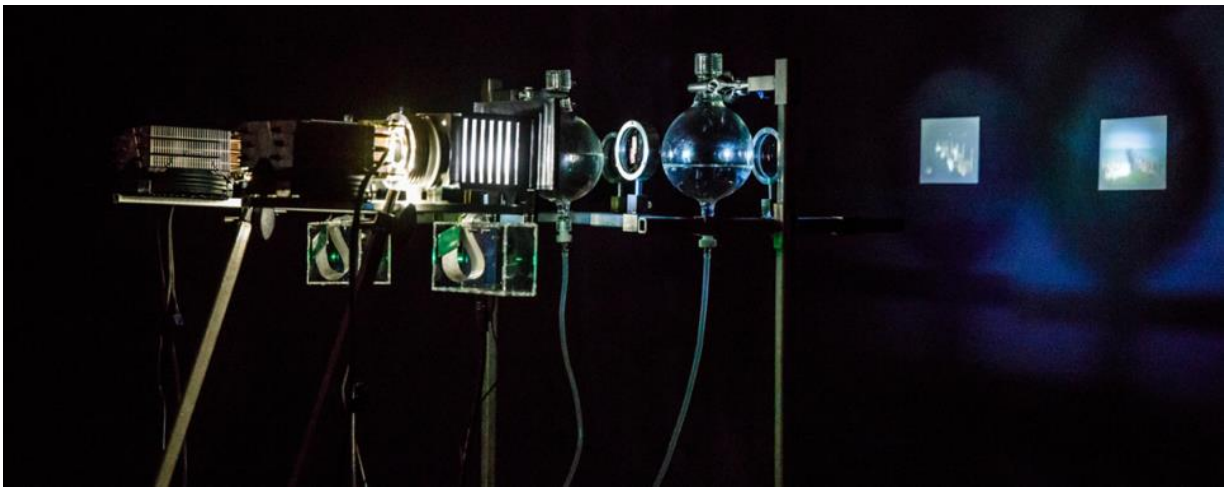


Figure 28 Deirdre Feeney, *Hollow Lens*, 2017–19, glass, water, electronic pump, steel, laser-cut acrylic, plastic tubing, Raspberry Pi, 3D-printed PLA, LCD screen, LED, and driver.

Art historian Dr Barbara Stafford, whose research focuses on imaging arts and optical sciences since the Enlightenment, observes that early modern technological devices, including mirrors, microscopes, telescopes, and optical apparatus, "artfully vied for our undivided attention" and "perceptually and cognitively focused our selective attention."[133] Optical advances and lighting practices rely on glass's ability to bridge distances both great and small. Contemporary artist-researcher Dr Deidre Feeney harnesses lenses to construct devices that reveal the functioning of optical apparatus,

[130] Malaquias and Morris, *Perspectives on Chemical Biography in the 21st Century*. 226 *Glassblowers And Scientists: The Forgotten* Link João Oliveira,' António Morais-

[131] Mark Miodownik, *Why Is Glass Transparent?*, *Ted Ed* supplemental learning materials on ed.ted.com, video Animation, 3:36

[132] Wave Behaviors - NASA Science.

[133] Stafford, Barbara Maria. "Seizing Attention: Devices and Desires." *Art History* 39, no. 2 (2016): 423.

acknowledging glass as an active participant in perception.[134] Her work features vision-enhancing scientific devices scaffolded with contemporary technology, revealing shifting projections of light that capture moments just passed (Figure 28). Like Feeney, my practice uses glass as an active constituent, directly influencing the plasma's luminous effects while allowing the proximity of the viewer-participant to exert their own influence.



Figure 29 Glass ingot samples produced by Michael Faraday. Royal Institution, London.

My visit to Michael Faraday's preserved laboratory at the Royal Institution in London, dating from approximately the 1820s, revealed samples of his rigorous attempts to produce high-quality optical glass (Figure 29).[136] His research underscores the historical significance of glassmaking in the acquisition of new knowledge.[137] Despite understanding the chemistry, Faraday concluded that successful glassmaking required years of experience. He abandoned production relying upon specialist suppliers,

[134] Feeney, Visibilities and Invisibilities of Wonder. 27

[136] Wall text from the Royal Institution, referring to Faraday's glass making endeavours:
"He [Faraday] had been asked to create high-quality glass without bubbles or other defects for use in optical lenses. With better lenses, instruments like telescopes and microscopes would be more accurate. .... Although Faraday understood the chemistry of glassmaking, he finally concluded that the secret lay in Fraunhofer's years of experience. Defeated, he gave up."

[137] "Faraday Museum | Royal Institution." Faraday's laboratory is ostensibly preserved in place in the basement of the Royal Institution

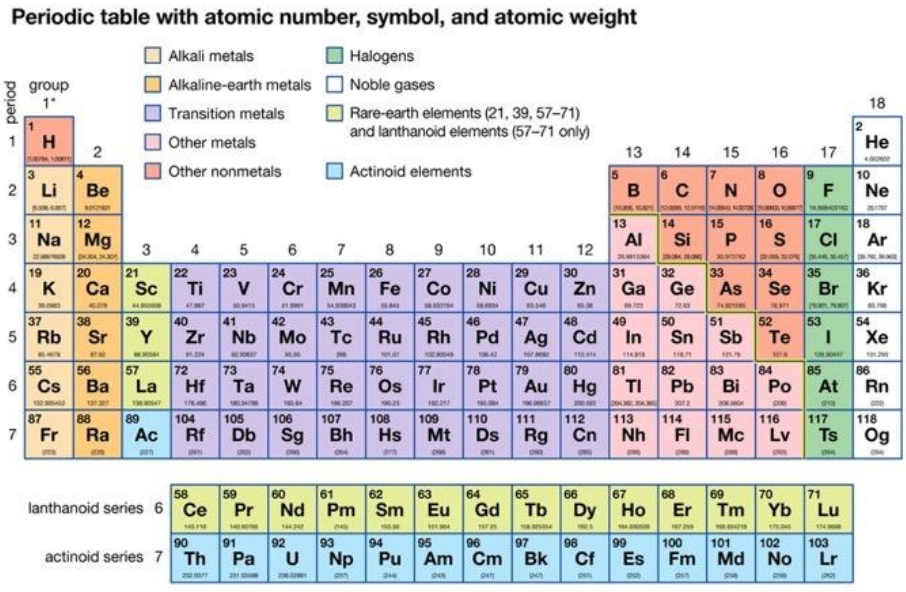
including Geissler. The experimental approaches established during Faraday's era, initially melting raw ingredients before outsourcing glassmaking, echo contemporary practice. Practitioners with scientific or flameworking backgrounds produce vessels from factory-manufactured borosilicate glass, ensuring consistent material specifications and quality, before manipulating the material over gas and oxygen torches in laboratories or private studios.[138] Contemporary glassblowing studios purchase pre-mixed raw ingredients called batch, which is melted and held within a furnace as molten glass. Despite multiple styles of glassmaking and glass types, this historical pattern of collaboration between scientists (glass chemists) and glassmakers, including inventors, artists, and fabricators, continues today.

2.8 Invisible Made Visible: Non-Reactive, Rare, Inert, or Noble Gases

To achieve specific luminous behaviours within plasma vessels, small quantities of non-reactive gases need to be reinserted into the object once the atmosphere has been removed. In 1869, Russian chemist Dmitri Mendeleev assembled one of the earliest periodic tables, based on observable chemical reactions.[139] The non-reactive gases that now populate Group 18 of the modern periodic table, colloquially known as “inert” or “noble gases,” remained invisible to Mendeleev's original formulation due to their lack of chemical reactions.[140] I consider this right-hand column of the modern periodic table as the invisible-made-visible column (Figure 30). In 1894, Sir William Ramsay and Lord Rayleigh discovered argon, an unrecognised constituent of air. Helium followed

[138] Tate McAluney, interview with the author, 20 November 2024, full transcript available in Appendix 1. Discusses creating “donut plasmas” with glass & gas fabricated by Zerg Labs (Russia), allowing McAluney to specialise in inductive power supply refinements. Whereas Lemaire, (Lemaire, interview with the author) discusses her intersecting roles as teacher, maker and fabricator, and how these roles require different means of communicating and working to create the best outcomes using glass and plasma.
[139] New Sci., “Dmitri Mendeleev.”
[140] Selig et al., “The Chemistry of the Noble Gases.” 66 non-reactive gases are often described as Inert or Noble gases; they populate the far righthand column of the modern periodic table.

shortly thereafter, with Ramsay postulating the existence of an entire group of similar elements (Figure 31).[141]



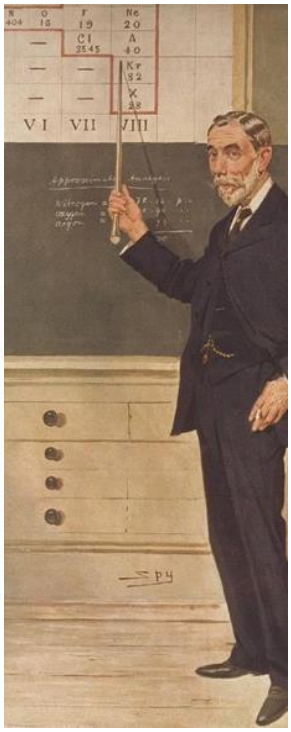


Figure 30 Modern periodic table showing Group 18, the noble gases (in white). *Encyclopædia Britannica*.

Figure 31 William Ramsay as the personification of chemistry. Leslie Ward, chromolithograph, *Vanity Fair*, 1908. Edgar Fahs Smith Memorial Collection, University of Pennsylvania.

Later discoveries show that at a subatomic level, the non-reactive gases feature a complete outer electron shell, providing exceptional chemical stability (Figure 32).[142] [The two-electron structure of in helium or eight in heavier atoms disallows most chemical reactions]. Within neon or plasma illumination, inert gases are used to inhibit electrode degradation of to the metallic components, allowing sustained illumination. These atom's chemical stability makes them ideal for creative practice.

[141] Vanity Fair image: Edgar Fahs Smith Memorial Collection, Kislak Center for Special Collections, Rare Books and Manuscripts, University of Pennsylvania.
[142] Selig et al., "The Chemistry of the Noble Gases." 70

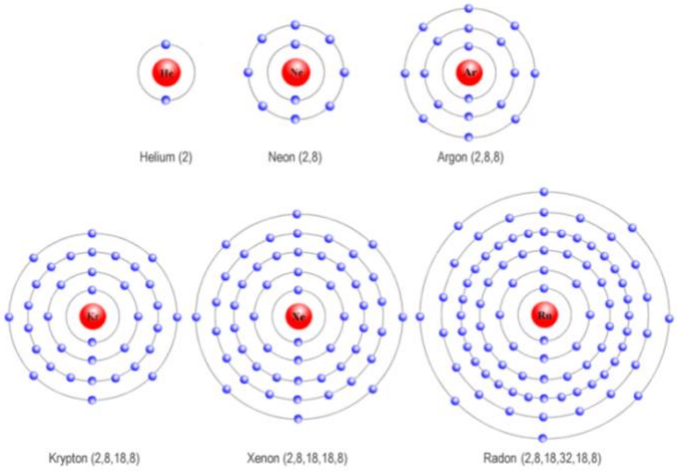


Figure 32 Diagram showing noble gases (Group 18) with stable outer electron shell configurations. Radon is radioactive. Technology UK, https://www.technologyuk.net/.

The early twentieth century witnessed the transition of gas discharge from scientific apparatus to an urban spectacle. French engineer and inventor Georges Claude innovatively repurposed the by-products of fractional distillation into early neon lighting.[143] Claude recognised the exceptional luminescent properties of rare gases, noting their remarkable spectra when energised. Neon installations by Claude illuminated Paris around 1910; initiating a profound shift in perception, his 1915 patent established that, as French philosopher and sociologist Louis De Miranda has observed, "Paris invented the neon light".[144] Cities around the world adopted luminous signage, ushering in modernity and changing the aura of the night sky of our cities.[145]

[143] Stern, *Let There Be Neon*. 15
[144] Miranda, *Being and Neonness*. 3
[145] Dydia DeLyser and Paul Greenstein, *Neon A Light History*; Boyd, Jane E. and Joseph Rucker, "A Blaze of Crimson Light"; Miranda, *Being and Neonness*. Stern, *Let There Be Neon*; Ribbat, *Flickering Light;* Kahn, *Energies in the Arts*, 143. Linda Dalrymple Henderson's revelatory text on Marcel Duchamps reference to Geissler tubes as the Bachelors in his "*Bride Stripped Bare by Her Batchelors, Even. (The Large Glass*) 1915-1923.

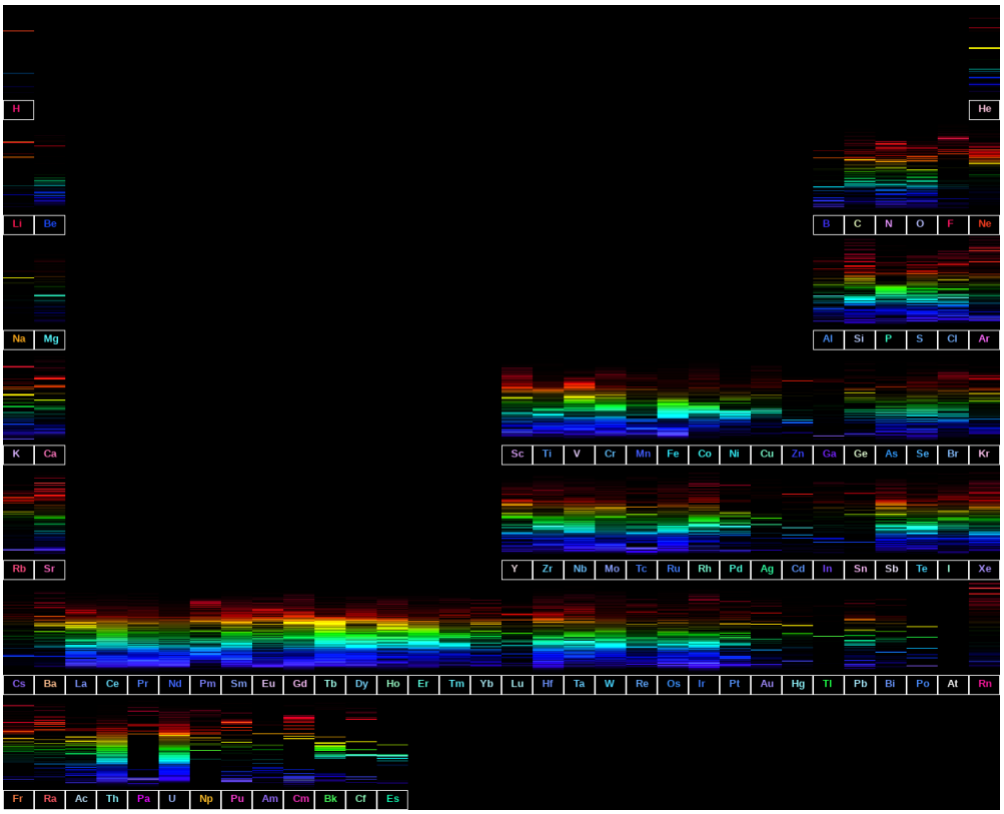
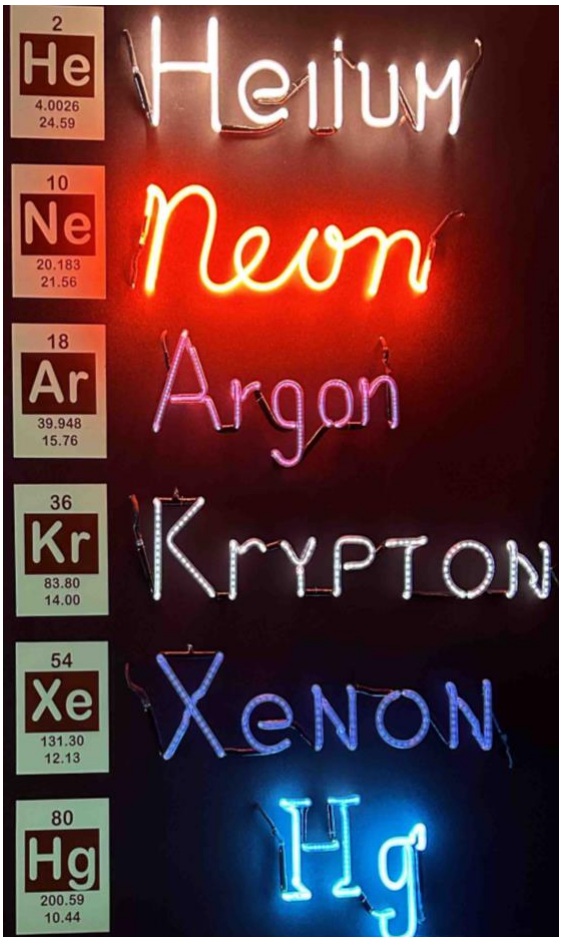


Figure 33 Emission spectral lines for elements in the periodic table. Atomic Spectra, Untitled [Interactive Atomic Table.] n.d.

Plasma-illuminated objects, including neon signage, harness the radiation of visible light by exciting predominantly non-reactive gases within a glass vessel. When an element, atom, and molecule are excited into a luminous state, specific spectral lines are radiated (Figure 33).[146] These spectral lines function as unique identifiers and

[146] Atomic Spectra. Untitled [Interactive Atomic Table.] n.d. Accessed August 30, 2025. https://www.atomic-spectra.net/spectrum.php. This website shares spectral emission data that is on the public domain from Atomic Spectra Database of the National Institute of Standards and Technology, USA, https://www.nist.gov/.

spectroscopy analyses the interaction between light and matter to extract information from the emitted radiation.[147]



Gas	Atomic Number	Colour at Low Pressure
Helium (He)	2	Peachy-golden
Neon (Ne)	10	Orange-red to pinkish-white
Argon (Ar)	40	Lavender-lilac
Krypton (Kr)	36	Dusty-white
Xenon (Xe)	54	Blue-white to green

Figure 34 Colour chart of noble gases ionised as plasma. Hg = mercury; argon with mercury produces high UV for phosphor-coated tubes. Strattman Studio, photographed during field research, 2023.

The ionisation and excitation of noble gases produce characteristic colours used in plasma illumination, as seen in the colour chart in Figure 34. My experience with these gases, or gas mixes, is informed by their discharge behaviours once luminous, ranging

[147] "Spectroscopy: A Measurement Powerhouse," *NIST*, March 28, 2025, https://www.nist.gov/spectroscopy/what-spectroscopy.

from aurora-like glows to meandering arcing discharges akin to lightning.[148] Broadly, helium is named after the sun, *Helios*.[149] Helium is an unusual member among the non-reactive gases. It is so small that it only has two electrons in its outer shell. Helium gas requires more energy to ionise, thus generating more heat during the ionisation and excitation processes. While neon's etymology (as *new)* has become synonymous with plasma's sign-writerly tradition.[150] Neon produces its characteristic orange-red glow at low pressures (5–25 Torr) and is the most legible gas over distances.[151] I describe its appearance within clear glass as orangey-red [r-orange] when at low pressure (5–25 Torr), then pinky-white at slightly higher pressures. Argon described (as *idle or inactive)* appears lavender-lilac at low pressures.[152] In the signage industry, argon-mercury provides white light, high in UV, to excite the phosphorescent interior coatings providing many colours. Krypton ascribed (as *hidden*, [or] *concealed*) appears dusty white at lower glow discharge pressures and lightning bright at higher pressures. When mixed with other gases, it has a tendency to produce branching *sprinkles* or tendrils of light.[153] Xenon (*strange*) is used in expensive car headlights; it emits blue to green streamers and is more likely to produce meandering lightning lines at relatively higher pressures.[154] These atoms and their energetic excitation contribute to the luminous palette that I employ within my practice.

[148] Bogaerts, "The Glow Discharge." 1375
[149] "Helium, n. Meanings, Etymology and More | Oxford English Dictionary."
[150] "Neon, n. & Adj. Meanings, Etymology and More | Oxford English Dictionary."
[151] Lees, "Construction," in *Neon Primer*.
[152] "Neon, n. & Adj. Meanings, Etymology and More | Oxford English Dictionary."
[153] "Krypton, n. Meanings, Etymology and More | Oxford English Dictionary." Along with Hepburn's description of the discharge behaviours of sprinkles or bugs. Hepburn, interview with the author.
[154] "Xenon, n. Meanings, Etymology and More | Oxford English Dictionary."

2.9 Sensing an Aurora



Figure 35 Aurora australis over Kunanyi/Mt. Wellington (palawa kani: Kunanyi), Hobart, Tasmania, August 2024.

Plasma's wonder is commonly seen as lightning, auroras, and light radiating from stars. Artist and educator Amy Lemaire describes auroras to her students as “plasma in the wild”.[155] Furthermore, second-generation neon artist Steven Cole describes plasma production, including neon bending, as creating “an aurora in a bottle”.[156] By eliciting plasma within glass vessels, makers collapse vast distances, allowing the viewer-participant to be proximal with phenomena typically experienced at cosmic scales. Auroras exhibit glow discharge behaviours as soft glowing sheets in the atmosphere (Figure 35). In 1931, American physicists Karl Taylor Compton and Irving Langmuir

[155] Amy Lemaire, interview with the author, January 25, 2024, full transcript available in Appendix 8. “You know that whole idea of ‘aurora in the wild’ was it was a way to [...] start with an idea that everybody knew what it was, right.”

[156] Steven Cole, interview with the author, 02 May 2024, full transcript available in Appendix 2. Here Cole shares “As I explained to people who come into my studio that we capture an Aurora inside glass.”

described how these charged particles cooperate to determine electrical discharge phenomena, noting "we shall have to deal primarily with the collective behaviour of these charged and uncharged particles."[157] These processes are governed by subtle electromagnetic fluctuations, where attractive or repulsive forces generate oscillating waves, pushed and pulled collectively by electric or magnetic forces. In an aurora, ionisation and excitation are powered by charged particles ejected from the sun, funnelled to the Earth's magnetic poles through electromagnetic attraction.[158] I began to consider the layers of our atmosphere as imperceptible vessels holding low-pressure gases within their volumes.

On a freezing, moonless August night at Kunanyi, Hobart, darkness and specific electromagnetic conditions high in our atmosphere provided the circumstances for perceiving an aurora. That night I saw only the palest translucent rays pressing through the enveloping darkness.[159] In our eyes, the distribution of rod and cone cells makes it difficult to perceive colour in low light.[160] Physicist Arthur Zajonc argues in *Catching the Light: The Entwined History of Light and Mind* that luminous phenomena and our visual senses constantly inform each other.[161] While I eagerly anticipating the aurora, my eyes could barely register the promising conditions.[162] My heightened sensitivity resonated with historian Douglas Kahn's hypothesis of "solarception," the broadening of visual

[157] Langmuir and Compton, "Electrical Discharges in Gases Part II. Fundamental Phenomena in Electrical Discharges." 192
[158] Marklund et al., "Temporal Evolution of the Electric Field Accelerating Electrons Away from the Auroral Ionosphere." 724
[159] August 4-5, 2024, experiencing the Aurora Australis with Matthew Curtis near Hobart in Tasmania.
[160] Goodwin, "Why Low-Light Events like the Northern Lights Often Look Better through Your Phone Camera." "Human eyes contain two types of cells that respond to light – rods and cones. Rods are numerous and much more sensitive to light. Cones handle color but need more light to function. As a result, at night our vision relies heavily on rods and misses color."
[161] Zajonc, *Catching the Light*. 35
[162] I was initially alerted via the *Glendale App* on my phone.

perception to include higher frequencies beyond the typically visible electromagnetic spectrum (Figure 36).[163]

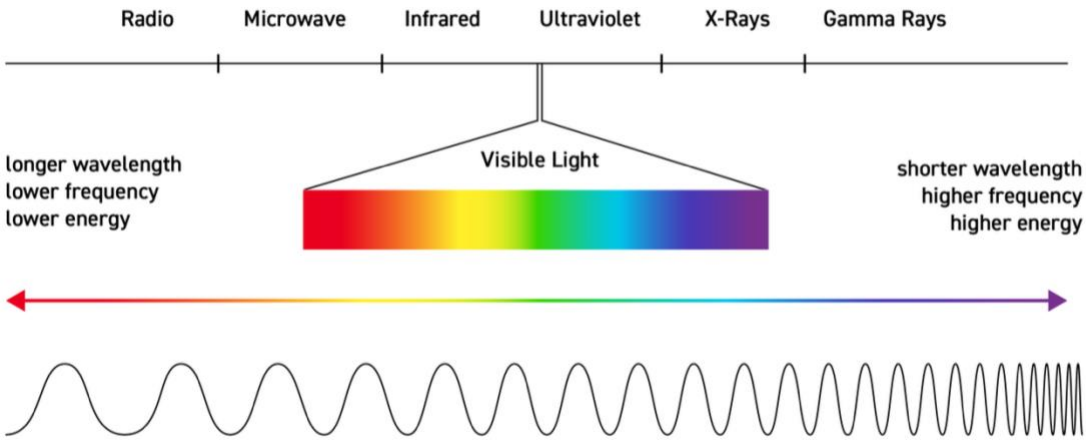


Figure 36 Diagram of visible light spectrum. National Institute of Standards and Technology (NIST), "What Is Spectroscopy?," n.d.

Although I saw mostly darkness that night, my smartphone's ten-second night-mode setting recorded and enhanced the aurora's light.[164] Experiencing and capturing the wonder of the Aurora Australis was an exercise in making the invisible visible.

2.10 My Community of Contemporary Plasma Practitioners

My studio practice is based in Canberra, where I am immersed in a community of studio glass artists, glassblowers, and technicians. Although I work with neon fabricators, I have few local plasma colleagues and rely upon an international community. As introduced in Chapter 1, the Plasma Art Alliance (PAA) explores plasma illumination as

[163] Kahn. Douglas James, *Solarception: A New Sense in the Eye*, *Green Revisited: Encountering Emerging Naturecultures in Art and Research*, edited by Rasa Smite, et. al. (Riga: RIXC, 2022), 275-284.
Kahn proposes solarception a sense extending our visual sense beyond the visible field of the of the electromagnetic spectrum.
[164] Goodwin, "Why Low-Light Events like the Northern Lights Often Look Better through Your Phone Camera."

an artistic medium.[165] Building on commercial neon knowledge, this community has expanded the medium's aesthetic, conceptual, and interactive possibilities beyond textual or pictorial representation. As a member, I am supported by this group of mentors, friends, makers, and innovators.[166] During research at the Corning Museum of Glass Rakow Research Library (2023), searches conducted with librarians using the terms plasma and gas-discharge illumination yielded limited results, necessitating a broader search under neon and related terms. [167] This process itself confirmed the significance of this research: the technical contributions documented here, alongside the nuanced insights gathered through conversations with established plasma practitioners, address a gap in the literature that existing library holdings made visible. In the following pages, I discuss a few exemplars, who represent a selection of contemporary practitioners dedicated to plasma illumination, working with this responsive, kinetic, and interactive state of matter. Limited by the scope of this project and the specificity of my inquiry, I cannot provide a full survey of all plasma practitioners. Rather, the following five artists (Strattman, Kirshner, Echols II, Hepburn, and Mróz) are a focused selection specifically related to my research. Of the eleven practitioners I interviewed as part of my research, selected for how they consistently exhibit plasma-illuminated artwork and engage viewers beyond the flickering draw of the medium and their sustained engagement within the field.

Strattman's systematic approach combines scientific principles with aesthetic considerations. His research is fundamental to our field and works such as *Emergent No. 1* demonstrate how plasma formations can resemble biological systems. In this work, separated glass components with varied gas mixtures at contrasting pressures

[165] PAA, "PLASMA ART ALLIANCE Plasma Art Alliance - Plasma Art and Glass Art." Founding members Dr Wayne Strattman and Ed Kirshner have developed distinctive practices that inform my understanding of the responsive potential of this medium.
[166] Cary Rapaport is the current president of the PAA and former studio assistance to Strattman.
[167] "Harriet Schwarzrock | Corning Museum of Glass."

demonstrate capacitive illumination (Figure 37).[168] His mentorship, examined in Chapter 4, influenced the development of my capacitive illumination strategies for interactive installations.



Figure 37 Wayne Strattman, *Emergent no. 1: Growth*, flameworked borosilicate glass, inert gas, electricity, 51 x 36 x 71 cm.

[168] "Wayne Strattman's Plasma Light Art- Luminous Glass Sculpture."

Ed Kirshner combines his interests in chaos theory and experimentation in geometry and aesthetics to showcase plasma's behaviours (Figure 38). [169] Kirshner's numerous innovations have led him to develop novel technical and aesthetic approaches to studio practice.[170] My interview with Kirshner substantiated his experimental and at times unorthodox approaches, which have influenced my practice. [171] His unique manifold configuration allows him to pursue refined discharges, which are discussed further in Chapter 4.

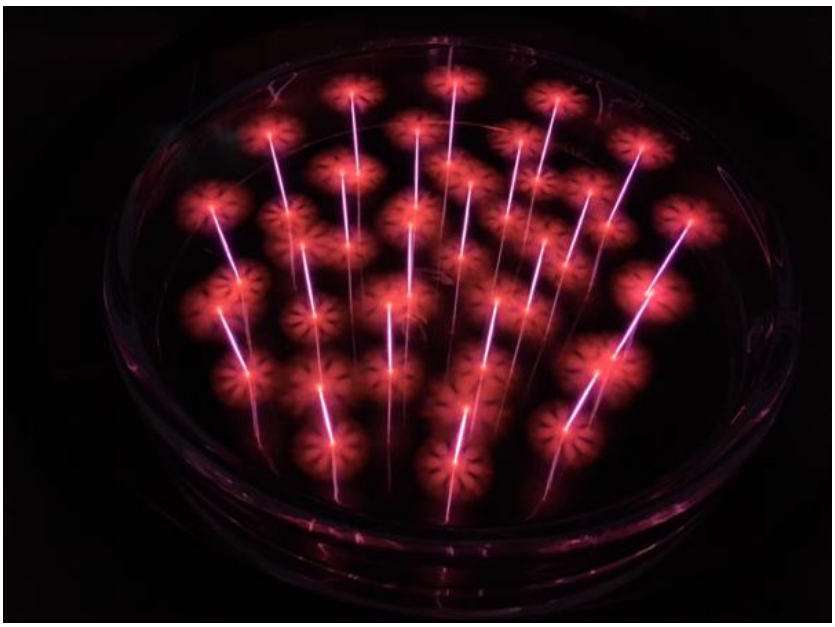


Figure 38 Ed Kirshner, *Dancing Mushrooms* (detail). From "Aurora Sculpt," artist's website, accessed October 1, 2025, https://www.aurorasculpture.com/.

Hepburn's lifelong work with plasma illumination involves every part of the tripartite process: from melting his own glass recipes, making electrodes, to winding coils for his transformers on a converted sewing machine in his kitchen.[172] What is clear in

[169] Kirshner, "AURORA SCULPTURE."
[170]Kirshner, interview with the author. Kirshner's use of specialised conductive glass contains plasmas electromagnetic radiation, rather than a being responsive to the external environment, these emanations of plasma light interact with their own fields, creating constantly re-forming moving chaos patterns.
[171] Kirshner, "AURORA SCULPTURE."
[172] I have been fortunate enough have intensive immersive visits with Hepburn and his partner Judy, a highlight in plasma mentorship and artistic innovation.

Hepburn's practice is that his glassblowing skills and the larger scale of his blown artworks allow viewers to see detailed and complex interactions of plasma illumination unfolding within over-size forms (Figure and).[173] Their beauty and changing expressions showcase the complexity of plasma interactions usually only glimpsed from a distance.

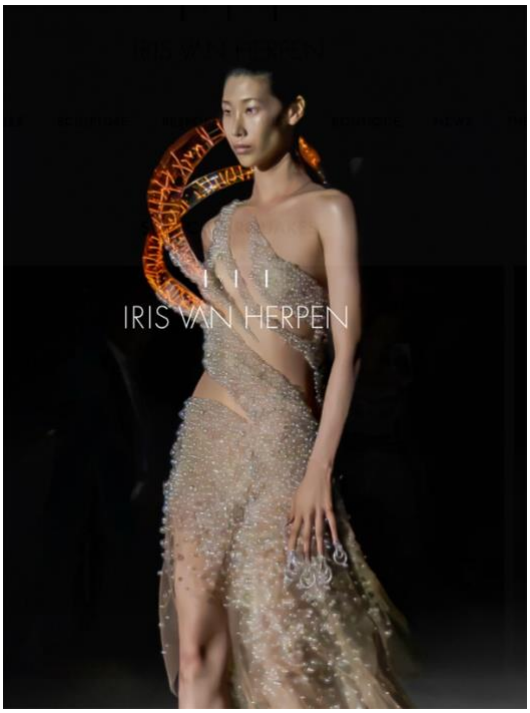




Figure 39 Iris van Herpen, *Helix Nebula,* 2026. In collaboration with plasma specialist Mundy Hepburn and glass artist Marc Barreda, Iris van Herpen unveiled the "Helix Nebula" dress, a garment that channels the energy of plasma - the fourth state of matter, part of the Sonic Starquakes, presented at Paris Haute Couture Week on July 6th, 2026.[174]

Figure 40 Mundy Hepburn, plasma vessel installation incorporating specialised electrodes and custom power supply, 2022. Hepburn, “Glass and Gass Sculptures of Mundy Hepburn,” n.d.

Percy Echols II is the plasma and neon technician at the Pittsburgh Glass Centre, and producer of *Taming Lightning,* a podcast dedicated to plasma practice. His artistic practice encompasses studio glassblowing, creating objects that serve as conduits for

[173] Mundy Hepburn, “Glass and Gass Sculptures of Mundy Hepburn,” n.d., accessed February 11, 2025, https://www.mundyhepburn.com/.

[174] Iris Van Herpen, “Sonic Starquakes | Haute Couture.”

storytelling (Figure 39 and Figure 40).[175] Echols speaks of his plasma practice as an act of artifice and alchemy, where he investigates colour and light.[176]





Figure 39 Percy Echols II, *Atupa, Aurora Purple*, 2024, furnace-blown and engraved glass, h. 15.5 in. (39.4 cm). Photo by Allison Burrell.

Figure 40 Percy Echols II, *Atupa, Aurora Purple,* Illuminated*,* 2024, furnace-blown and engraved glass, h. 15.5 in. (39.4 cm). Photo by Allison Burrell.

Dr Kamila Mróz's research offers perspectives into the specific considerations of plasma illumination, distinct from her neon practice. Describing her glass-forming approach, she writes, “In my work, I begin by marking out the glass boundary, where I enclose reactive plasma. But I don’t see the glass as a limitation—rather, it’s a surface

[175] *Atupa* is a Yoruba word from West Africa, referring to a lamp or lantern.
[176] *Podcast - Taming Lightning LLC*. Initially I corresponded with Echols through his Taming Lightning Instagram account. I have been I have also been fortunate to co-teach with Echols at the Pilchuck Glass school and twice been interviewed.

of contact between two worlds" (Figure 41).[177] When we discussed responsiveness in relation to plasma illumination, it was clear that Mróz had an "interactive" interpretation of this state of matter; she felt that responsiveness simply wasn't enough of a description. I had also come to this conclusion that responsiveness provided a broader technical description, yet I began to understand that I employ plasma as a relational medium within my practice.



Figure 41 Kamila Mróz, *Intrinsic Bond Energy II* (installation detail), 2023. Photo by Zuzanna Czech.

The practitioners discussed here are deeply engaged in the wonder and challenges of working with this medium, and their skills and nuanced understanding contribute to a continuum of exploration and experimentation with plasma illumination, providing insights that can only be gained through sustained repetition of making.

[177] "Kamila Mróz Interactive Light – the Use of Plasma Discharges in Noble Gases as a Medium of Applied Art. Pdf," preprint, n.d.

2.11 Contemporary Art Practice with Plasma

For this research, I have also examined the work of contemporary artist researchers for how they harness plasma illumination within multidisciplinary practices, creating installations and performances through which the invisible becomes visible. Catherine Richards, Tavares Strachan, David Haines, and Joyce Hinterding incorporate plasma phenomena into their practices, tangibly presenting the body as integral to these physical systems.

Canadian new media artist and researcher Catherine Richards's installation *L'intrus* (2012) exemplifies an approach to harnessing plasma's responsive potential. By presenting a scientifically blown-glass heart that "excites" when held, she makes visible the electromagnetic relationships between human bodies and technological systems.[178] Richards describes how "we are now always 'plugged in': it is the electro-magnetic collusion and collision of our bodies and our new technologies."[179] By touching Richards's glass forms, the flow of energy between humans and technology becomes visible, demonstrating how people function as one physical phenomenon among many ((L) Figure 42 and R) Figure 43). Theorist Dot Tuer experiences this "interface" of the interactive luminous heart forms as "a visual cipher of a field of electromagnetic signals that connects the electrons of our bodies to those of televisions, computers, high-voltage lines; and connects the cognition of these invisible fields of energy to cultural narratives of intimacy".[180] Within my own vascular plasma

[178] "Catherine Richards | L'intrus (2012)." From Richard's artist statement on her website: about the work *L'intrus.* Commissioned by the National Gallery of Canada. Supported by AT&T Canada and the Canada Council for the Arts.
[179] *Podcast - Taming Lightning LLC*. "Catherine Richards | L'intrus (2012)." From Richard's artist statement on her website: about the work *L'intrus.* Commissioned by the National Gallery of Canada. Supported by AT&T Canada and the Canada Council for the Arts.
[180] Richards, *Catherine Richards: Excitable Tissues*. Dot Tuer essay 101

vessels, my intention is similarly to make visible intersecting energetic fields, allowing observers to notice their own presence and connectivity.



(L) Figure 42 Catherine Richards, *L'intrus*, 2012, interactive glass heart with electromagnetic properties. Artist's website.



(R) Figure 43 Catherine Richards, *L'intrus*, 2012, illuminated, when handled by spectators, the jar and glass heart excite, phosphoresce, and beat.

Bahamian conceptual artist Tavares Strachan investigates science technologies and histories through installations such as *Robert* (2018), which explores concepts of interiority and intangibility through plasma illumination. Exhibited in the 58th Venice Biennale (2019), this work traces a luminous tendril-like figure suspended in a darkened space. According to Thisbe Gensler, "It is a portrait of Major Robert Henry Lawrence Jr., the first African American to be selected as an astronaut... Robert died in a training accident in 1967."[181] The installation deals in invisibility, portraying a void surrounded by darkness, demonstrating plasma's ability to make visible what is usually invisible or forgotten (Figure 44).

[181] Thisbe Gensler, "Illuminating the Invisible," *Getty News*, April 28, 2022, accessed May 4, 2022, https://www.getty.edu/news/illuminating-the-invisible-tavares-strachan-robert-henry-lawrence-astronaut/.



Figure 44 Tavares Strachan, *Robert*, 2018, blue neon, purple neon, Pyrex, transformers, MDF box, dimensions variable. Installed at 58th International Art Exhibition, La Biennale di Venezia, *May You Live in Interesting Times*, 2019. Photo by Andrea D'Altoè/Neonlauro, courtesy of the artist.

Both Strachan and Richards use borosilicate glass vessels, which are fabricated by skilled technicians and scientific glassblowers, who also create apparatus and medical models out of glass for teaching purposes.[182] The references to the body are exacting, though the body itself is absent. Notably, their fabricators' contributions remain unacknowledged in exhibition materials, despite contributing significantly to these projects.

Contrastingly, David Haines and Joyce Hinterding's video work *Encounter with the Halo Field* (2016) makes visible their unchoreographed movements by employing commercially produced fluorescent tubes beneath high-voltage transmission lines (Figure 45).[183] As curator Anna Davis describes of these artists engagement with

[182] These vessels are then made luminous by other scientific glassblowers, plasma artists and neon practitioners in studios across North America.
[183] "We Are Electric." *We Are Electric: Extraction, Extinction and Post-Carbon Futures* 14 February – 24 June 2023 curator Anna Biers.

electromagnetic radiation, “When rain falls from the sky, we can see it falling… but our senses alone are not enough to perceive the cosmic rays and charged particles that constantly shower the Earth.”[184]



Figure 45 Haines & Hinterding, *Encounter with the Halo Field*, 2016, video, 5:23 min. MCA Australia. Installation views, *Extraction, Extinction and Post-Carbon Futures*, UQ Art Museum, 2023.

This work demonstrates capacitive illumination, where the charged atmosphere between transmission wires and earth illuminates’ tubes held by the artists.[185] Light appears more defined at points of touch; this energetic interplay makes visible the connectivity between human bodies and electromagnetic fields.

My installations discussed in Chapters 4 and 5 also harness capacitive illumination, reflecting upon the agency of proximity as a means of making interconnectivity visible.

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[184] “Haines & Hinterding | MCA Australia.” Parts of this essay have been adapted from Anna Davis, 'Energies and apparitions', in *Energies: Haines & Hinterding*, exh. cat., Museum of Contemporary Art, Sydney, 2015. The film stills for this work have been held in my imagination for as long as I have been interested in contemporary practice. I did not understand until much more recently that this leaky circuit encompassed plasma illumination. The work offers a moment of modern curiosity.

[185] Burm, K. T. A. L. “Plasma: The Fourth State of Matter.” Plasma Chemistry and Plasma. 407 Processing 32, no. 2 (April 1, 2012): 401–7. https://doi.org/10.1007/s11090-012-9356-1.
This performance makes vivid the description by physicist Karel Burm: “A gas under the right conditions can become plasma.

Investigating these differing artists' methodologies, I consider my practice as inhabiting a space between maker/practitioner and artist-researcher. By navigating the leaky and tangled methods for plasma illumination, and through installation choices, I create the specific conditions where the luminous plasma becomes heightened through the relationship between the electromagnetic field and the proximity of the viewer-participant.

2.12 Darkness as Collaborator

Within a plasma illumination practice, darkness emerges as a critical collaborator, enhancing the viewer-participants' ability to perceive the subtle behaviours of this light. Within my artistic practice, darkness is essential for both creation and presentation; diurnal rhythms dictate when I fill and test my work. Darkness complements the experience of viewing these objects, perceptually enhancing plasma's luminosity. Strattman notes the irony that artists who work with light crave darkness, suggesting it "serves as the canvas against which they work their magic."[186]

This interplay between darkness and light transforms perception, offering observers an intimate experience with artworks. Anthony McCall's *Line Describing a Cone* (1973) features a projected line traced upon a screen in a dark space (Figure 46).[187] The observer becomes enveloped within this controlled work as the white form penetrates both the space and one's consciousness. I experienced this work at the Tate Modern Gallery, and as I navigated this dark space, my body was met by a plane of light, appearing to undulate as it encounters impurities floating in the air. Here the structure is the darkened room, the penetrating lines and cones of light become shifting membranes that the observer can touch, affecting the light. McCall speaks of the

[186] "Wayne Strattman's Plasma Light Art- Luminous Glass Sculpture."3
[187] Godfrey, "Anthony McCall's Line Describing a Cone – Tate Papers."

“threshold between darkness and light… where one is the medium for the other.”[188] The potential of darkness within a gallery space, a built darkness rather than outdoors, offers moments of suspended disbelief, recalling visits to the circus or the moment where light fades in the theatre.[189]



Figure 46 Anthony McCall, *Line Describing a Cone*, 1973. Installation view, Tate, London, September 2024.

I found a resonance between how I conceptualise a vacuum and the darkness I experience in McCall's work: a potentially teeming emptiness. Just as darkness is not empty, neither is a vacuum; evidence suggests it is a seething mass of particles and antiparticles.[190] These controlled environments create conditions for light responsive qualities to become perceptible. Darkness functions not merely as an absence of light

[188] Joelson, *Library of Light*. 129

[189] Gt. Mosc. Circus, “Home.” Periods of my childhood were spent with performers from this and other circuses.

[190] “BBC Four - Atom, Atom.” Accessed June 12, 2025.
Nuclear physicist Jim Al-Khalili informative documentary on the Atom describes the activity of quarks, the energetic constituents of protons and neutrons.

but as an active structural condition. Darkness transforms space and material, providing artists with a versatile medium to explore emotional, temporal, and atmospheric themes while fostering sensory engagement and even connection.

2.13 Wonder as a Catalyst

I have come to understand that wonder functions as a tool, an indicator within my practice, alerting me to materials and phenomena requiring deeper investigation. As I harness plasma illumination to make visible subtle moments of connection, the expression of wonder provides feedback, alerting me to active engagement. These responses motivate my investigations, creating a productive tension as I navigate contradictions between scientific conceptualisation and aesthetic decision making.[191]

During my interview with plasma practitioner Dr Daniel Davis, previously a lightning researcher and now director of science demonstrations at Harvard University, he described wonder as "the *wow* to the *why*". [192] He characterises wonder as driving new scientific knowledge, a sensorial response that motivates rigorous investigation. Etymological roots illuminate this interconnection: "wow" derives from amazement, historically meaning to "overwhelm or confound with sudden surprise", denoting temporary lack of understanding.[193] Wonder signifies "a cause of perplexity, a conundrum", the spectacle that disrupts and demands investigation.[194] As a maker, unravelling the "why" heightens my "wow", creating a productive cycle between intellectual understanding of phenomena and implementing these insights within

[191] Mieves and Brown, *Wonder in Contemporary Art Practice*. 132
[192] Daniel Davis, interview with the author, April 21, 2023, full transcript available in Appendix 3.
[193] *Etymonline*, "Wow - Etymology, Origin & Meaning," accessed September 20, 2025, https://www.etymonline.com/word/wow.
[194] *Etymonline,* "Wonder – Etymology of Wonder by Etymonline," accessed September 20, 2025, https://www.etymonline.com/search?q=wonder.

projects. Scientific inquiry and aesthetic wonder are not opposing forces but complementary modes of engagement that amplify one another.

Within the entangled tubular objects and installations that will be discussed in Chapter 4, I represent circulatory systems pulsing with lively rhythms; their flickering responsiveness invites viewer-participants to engage with these luminous phenomena through intrigue rather than purely rational engagement. Philosopher Jesse Prinz describes wonder's sensory response: “Wondrous things engage our senses, we stare and widen our eyes… perplexing because we cannot rely on past experience to comprehend them.”[195] My intention with this momentary disruption of habitual perception is that the viewer-participant might experience plasma not merely as a scientific phenomenon, but rather as medium that makes visible their influence and affective presence.

Knowing yet still wondering has driven me to understand these phenomena more deeply. I aspire to create experiences where wonder encourages viewer-participants to contemplate their relationship with the material world through sensory engagement and intellectual curiosity. Importantly, I do not seek to provide definitive explanations; instead, I invite (and have been invited) to dwell in that productive uncertainty between knowing and not-knowing, where questions remain open and wonder persists even as understanding deepens.

[195] Prinz, “Why Wonder Is the Most Human of All Emotions.” Prinz expands upon 18th c. Scottish moral philosopher Adam Smith’s account of wonder, writing “These bodily symptoms point to three dimensions that might in fact be essential components of wonder. The first is sensory: wondrous things engage our senses — we stare and widen our eyes. The second is cognitive: such things are perplexing because we cannot rely on past experience to comprehend them. This leads to a suspension of breath, akin to the freezing response that kicks in when we are startled: we gasp and say ‘Wow!’

2.14 Touching but Not Touching

When I approach one of my plasma vessels, the luminous tendrils within begin to shift, meander, or pulse before physical contact, influenced by my presence. The phenomenon inside the glass is affected by interactions beyond the vessel, ensuring we never truly touch. Yet, this paradox of influence without contact reveals something profound about our presence.

As I contemplate proximity's role in influencing plasma's behaviours and how plasma reveals relational dynamics between viewers and artworks, Karen Barad's description of electrons disallowing physical touch resonates. This responsive quality opens questions central to my research: How does this medium make visible our proximity? What does it mean to influence and connect without contact? Through plasma's luminous responsiveness, we encounter how our presence makes visible the minutiae of subatomic dynamics that continuously shape our experience. Barad writes:

> You may think you are touching… but what you are actually sensing is the electromagnetic repulsion between the electrons of the atoms that make up your fingers…. Electrons are tiny negatively charged particles that surround the nuclei of atoms, and having the same charge, they repel one another, much like powerful little magnets. As you decrease the distance between them the repulsive force increases. Try as you might, you cannot bring two electrons into direct contact with each other. [196]

Barad's account of "touching but not touching" explains the role of electrons in sensing touch, revealing that electrons, with their seemingly imperceptible structure, attractive and repulsive electromagnetic forces, demonstrate that at the subatomic level, all

[196] Barad, "On Touching—the Inhuman That Therefore I Am." 209

human touch is proximal. From a practitioner's perspective, Steven Cole describes the changes to luminosity within a plasma vessel through the influences of our electric body:

> As we know, the human body is also an electrical field. So, when you go near a plasma vessel that is already illuminated, it can be enhanced by that electrical field... [The vessel] draws more current because the atmosphere outside the vessel is actually the grounding of the field. So, when you touch it or you place some of your body near it, it's actually drawing from your presence.[197]

Cole's explanation of "drawing from your presence" rather than direct touch aligns with electrons' counterintuitive role in not touching. The shifting light within these plasma objects describes how our proximity, the vessel, electromagnetic activation, and environment alter regions of charge, affecting plasma's visible behaviours.[198]

2.15 Excitation: Light Production

Excitation is the luminous draw of plasma; it is the physical process through which visible light is radiated, it is the aim of a plasma illumination practice. Nobel Prize–winning physicist Richard Feynman describes the subatomic complexity underlying this phenomenon through Quantum Electrodynamics (QED), summarising three basic actions: a photon goes from place to place, an electron goes from place to place, and an electron emits or absorbs a photon.[199] This seemingly simple framework underlies

[197] Cole, interview with the author.
[198] Chamberlin et al., "Analysis of the Charge Exchange Between the Human Body and Ground," 246. The data collected in this study show that charges flow between the human body and ground if a ground path exists. That charge flow is small, with a magnitude of less than 10 nA after the ground path has been established. The currents correlate with human subject motion; and no other information appears to be present, such as heartbeat, respiration, or other earth-body communication.
[199] Feynman, *QED*. 85 Also described on this informative site; "The Vega Science Trust - Richard Feynman - Science Videos." "Science – Richard Feynman." Accessed May 29, 2025. https://feynman.com/science/.

complex visual phenomena, where countless photon–electron interactions create the characteristic colours and patterns associated with distinctive gases.

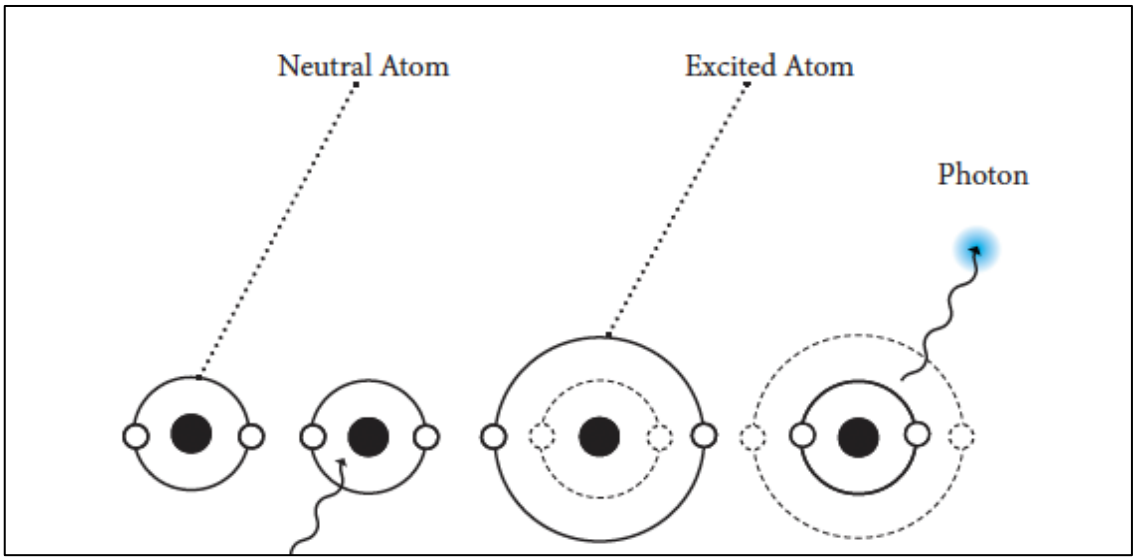


Figure 47 Kacie Lees, orbital ring diagram showing the excitation of helium, *Neon Primer: A Handbook on Light Construction*, 69.

One model for thinking about these actions involves visualising orbital rings; as an electron absorbs energy via a photon (packet or grain) of specific energy, so that electron is elevated into a higher orbital ring (Figure 47).[200] Photons are described as "massless carriers" of the electromagnetic force; their absorption and emission reveal the electromagnetic spectrum.[201] Electrons are classified as "fermions" and photons as "bosons". Only one "point-like" negatively charged electron can occupy the same space at a given time, creating the structures and masses of matter, whereas multiple massless photons can occupy the same space.[202] The visual concept of orbital rings is

[200] Although orbital rings are convenient means by which to conceptualise and atom, the electrons position cannot be easily measured, as such its position is better described through probability. Lees, *Neon Primer: A Handbook on Light Construction*. 69.
[201] BBC, "BBC Radio 4 - In Our Time, The Photon." (12 .02.2015)
[202] BBC, "BBC Radio 4 - In Our Time, The Electron." Audio 19 minutes Victoria Martin Professor of Collider Physics at the University of Edinburgh, describes electrons as "disappearingly small" "point like particles"

used to ascribe specific relationships to the nucleus; electrons can occupy only determined orbits, which are also described as rungs on a ladder.[203]

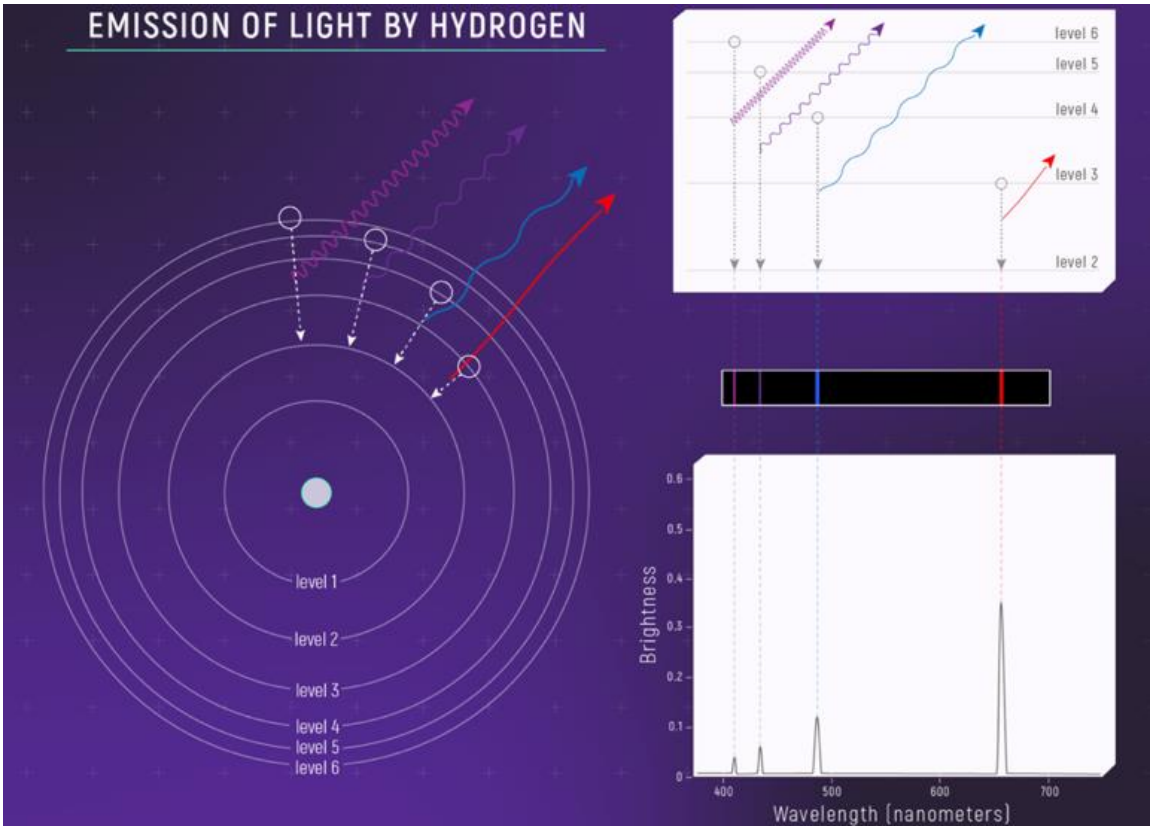


Figure 48 Emission of light by hydrogen. NASA, "Spectroscopy 101 – How Absorption and Emission Spectra Work," n.d.

After the electron is excited into a higher orbital ring, it drops or relaxes back to its ground state. This action releases the previously absorbed energy as heat, or as a photon of light. Visible light is perceived by human eyes only when an electron drops back into the second orbital ring (the n = 2 orbit of the atom); this radiating energy is

[203] BBC, "BBC Radio 4 - In Our Time, The Electron." Frank Close speaks of electron orbitals are often described as rungs on a ladder or steps, because one cannot stand between the steps or rungs, while also referring to their wave like quality.

perceived as light in our visible spectrum (Figure 48).[204] This emission spectra is referred to as the Balmer series (Figure). [205] When electrons drop to other orbits, the radiation corresponds to non-visible sections of the electromagnetic spectrum, such as infrared or ultraviolet radiation.

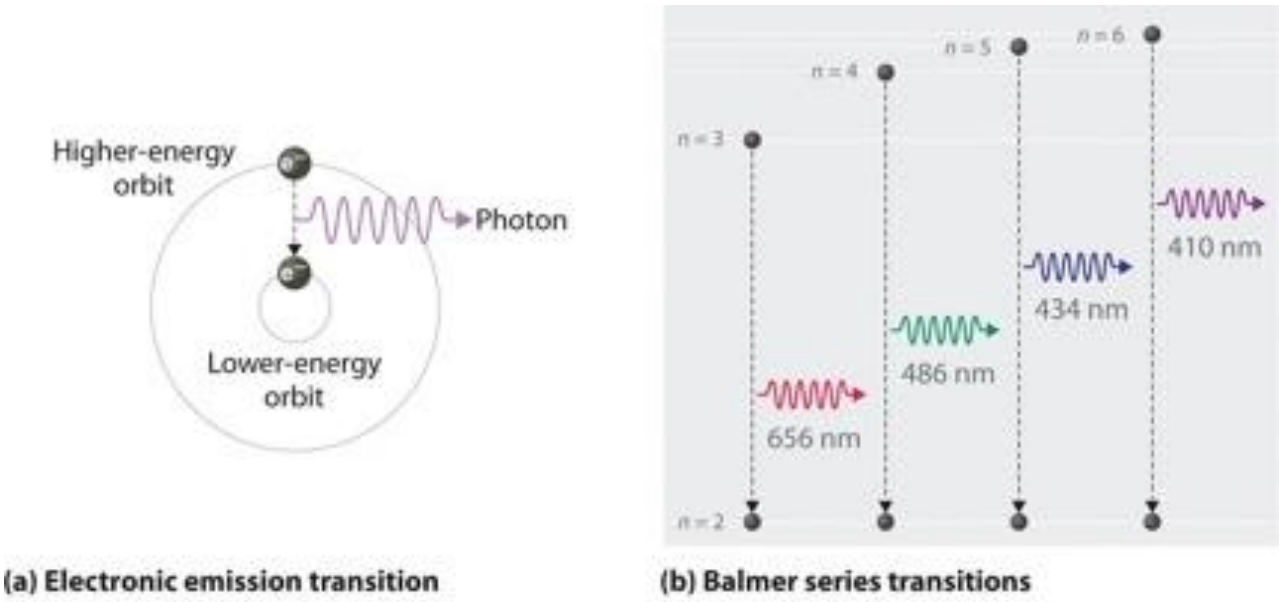


Figure 48 Hydrogen emission (Balmer series). "Line Spectra and the Bohr Model," *Chemistry LibreTexts*, 2024.

[204] NASA, "Spectroscopy 101 – How Absorption and Emission Spectra Work," n.d., accessed September 1, 2025, https://science.nasa.gov/mission/webb/science-overview/science-explainers/spectroscopy-101-how-absorption-and-emission-spectra-work/.

[205] "6.3: Line Spectra and the Bohr Model - Chemistry LibreTexts." Accessed June 2, 2024. https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-_The_Central_Science_(Brown_et_al.)/06%3A_Electronic_Structure_of_Atoms/6.03%3A_Line_Spectra_and_the_Bohr_Model. "Light is emitted when the electron undergoes a transition from an orbit with a higher value of *n* (at a higher energy) to an orbit with a lower value of *n* (at lower energy). (b) The Balmer series of emission lines is due to transitions from orbits with $n \geq 3$ to the orbit with $n = 2$. The differences in energy between these levels corresponds to light in the visible portion of the electromagnetic spectrum."

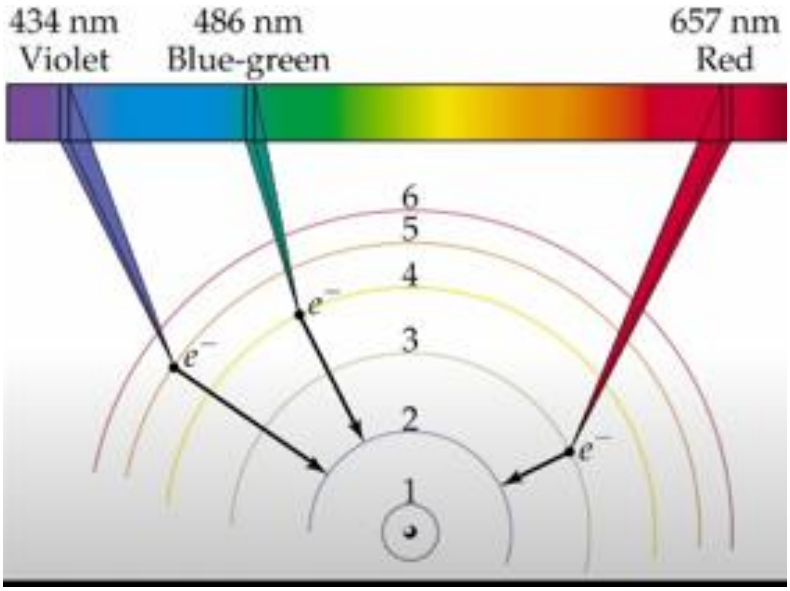


Figure 49 Video still from "Understanding Electric Discharges," See the Pattern, YouTube, posted 9 August 2023, https://www.youtube.com/watch?v=0Pl5qBajPLk.

Plasma Illumination elicited within a studio context is described as low-temperature plasma, revealing oscillating behaviours as glowing matter, or arcing discharges.[206] The objects I produce radiate light through a combination of the mechanisms, resulting in a shifting hail of photons.[207] Physicists H. Gundel, E. Hantzsche, and H. Hess describe three distinct light-producing mechanisms in low-temperature plasmas:

- Bound-bound radiation: When electrons transition between specific energy levels within an atom, producing distinct spectral lines characteristic of each gas *species*.

[206] Gundel et al., "Low Temperature Plasmas." 43
"In optically thin plasmas the radiation emitted strongly depends on the species and on the kind of electronic transition which underlies it. Elementary processes such as excitation and deexcitation, ionization and recombination and deceleration or acceleration of the electrons in the atomic and ionic potentials give rise respectively to line spectra (bound-hound transitions), to continuous recombination radiation (free-bound transitions), and to continuous bremsstrahlung (free-free transition) in emission or absorption."
[207] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics.* 76 Rovelli writes "The solidity of the world to which we have become accustomed in our daily lives does not reflect the actual grain of reality: it is the result of our macroscopic vision. A lightbulb does not emit continuous light, it emits a hail of evanescent photons. At small scale there is no continuity, or fixity, in the real world; there are discrete events, interactions, gapped and discrete."

- Free-free radiation: When free electrons interact with ions, they produce continuous spectrum emissions.[208] The term Bremsstrahlung, or braking radiation, is used because electrons and ions might bend each other in space, and they give off that energy (photons) as they slow down.[209]
- Free-bound radiation: Occurs when there is a recombination from a free electron, in the electron-ion balance of a plasma, which becomes part of the ionic-atomic or molecular structure. This can potentially emit photons of light.[210]

Plasma illumination involves ionising and exciting atoms and ions within glass vessels. The resulting luminosity is shaped by the plasma's own electromagnetic conditions, and the interplay between the various light-producing mechanisms described above, in conjunction with the interior surface of the vessel, all contributing to the plasma's fluid appearance, splashing, sparkling and glowing within the vessel.

2.16 Reflections: Toward a Relational Understanding of Plasma

By investigating methods and materials that contribute to the tripartite process of producing plasma illumination (glass vessel formation, atmospheric manipulation and electromagnetic activation), this research has demonstrated their interconnectivity. I have traced histories of gas-discharge vessels and their phenomena from scientific curiosity to artistic medium, examining their material constituents, and how contemporary discussions and the materiality of light evidence plasma as a responsive medium.

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[208] Potentially witnessed in the green glow often seen in xenon-filled vessels, produced when electrons decelerate in the electric field and give off their photons, rather than discreet spectral line, it is a continuous spectrum.

[209] BBC, "BBC Radio 4 - In Our Time, Plasma." Audio 09:20, Kate Lancaster
Research Fellow for Innovation and Impact at the York Plasma Institute at the University of York, discussing Bremsstrahlung. (October 13, 2016)

[210] Davis, interview with the author. Davis wonderfully describes these complex interactions as certain atoms or ions absorb photons to form metastable states, as they subsequently give off their energy those photos provide energy in the plasma.

As a glassblower, I have reflected on how early scientific experimentation relied upon and was influenced by skilled glass workers for the manufacture of apparatus for experimentation. Gas-discharge illumination became a tool for discovering the particulate nature of matter. Where creating the conditions for plasma phenomena within glass vessel revealed a dynamic state of matter that made visible otherwise invisible electromagnetic interactions.

This chapter has established the potential for plasma illumination to be reframed from a responsive to a relational medium capable of making visible typically invisible connections between viewers and artworks, an area that remains underexplored. Artistic research and making reveals experiential dimensions of physical phenomena that complement rather than compete with scientific understanding. Within creative practice, plasma-illuminated objects offer the viewer-participant experiences of shifting luminosity. This investigation positions plasma illumination as more than visual phenomenon; it emerges as a relational medium that bridges historical craft and scientific knowledge with contemporary practices, reliant upon of subatomic processes that indicate the fundamental interconnectedness between matter and energy.

Chapter 3: *Intra/twined* and *Chambered Vessels*—Exploring Plasma's Responsive Nature within Blown-Glass Vessels

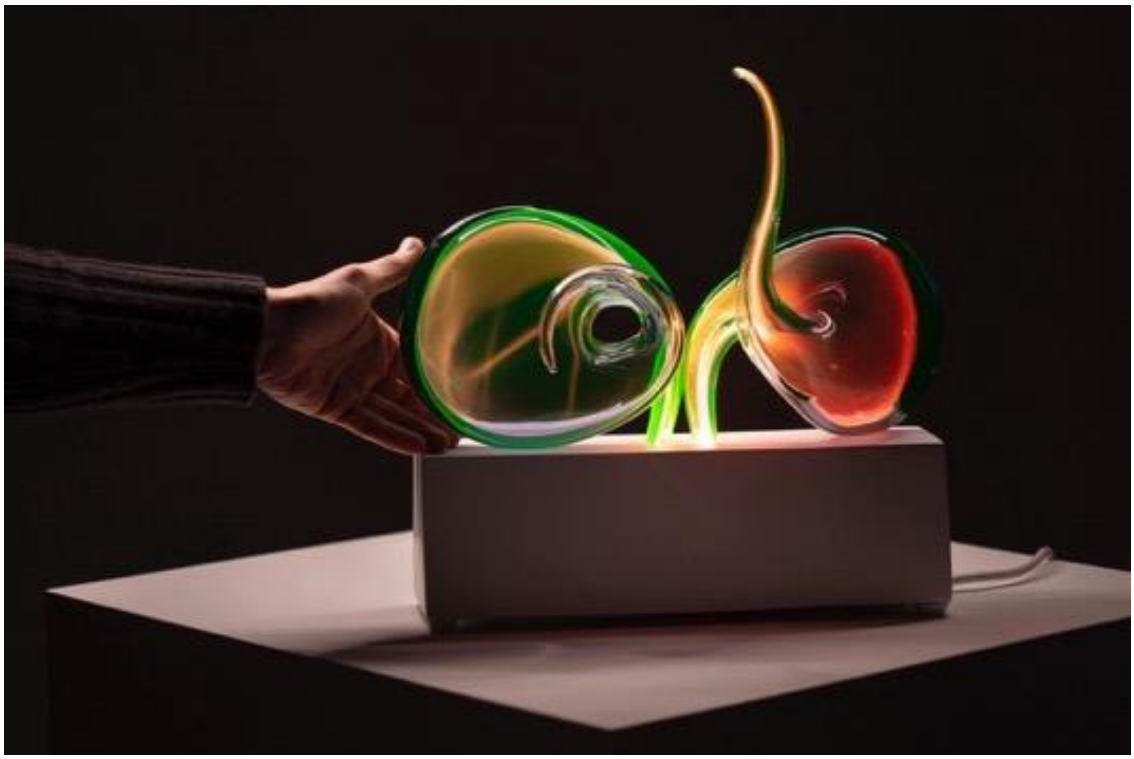


Figure 50 *Intra/twined (uranium)*, 2023, blown glass, ionised gases, paired plasma forms sharing a single transformer, 30 x 40 x 16 cm. Photo by Suki & Hugh Gallery.

This chapter documents the development of two series of blown glass plasma objects: *Intra/twined* and *Chambered Vessels*. Having established in Chapter 2 how plasma's responsive behaviours are influenced by material interactions, I foreground this chapter with a detailed analysis of my making process, including experimentation and material explorations focussing on glassblowing methods. As I explained in Chapter 1, my practice employs what I term “leaks and tangles”, reflective of how I experience and implement plasma illumination's tripartite process. This includes glass vessel formation, atmospheric manipulation, and electromagnetic activation, which are implicitly interconnected, exacting tasks and cause the plasma vessel to leak or fail if

not well executed.[211] In this chapter, I address my central research question: how might novel studio glassblowing techniques and vessel formation affect plasma's luminosity? I draw upon the insights and influences of my mentors and on my interviewees' working methods. Through detailed examination of studio practice, I employ anthropologist Tim Ingold's concept of flux, which acknowledges that materials and processes are "continually on the boil".[212] I investigate these multiple factors for how they constantly influence and contribute toward eliciting plasma illumination.

A material dialogue with historic Geissler tubes stimulated this investigation.[213] With their complex internal geometries, these gas-discharge objects from the mid-1800s reveal varied expressions of plasma illumination; for example, constrictions in the glass cause a brightening, appearing diffuse in wider volumes (Figure 50). These luminous expressions are largely driven by invisible interactions between the plasma itself, or in relation with the interior surface of the glass vessel, played out at subatomic scales.[214]

I begin the chapter by reflecting on two installations that pre-date my PhD research: *Between Movement and Stillness* (2018) and *Spaces Between Movement and Stillness* (2021). Their framing provides an important contextualisation for the current investigation. I then analyse the making of two series of blown-glass objects developed during this research: *Intra/twined* (2023–ongoing) and *Chambered Vessels* (2024–ongoing). These objects evidence how vessel architecture influences plasma's pulsing luminous and responsive qualities. I revisit these objects in Chapter 5, in which I discuss their installation, exhibition and viewer-participant engagement, considering

[211] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 11.
[212] Ingold, *Bringing Things Back to Life*, 8 Ingold writes about, "The EWO [Environment Without Objects], I contend, is not a material world but a world of materials, of matter in flux. To follow these materials is to enter into a world that is, so to speak, continually on the boil."
[213] During field research to Massachusetts Amhurst University, glassblowing laboratory with "Sally Prasch."
[214] Tsytovich, *Lectures on Non-Linear Plasma Kinetics,* 13.

the relational dynamics between viewers and artworks, evidenced through the shifting quality of plasma illumination.

3.1 From Haptic to Proximal Interaction: *Between Movement and Stillness*



Figure 51 *Between Movement and Stillness*, 2018, blown glass, transformer, ionised gases. Installation view (detail), Canberra Glassworks. Photo by Suki & Hugh Gallery.

My initial experience with plasma illumination began during a 2017 residency at Canberra Glassworks, which included a masterclass with UK neon artist Richard Wheater. I learnt to combine neon bending with traditional glassblowing and colour application methods.[215] The residency culminated in an installation of sixty interactive, plasma-illuminated heart forms (Figure 51).[216] This project initiated my understanding

[215] *Art, Not Just in Name - Art Group*. Art Group Fellowship at Canberra Glassworks which included a neon masterclass by UK based artist Richard Wheater. Mysite, "Artist | Richard Wheater."
[216] Cousins, "Hearts and Minds by Harriet Schwarzrock and Penny Byrne at Canberra Glassworks."

of plasma's responsive behaviours, informing my current research methods. Luminosity was elicited within asymmetrical vessels, creating a visual and conceptual resonance between pulsing plasma and rhythmic heartbeats, celebrating the literal and poetic electrical behaviour of our bodies.[217] The stylised forms reflected upon the heart as an emotional centre and a generator of bioelectricity.[218]

I developed installation strategies to accommodate electrical power supplies and transformers. The objects were mounted on non-conductive materials. High-voltage cables connected the transformer to the vessel's electrode (Figure 52), and the entire unit was fixed to walls by aluminium split battens. This mounting design permitted air flow while concealing and preventing electrical components from being touched, allowing close inspection while ensuring electrical safety. Installed in the darkened gallery, the forms were suspended from the walls. Viewers were permitted to gently touch the work, seeing their effect and influence on these objects through the pulsing and flickering luminosity.

[217] Foundation, "I Sing the Body Electric by Walt Whitman."
[218] Geselowitz, "Electric and Magnetic Field of the Heart." 1973 https://doi.org/10.1146/annurev.bb.02.060173.000345 37 The heart's tissues create measurable voltage differences.



Figure 52 Rear view of wall-mounted system: Neoniser 21 driver (black rubber-dipped unit) and Meanwell 120–240-volt power supply (silver unit) connected to mains power, 2020.

During the second installation at the National Portrait Gallery (2021), touch was disallowed due to institutional guidelines.[219] Instead of encouraging haptic engagement, I became attuned to the proximal influences that plasma illumination

[219] Natl. Portrait Gallery Exhib., "Harriet Schwarzrock." Touch was also generally discouraged due to COVID-19 guidelines.

affords. Rather than understanding physical touch as the cause of the change within the vessels, my focus shifted to the influence exerted proximally upon electromagnetic fields. I witnessed how plasma luminosity pulsed and shifted in response to the observer's approach. Changing luminosity provided visual evidence of influences that usually remain invisible, catalysing the investigation of plasma's responsive potential that now forms the methodological core of this PhD research.

3.2 Tripartite Process: Blown-Glass Vessel Formation

As explained earlier, I employ the tripartite process toward the production of plasma-illuminated vessels, these interconnected methods rarely follow a linear trajectory. The making practice begins with glassblowing, where I develop asymmetrical objects, informed by Geissler tubes that simultaneously reference chambers of the heart. I create complex internal surfaces within the vessels by integrating traditional Italian vessel-forming techniques within my sculptural glassblowing practice. Using heat, gravity, and breath, glassblowing informs the morphology of the vessel; as maker and materials exist in flux during fast-moving processes.[220] Glassblowing requires continuous turning of the blowpipe to manipulate molten matter, generating centrifugal forces that counteract the downward pull of gravity. Glassblowers negotiate the forces of their material and their desire to shape a three-dimensional form. It becomes a dance, reflective of Ingold's suggestion that,

> things are active not because they are imbued with agency but because of ways in which they are caught up in these currents of the lifeworld. The properties of materials, then, are not fixed attributes of matter but are processual and relational.[221]

[220] These interactions involve concerns such as body positioning, the adaption of techniques, temperature of the studio, attention to detail and hydration amongst countless other contributing concerns.
[221] Ingold, "Materials against Materiality." Archaeological Dialogues 14 (Cambridge University Press doi:10.1017/S1380203807002127, 1

During this fluid yet choreographed process, vessel shapes become elongated or more bulbous dependent upon glass colour, glass temperature, and even who I am working with. Properties emerge through process, rather than existing as fixed attributes. Productive complications arise during the creative process, and these variations influence outcomes. During glassblowing, a choreography of material, energy and human interaction is revealed, resonating with Ingold's description of how “kite, kite flyer and air” animate each other.[222]

The term “animacy,” derived from the Latin *animare* (to give breath to), is pertinent to the breath-forming practices of glassblowing.[223] It is a physically demanding craft with a rapidly cooling molten material. I gather glass onto a hollow blowpipe from a furnace heated to 1100°C. I blow down the hollow pipe, trapping air with my thumb. The air expands from the glass's heat forming a bubble (Figure 53). I hang the blowpipe down and use gravity, a pad of damp newspaper, specialised multipurpose tools called jacks and tweezers to create an initial teardrop shape (Figure 54).



Figure 53 Glassblowing demonstration showing inflation of glass bubble through hollow blowpipe, Canberra Glassworks, Canberra, ACT, 2023. Video still courtesy of WEFT Production.

[222] Ingold, Making. Bodies On The Run, 100
[223] “Animacy | Search Online Etymology Dictionary.”

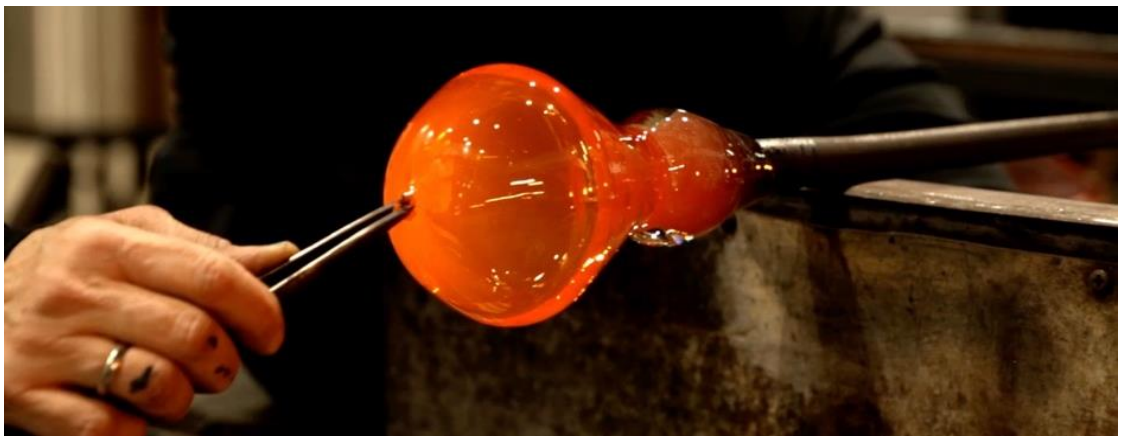


Figure 54 Glassblowing demonstration showing shaping of molten glass bubble using tweezers, Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production.



Figure 55 Glassblowing demonstration: transferring bubble from blowing pipe to punty, transitioning from bubble to vessel. Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production.

By transferring the glass bubble from the hollow blowpipe to the punty iron (a solid metal rod), I transform the bubble into a vessel (Figure 55).[224] Intermittently reheating

[224] "Pontil | Corning Museum of Glass."

the glass softens it, enabling me to open, squeeze, pinch, cut, and pull the glass, as I investigate stylised organ-like morphologies (Figure 56).



Figure 56 Glassblowing demonstration showing tweezing and changing the diameter of a puntied Chambered Vessel, Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production.

I prepare a hollow vessel with only one tubular opening of a reduced diameter, where the electrode will later be attached (Figure 56 and Figure 57). During the glassblowing process, the molten material cools to become solid, intermittently re-heated to well over 600°C to further shape it. Once the vessel is fully formed, it is placed in a kiln to anneal. Annealing ensures the glass cools to room temperature in a controlled fashion, relieving stresses from the making process.[225]

[225]After the vessel is finessed it is still over 700.C, it is placed in an annealing kiln at 495-505°C for controlled cooling, which prevents thermal stress and cracking.
Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 75 Discusses annealing and strain points of glass as relevant to plasma process (this temp is essential for the removal of water vapour). Stain point for soda-lime glass approx. 389°C



Figure 57 Glassblowing demonstration showing a puntied Chambered Vessel. Pulling the heated material changes the diameter of the opening, which later becomes the attachment point for an electrode. Canberra Glassworks, Canberra, ACT, 2023. Photo courtesy of WEFT Production.

3.2.1 Coloured Glass Applications

This section outlines the colour application methods that I have employed within this project. These processes affect the way the light interacts with the materials, in turn changing how we perceive them. I can incorporate multiple colour application techniques within one object, manipulating the colour of the glass during the glassblowing process uniquely contributes to the practice of plasma illumination.

Colour can be added to a vessel as a veneer on the inner surface of the bubble, changing the appearance of clear glass into one that holds colour. This thin coloured membrane (veneer) of glass on the innermost surfaces of a vessel is rich in coloured pigments. Much like glaze application in ceramics or applying paint to a canvas, glassblowing uses layers of pigments perceived by the human eye as colour. As more layers are added, light is increasingly absorbed and the material appears darker. This is an example of subtractive colour, whereas when multiple-coloured lights are brought

together, additive colour principles apply: the increasing addition of colours of light is perceived as white (Figure 58). [227]



Figure 58 Interactive Colour System. Lisa Cianci, screenshot from "Additive [L] and Subtractive [R] Colour Systems," 2023. Licenced by Creative Commons 4.0.

Plasma-illuminated objects that incorporate coloured glass membranes offer a unique interplay between subtractive and additive colour principles, shifting our perception of colour in unexpected ways. Applying phosphorescent coatings to the interior surface of a vessel, such as in commercial fluorescent tubes, exemplifies additive colour principles (Figure 58).[229] The more phosphor colours you add, the closer it appears to white. Phosphorescent powders are composed of minerals that instantaneously absorb and emit light; therefore, their application is a form of painting with light. [231]

I experimented with several application methods, including Hepburn's "town sand technique", where phosphor mixed with sand is shaken into vessels and distributed around interior surfaces. My approach strategically implements Hepburn's method of shaking sand with small amounts of phosphor around the vessel; yet rather than

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[227] Lisa Cianci, "Additive and Subtractive Colour Systems," in *Colour Theory: Understanding and Working with Colour* (RMIT, 2023), https://rmit.pressbooks.pub/colourtheory1/chapter/additive-and-subtractive-colour-systems/.
[229] Cianci, "Additive and Subtractive Colour Systems."
[231] Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 40-42

coating entire inside surfaces, I began to apply colour only to back interior surfaces, maintaining visibility through uncoated front surfaces. This strategic application creates optimal visual effects, allowing observers to look through clear front surfaces while seeing activated velvety phosphor on back interior walls. [232]

Glass itself can also fluoresce, holding light within its liminal edges. Fluorescence is described by spectrochemical analysts Butler, Laqua, and Strasheim as a combined process of "photon absorption by an atom followed by spontaneous photon emission".[233] The glow occurs when a material absorbs light energy and then re-emits it as a different wavelength or colour than the original source. An example is when I use uranium oxides applied during the glassblowing process to exploit fluorescence. Uranium reveals its eerie green-yellow light when excited by energetic blue-white light from the ultraviolet end of the visible spectrum (Figure 59).[234] Uranium oxides and fluorescent liquids were used in Geissler tubes for the intrigue of the observer (Figure 60).[235] Within my plasma vessels, incorporating uranium oxide harnesses fluorescence. As my hand touches the illuminated form, it draws the bright xenon plasma toward the surface. This thin layer of uranium glass glows through luminous interactions (Figure 59).

[232] Hepburn introduced techniques to me during field research in 2023.
[233] Butler et al. "Nomenclature, Symbols, Units and Their Usage in Spectrochemical Analysis," 1463.
[234] Strahan, "Uranium in Glass, Glazes and Enamels." 188.
[235] Sella, "Geissler's Glassware." Andrea Sella writes, "Often made in fluorescent uranium glass, or with sections surrounded by a jacket containing fluorescein or other dyes, and powered by Rühmkorff's induction coil, Geissler's exquisite designs – full of bubbles, curves and twists – gave off a mesmerising glow when a high voltage was applied. Soon Geissler tubes and their mysterious 'electric light' were in demand, both for scientific demonstrations and as spectacular adult toys for middle class gentlemen."

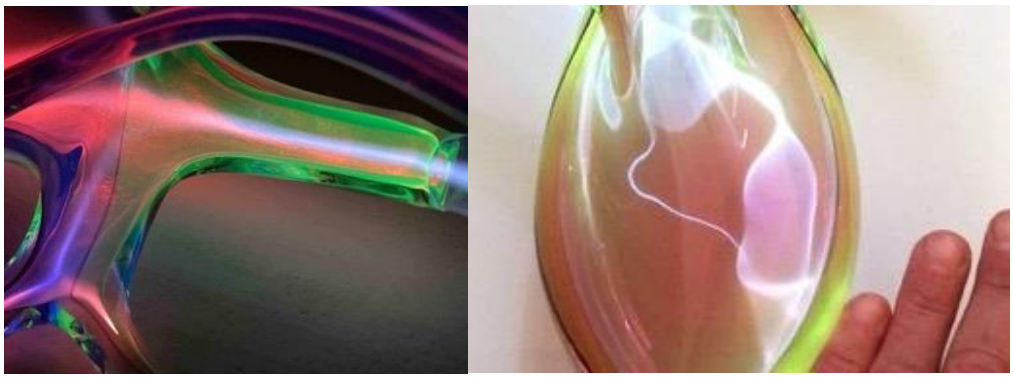


Figure 59 Plasma vessel detail showing colour variation at point of touch, 2021: ruby veneer (L), ruby pink over uranium with electrode displaying fluorescence (R).

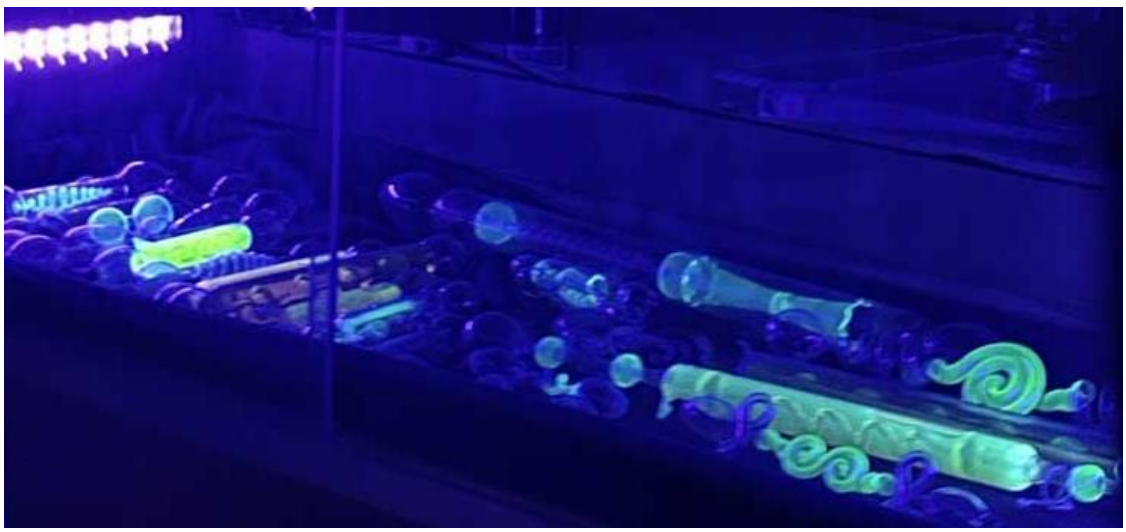


Figure 60 Geissler tubes from Spark Museum Collection displayed under ultraviolet light, illustrating fluorescence of liquids and uranium oxides in glass, Spark Museum of Electrical Invention, Bellingham, Washington, 2023.



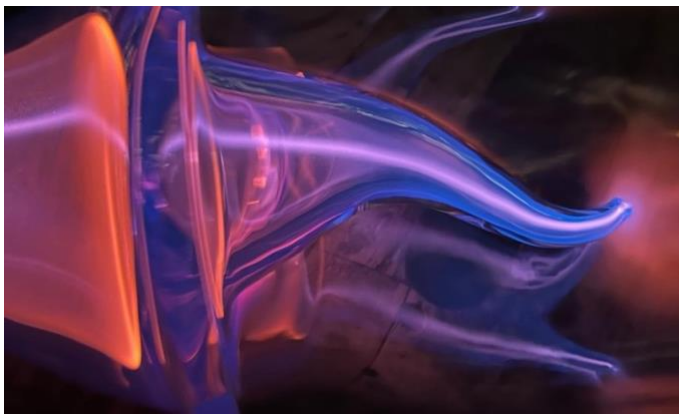


Figure 61 *Chambered Vessel* (work in progress), 2022, blown clear glass with ruby red veneer. Studio view in natural daylight

Figure 62 *Chambered Vessel* (detail), 2023, blown glass with pink veneer, ionised gas. Under plasma illumination, the pink veneer appears blue

Pigments containing gold-ruby oxides appear transparent pink in daylight (Figure 61). When illuminated with ultraviolet-emitting plasmas, these same vessels appear blue. The ruby veneer absorbs light from the red end of the visible spectrum, and with the slight fluorescing of the clear glass, the vessel appears eerily blue-tinted when illuminated (Figure 62). The combination of glassblowing colour application, phosphorescing materials, and the potential fluorescing properties of glass offers a unique interplay of light through plasma illumination. This broadened visual palate of associated techniques and luminous phenomena contributes to the effects produced within plasma illuminated artworks.

3.3 Tripartite Process: Atmospheric Manipulation and Electrode Attachment

The tripartite process requires atmospheric manipulation to achieve specific low-pressure conditions within the glass vessel. I experience these methods as intricate and involuted. To connect glass vessel formation, atmospheric manipulation, and

electromagnetic activation for plasma vessels requires (in most cases) the application of specialised electrodes, welded onto the glass objects (Figure 63).



Figure 63 Soft-glass electrodes showing blow hose attachment system for glass tubulation. Image shows tubulated electrodes oriented upwards, with one connected to orange blow hose.

Successful electrode application requires a seamless connection for electrical conductivity and vacuum integrity. This technique is standard in the neon signage trade, where electrodes are welded onto each end of a tube. Once welded to the glass, one electrode in each pair has a hollow tubulation that allows for a connection to be made with the manifold (Figure 63 shows tubulated electrodes pointing upwards).[236]

[236] Strattman, Crookes, Lees, Miller and Mason all have sections on electrode application, I have referenced sections with varied approaches to these techniques. Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 29, Crook & Fishman, *The Neon Engineers Notebook*. 176, Mason, *Neon*. 7, Lees, *Neon Primer: A Handbook on Light Construction*. 141, Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity* . 65.

The electrodes must be made from the same or very similar glass, as dissimilar glasses joined or welded together will crack. Electrodes manufactured from soda lime glass are described as soft-glass and have a coefficient of expansion (COE) of between 92-96, whereas borosilicate glass, or hard-glass, has a COE of 33. This number describes the rate at which the glass contracts and expands (Figure 64).[237] Neon tubing has very similar expansion rates as the glass melted in many glassblowing studios. Therefore, the electrodes for soft-glass neon fabrication can be welded together with most furnace glass.[238]

Physical Attributes of Various Glasses

	Lead	Soda	Color Tubes	Lead-Free	Borosilicate	Quartz
C.O.E.	94	90	95.52	92.5	33	5
Strain °F	743	743	835	851	950	1877
Strain °C	395	395	446	455	510	1025
Anneal °F	810	815	900	914	1040	2048
Anneal °C	432	435	482	490	560	1120
Work °F	1778	1805	N/A	N/A	2280	3632
Work °C	970	985	N/A	N/A	1260	2000
Density	2.85	3.05	N/A	N/A	2.23	2.2
Refraction	1.54	1.56	N/A	N/A	1.47	1.46

Figure 64 *Physical Attributes of Various Gases*. Crook & Fishman, *The Neon Engineers Notebook*. 226

[237] See Crook & Fishman, *The Neon Engineers Notebook*. 226.
[238] "Soft glass" or soda lime, is the industry standard for neon in North America, England, Australia and much of Europe. France has a borosilicate or laboratory glass tradition for their neon trade these electrodes are not interchangeable.

Several methods exist for attaching electrodes to blown-glass objects.[240] In contrast to neon tubing, the blown-glass vessels I produce are thicker and less capable of withstanding sudden thermal shock when heated with a gas torch. In his practice, Echols II hybridises glassblowing and neon techniques, applying the electrode while the blown-glass vessel is still hot (Figure 65).[241] The electrode is held in a specialised clamp, while the vessel aperture and the electrode rim are spot heated before being pressed together. If the electrode is at room temperature, a hose can be attached. Slight air pressure from blowing can be introduced during the application of the electrode, assisting to achieve even wall thicknesses between the joined glass. After the electrode is applied, the blown glass piece is immediately placed in a heated kiln to anneal. Annealing slowly cools the glass to room temperature to avoid thermal shock, relieving stress from uneven temperature distribution.[242] I found negotiating the extreme temperature differential between electrode vessel and torch, along with the precise timing difficult to replicate consistently.

[240] The round tubular shape also provides a certain physical structural robustness.
[241] "Taming Lightning x GEEX."
[242] Kirshner, interview with the author. During the interview Ed discusses another approach to electrode joining where he has refined his innovative electrode attachment, making electrode joins with solder (a ceramic glaze like process in a kiln).



Figure 65 Percy Echols II and Ben Orozco, “Taming Lightning × GEEX” Electrode application, 2021.

Rather than applying electrodes during the glassblowing process, I began to anneal and cool the glass to room temperature, further grinding and polishing the glass to remove any sharp shards.[243] Once the vessel is cleaned and dried, I began to hybridise neon trade methods, bringing together room temperature components.[245] With the glass vessel at room temperature the electrode is welded on by heating only the rims of the tube and electrode before they are pressed together.

[243] At this stage, glass grinding techniques known as coldworking can also be used to add textures to the surface of vessels.

[245] Hepburn, in a private correspondence, recommended using distilled water and flowing air (e.g., from a hair dryer) to clean and dry out vessels if needed. All vessels that have been open to the air need to have water vapour removed by heating the glass.



Figure 66 Electrode attachment process, film still, 2024. Video documentation by WEFT Production.

After failures, due glass vessels cracking from thermal shock, I experimented, developing a reproducible warm-welding technique informed by my experience with neon bending. Attending to the risk of thermal shock due, to the scale and uneven thicknesses of my glass vessels, I added a pre-heating stage to my electrode attachment method. Allowing me to work with the expanded scale and complexity of the vessels I could produce. Pre-heating the vessel in a kiln to 70°C prior to electrode attachment significantly reduced thermal shock and cracking. I remove the vessel from the kiln, setting it on a wooden worktable using heat-protective Kevlar fabric to stabilise the asymmetric form if needed.[246] Using a fishtail torch, which has opposing burners, I gradually heat the vessel and electrode rims (Figure 66). An orange glow indicates melting and adequate working temperature, (incidentally the heated glass may begin to slump, therefore the electrode or vessel may need to be rotated or flipped intermittently) before the two surfaces can be pressed together (Figure 67 and Figure 68). By connecting the tubulated electrode to a blow hose, air can be puffed into the piece during attachment, gently increasing the internal air pressure. This ensures even diameters and smooth interior welds at the joins. It is important achieve an even

[246] Kevlar gloves can be worn which can stand extreme temperature, used in metal foundry and glassblowing applications.

thickness of glass at the join, if the material tacks together jaggedly, these points introduce stress to the weld (causing a crack to appear and failure). Re-heating and gently re-inflating these joins welding can mitigate stress, achieving smooth welds.



Figure 67 Heating electrode for attachment to glass vessel, film still, 2025. Video documentation by WEFT Production.



Figure 68 Joining electrode to glass vessel, film still, 2024. Video documentation by WEFT Production.

Electrode attachment is a delicate operation that requires precise temperature control to create airtight seals (without thermally shocking the adjoining glass). Even after the tubulated electrode is attached, it is still a vessel open to the atmosphere. The next stage of the tripartite process creates the clean and altered atmospheric conditions within the vessel. Refining reproducible electrode welding technique bridges glassblowing and neon fabrication practices. This allows me to separate working at the furnace from working at the manifold, expanding the vocabulary of form that I could develop.

3.3.1 Atmospheric Manipulation—Manifold as Connector

The plasma manifold assists to alter the atmospheric conditions within the glass vessel, to achieve low pressures within. A manifold epitomises multiple definitions: "embracing many features" and functioning as a "pipe with several outlets" (Figure 69).[247] It facilitates the critical atmospheric alterations, as atmospheric contents can removed via a powerful vacuum pump. Following this, pure non-reactive gases can be inserted into the vessel (via the same manifold) and then sealed inside. The manifold connects and separates volumes through closable valves. Facilitating evacuation using a low-vacuum pump, to attain below atmospheric pressures within the vessel.[248] A true vacuum is unachievable, yet conditions below 1 Torr are ideal. Every connection, valve and glass weld must be capable of holding a vacuum to stop air leaking back in. The manifold requires airtight, low-vacuum fittings, specialised valves, and low-pressure gauges, glass/stainless/brass tubing, ports to connect non-reactive gas bottles and a blow hose.

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[247] "Manifold | Search Online Etymology Dictionary."
[248] Crook & Fishman, *The Neon Engineers Notebook*. 16-18.
Lees, *Neon Primer: A Handbook on Light Construction*. 122,123.
Mason, *Neon*. 9,10.
Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 122-124.

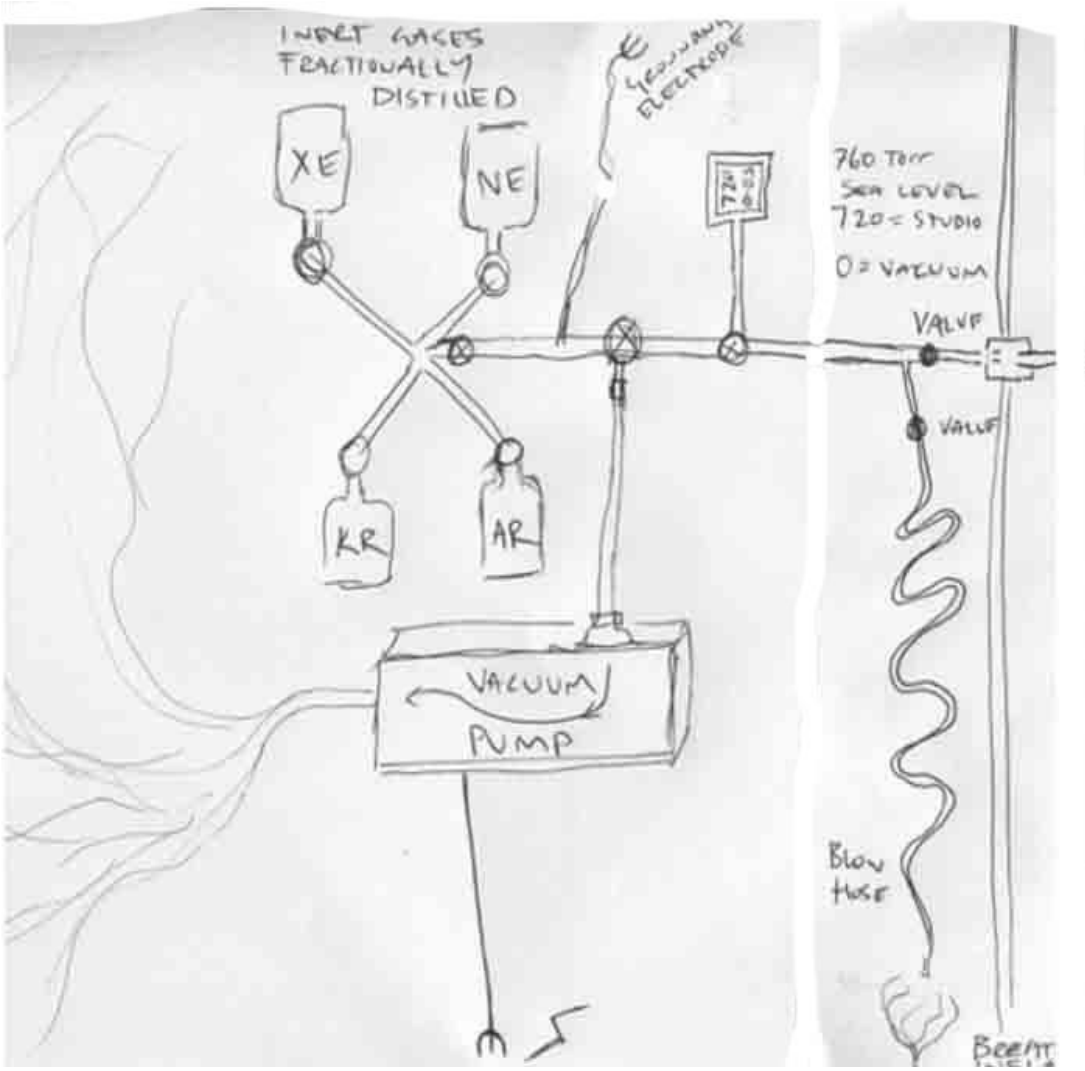


Figure 69 Sketch of manifold, iteration 3, 2023, showing vacuum pump, gas bottles, valves, and blow hose. The work within the kiln would be connected to the right of the sketch.

I have constructed many manifolds to accommodate changes in my practice, progressively un-crafting and crafting based on my experience and advice. I have been assisted by my partner Matthew Curtis, mentors Cole, Strattman and other PAA members, particularly in navigating non-standard fittings and connections (Figure 70 and (R): Figure 75). Each iteration accommodates and is extended by a more nuanced understanding of the methods and equipment required for atmospheric manipulation.



Figure 70 Manifold 1, 2020, depicting connecting pipes with valves, CGA 580 fittings for gas bottle connections, and vacuum pump (grey) on lower shelf.



Figure 71 Manifold 1, 2020, showing connection of disposable (lecture) gas bottles (white) to CGA fittings during vacuum draw. Valve to blow hose (red) is closed; valve to DVR2 gauge (blue) is open, reading atmospheric pressure within manifold at 0 Torr

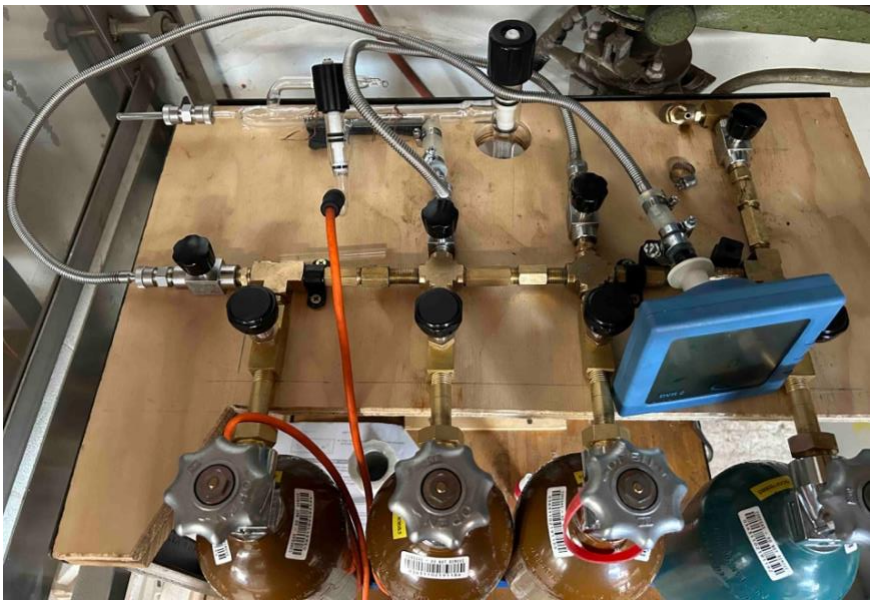


Figure 72 Manifold 2, 2022, showing improvements including orange blow hose, flexible stainless-steel bellows for manifold pipes (particularly to DVR2 atmospheric gauge), and D-type gas bottles attached with T100 fittings.



Figure 73 Manifold 3, iteration X, 2023, T100 fittings for gas bottles with variety of gauges being tested to measure pressure below 1 Torr within manifold.





(L): Figure 74 Capacitance manometer replacing DVR gauge (blue), 2024, for precision readings in 0–1 Torr range. Display shows 2.3 × 10^{-3} Torr, indicating a low molecular density in manifold.
(R): Figure 75 Swagelok compression fittings for connecting flexible stainless-steel bellows or glass on manifold, 2024. Swagelok, "Ultra-Torr Vacuum Fittings," https://products.swagelok.com/en/all-products/fittings/ultra-torr-vacuum-fittings/c/169

My manifold has glass sections fabricated from borosilicate (laboratory glass), while the blown-glass forms such as the *Chambered Vessel* series use soda lime or soft-glass; these glasses cannot be welded together. Ultra-Torr vacuum fittings have compression seals with O-rings, which allow incompatible glass to be joined outside of the kiln ((R): Figure 75).[249]

3.3.2 Connecting the Vessels to the Manifold

The plasma vessels I create have predominantly only one electrode. It is through this electrode, via a small hollow glass tubulation, that I directly weld the vessel to the manifold. This process is like welding electrodes to glass vessels, but performed at a frustratingly miniature scale, as the tubulation is often only 2.5 mm in diameter.[250] Before welding these delicate tubulations together, I attach a blow hose to a manifold port, (closing off the valves to the pump and gas bottle). Using small torches I heat the

[249] "Ultra-Torr Vacuum Fittings | Fittings | Swagelok."
[250] If no electrode is required a narrow diameter tube must be welded to the vessel before processing to make the connections and removal point from the manifold.

tubular section rims; when glowing, they are pressed together. By gently puffing air through a blow hose, I can inflate the joins, achieving even diameters, ensuring smooth welds. Several vessels can be welded onto a single branching glass straw within a kiln. This allows me to manipulate the atmosphere of several objects simultaneously (Figure 76).

I use an oven pumping technique, known as "bake-out",[251] which uses radiant heat inside of a kiln to heat the glass.[252] Where the manifold is stationed beside a kiln, a tubular glass extension perforates the kiln wall, connecting the manifold with the inside of the kiln. The aim is to create a continuous connection between the vessels (inside of a kiln), via their glass tubulations, to the branching connector tube, on to the manifold, (with its valves, gauges, vacuum pump and gas bottles) which is beside the kiln.

3.3.3 Testing for Leaks

Testing for imperceptible leaks within the interconnected and extended manifold system involves checking and reading pressure gauges while testing for cracks or holes in the glass. Each welded join is a potential site for atmospheric impurities to leak back

[251] In the signage trade, cleaning is facilitated by an electron bombarder, which heats the inside of the glass units via their paired electrodes, using the ionising atmosphere within the tube as a plasma filament. See Miller and Strattman, *Neon Techniques Handbook of Neon Sign,* 142-153; Crook & Fishman, *The Neon Engineers Notebook*, 21–30, Mason, *Neon*, 9; Lees, *Neon Primer: A Handbook on Light Construction*, 91.
[252] Rovelli, *Seven Brief Lessons on Physics*. 50-54, where Rovelli discusses heat in relation to chance.

into the system. A crack in the glass or a pinhole at a join will eventually cause the plasma vessel to fail, as ideal atmospheric conditions are not maintained.[253]



Figure 76 Atmospheric manipulation, 2023. Showing the manifold connection between the *Intra/twined* vessels and the branching tubular manifold extension. The transformer visible in foreground ionises and excites the low-pressure atmosphere within the tubes, exciting a pink light, indicative of the oxygen and nitrogen in our atmosphere.

When all vessels are welded together within the kiln and pump connections have been made, the stopcock to the vacuum pump can be opened (Figure 76). This draws down

[253] If the leak is large enough, the low-pressure environment within the manifold is compromised; the transformer can no longer elicit the change in state from gas to plasma, resulting in immediate failure. Conversely, if there is only a tiny leak in the system, failure will be prolonged as the electrode degrades over time. If contents contain gases other than non-reactive gases, chemical degradation and oxidisation of the electrode occurs. If not using an electrode, and if the pressure within the vessel is low enough to ionise and glow through capacitive powering, the effects of whatever gas mixture is trapped within the plasma vessel can be observed. Alternatively, gettering can be used to clean the vessel.
Feigen, interview with the author.

to ever lower pressures. If gauge values do not decrease, extra tests must be performed to locate leaks. My initial manifold iteration included gauges roughly measuring one Torr increments up to atmosphere (760 Torr at sea level). While drawing the vacuum, I would attach a transformer to an electrode to test ionisation of the internal atmosphere within the manifold.

If the manifold and vessels have no leaks, the luminous quality of our atmosphere ionising at low pressures reveals a lurid pink candy-floss colour, this then ebbs to an ever-paler pink (Figure 76). With no leaks, the dimming continues until the light flickers to pale white. At this point there are so few molecules in the vessel that my small transformer can no longer sustain excitation, and the light goes out.[254] Pinholes in vessels compromise low-pressure environments, resulting in short-lived, suboptimal, and failed illumination. Before owning specialised equipment, I would test for leaks by eye, observing these colours associated with our ionising atmosphere, a sustained pink glow, while the object was still connected to the vacuum pump, indicated a leak.

Avoiding leaks is vital to ensuring the quality of luminosity, as a clean specific low-pressure environment must be maintained. During my candidacy, I was introduced to a technique that neon artist Emma Kate Hart shared: if leaks occur at failed electrode joins, you can potentially detect it by delicately listening or feeling around welds while the pumps is drawing a vacuum.[255] Using this advice, I attempted to feel for a leak around the glass welds. I had inadvertently left the small single-ended transformer connected to an electrode inside the kiln as the vacuum was attempting to draw the vacuum, the pink glow was evidence of the leak.[256] This small error in judgement

[254] When pressure drops below 1 Torr, distance between molecules and their interactions become so great that excitation can no longer be sustained.
[255] "Emma-Kate HART."
[256] I will briefly insert a neon trade refrain shared by Richard Wheater: "Volts shock, amps kill" (Richard Wheater, neon workshop, Canberra Glassworks, 2017). The small transformer I use, although high voltage, has very low amperage.

(leaving the pump connected), revealed plasma's essential nature: that it is a gas-like state capable of carrying charge. As my finger touched the crack in the glass, and thus the leak, I felt the spicy buzz of high-voltage transformer zap through the charge-carrying plasma.[257] [As I use small transformers, I sustained no injury, just a jolting insight.]

When leaks are detected, they must be isolated. The damaged section can be removed from the manifold sealed off by using a torch.[258] Alternatively, if the leak can be fixed, I connect a blow-hose to a manifold port, while I spot heat the leak to gently "breathe" the glass together.[259] Spot heating glass causes the glass to thicken as it becomes more liquid. By gently changing the air pressure inside the vessel through breathing into the blow-hose, the heated section expands. Heat causes the glass to pool together: repeating this expansion and contraction can remelt and seal holes.[260] The difficulty with this technique relies upon on the chemistry of the glass. Furnace glass suffers from thermal shock and cracks easily. To avoid this, I pre-heat the cold glass using a very gassy orange flame before slowly introducing air or oxygen; this hotter oxygen rich flame can then melt the glass.[261] Borosilicate glass is far less susceptible to thermal shock, making leak repairs less stressful. These techniques associated with working on

[257] Thankfully, this transformer is high voltage, yet has low amperage, so my experience of sensing the plasma imparted a charged buzzlike sensation rather than an electrical burn.
[258] I managed to navigate a primitive method of leak checking, predominantly because I was using the softer soda lime glass. The difficulty with soda lime glass lies in repairing holes if there is a problem, this glass is more prone to thermal shock and may (will) crack more easily. Re-heating for repairs needs to happen slowly, using a small gas and air torch before fixing any welds.
[259] Steven Cole spoke about this way of breathing into-with the material.
[260] Mentored by Cole in this technique, primarily for the application of the electrode.
[261] Kirshner, interview with the author. This is an intricate process which I refer to as kiln yoga. During our interview, Kirshner describes his process for filling which occurs at his manifold station, not inside the kiln. The kiln, being metal, can have a shielding effect much like a Faraday cage, this metal certainly influences the subtle electromagnetic effects.
[261] Hepburn, interview with the author.

the manifold and the *Entangled Vessels* made with borosilicate glass are discussed in Chapters 4 and 5.

Detecting leaks safely, without testing using Hart's tactile approach, requires meticulous attention. Digital gauge measurements play a crucial role in identifying leaks and subsequently assist in measuring the small quantities of non-reactive gases that are reinserted into the vessels during the re-filling of the vessel (Figure 73 and (L): Figure 74).[262]



Figure 77 Tesla coil, spark tester.

For leaks arising from cracks or pinholes, I now use a spark tester called a Tesla coil (Figure 77).[263] This high-voltage instrument generates a mini lightning-like spark in the air, an example of dialectic breakdown.[264] Digital gauges must only be attached to the manifold if the manifold is sufficiently grounded. Digital gauges are damaged by high voltage electricity, (written from painful experiences, also shared by other practitioners). Any metal part of the manifold will become conductive; I ensure the kiln

[262] Miller and Strattman, *Neon Techniques Handbook of Neon Sign and Cold-Cathode Lighting*. 116-119. https://cdn.instructables.com/ORIG/FWT/20RW/HRI96Z5E/FWT20RWHRI96Z5E.pdf This has been a useful resource for converting pressure readings.
[263] A Tesla Coil is a high voltage electrical device that creates a lightning plasma spark, which can be used as a leak detector..
[264] Kikunaga and Terasaki, "Demonstration of Static Electricity Induced Luminescence." https://doi.org/10.1038/s41598-022-12704-5, 1

is earthed. I also have an electrode welded into my manifold, from which I connect a ground lead to a plug which I earth through a 3-pin electrical plug. Any transformers for plasma illumination must be attached to the work before the transformer is turned on. When this spark is held near the site of a leak as a vacuum is being drawn, the electrical current seeks the path of least resistance. If grounded the spark is drawn into the partial vacuum within the vessel, indicating the hole that could render the processing useless (Figure 78).[265] These pinholes are too small to see yet can be detected by the spark. Once identified, the leak location is marked, reheated and sealed. The vacuum can be re-established, removing atmospheric impurities.[266] For indicating leaks, Feigen, Strattman, Echols II, and Ristau all emphasised the importance of precision gauges that read pressure values between the 0 and 1 Torr range ((L): Figure 74).[267]

[265] These spark testers can also create pin holes, I have shown an image with a large spark, which I would not use to test for leaks, ideally one dials down the voltage to an almost imperceptible spark. It is also possible to purchase a metal brush tip for these devices, so the spark is even smaller.
[266] The fix involves turning off the vacuum, allowing atmospheric pressure to return, then attaching and opening the blow hose port. Then by heating the section where the hole is, a hot torch gently melts the area together, which can be gently inflated thorough the blow hose, so that the tube remains open. The glass should be re cleaned with heat, once cooled the vacuum can be redrawn.
[267] Feigen, interview with the author.
Ristau, interview with author.
Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 88-89
Echols II, Percy, *Taming Lightning EP 59*. Neon Insights: Alta Robbins' Valve Innovations with Greg Wilson, discusses the high precision instruments that contribute to achieving leak free conditions and measurements on a plasma manifold.



Figure 78 Tesla-coil spark crawling into partial vacuum within glass form, 2024. Pink hue of ionising atmosphere appears where vacuum is stronger. Tubing at left remains clear as pressure is insufficient to ionise atmosphere due to leak.

3.3.4 Removing Atmospheric Impurities: Cleaning the Vessel

At this point of the process, the interconnected vessels now require cleaning with heat to remove atmospheric impurities, including water vapour which adheres to the interior surfaces of a glass vessel when exposed to air. Once welds are tested, I heat the glass within the kiln to the annealing point, a temperature range determined by glass chemistry.[268] Annealing dissipates stress within the glass caused by spot heating and electrode attachment. Kirshner and Strattman indicate glass should cool below strain point, which is lower than annealing point, before vacuum pumps are activated.[269]

[268] Crook & Fishman, *The Neon Engineers Notebook*. 226.

[269] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*.75. Strattman and Kirshner both emphasised during conversations, the importance of only drawing the vacuum below the strain point of the glass, (which is below the annealing point). These are temperatures, dependent upon the chemistry of the glass, that ensure that the heating stresses are evened out throughout the glass. Both practitioners emphasised that drawing a vacuum below these points introduces added strain to the glass. Within my practice, this means that I test for vacuum seals early in the process but only draw the vacuum and remove the atmosphere after the temperature of the vessels has dropped below the strain point of the glass.

Heat increases molecular movement as energy is added; the description of the heat within an oven can be described as a "gas of photons", reiterating the breadth of the electromagnetic spectrum beyond the visible.[270] As my kiln heats up, it increases molecular activity within the vessel, encouraging impurities to ricochet around, allowing gases inside the vessel to be exhausted more effectively by the pump. The removal of atmospheric contamination establishes the conditions necessary for plasma illumination. Without this careful preparation of low-pressure conditions, the non-reactive gases introduced could not exhibit their specific spectral lines, also contamination causes the metallic components of electrodes to oxidise.

3.3.5 Playful Plasma Colour Testing and Luminous Effects

During my interviews, almost all discussed adding or tuning of luminosity as a playful, experimental part of the process. By inserting specific gas combinations at varied pressures, wondrous plasma phenomena can be elicited. After evacuating the contents, the manifold valve to the vacuum pump is isolated, and small quantities of non-reactive gases can now be inserted. Inside the kiln, once the forms have been heated and the glass has cooled sufficiently, I can then insert non-reactive gases. The specialised valves simultaneously accommodate low vacuum pressure and cylinders of non-reactive gases at high pressure, enabling small quantities of the rare gases to be introduced.[271] The manifold's contents are measured via gauges that read the low pressures within the entire system.[272] By attaching a transformer to the electrode

[270] Rovelli, *Seven Brief Lessons on Physics*. 56 "We know what happens to a heated electromagnetic field: in an oven, for instance, there is hot electromagnetic radiation, which cooks a pie, and we know how to describe this. The electromagnetic waves vibrate, randomly sharing energy and we can imagine the whole as being like a gas of photons that move fast and randomly like the molecules in a hot balloon."

[271] Taming Lightning, dir. EP 59: Neon Insights: Alta Robbins' Valve Innovations with Greg Wilson. 2024. 55:40. https://www.youtube.com/watch?v=fmCWTbyhPqU. *EP 59*.

[272] Ristau, interview with author. Ristau speaks about after installing multiple gauges in his system so he can see pressure read outs at multiple locations in the interconnected manifold. He implemented this after seeing the flow-through filling technique demonstrated by Strattman during a PAA symposium.

vessels after the desired quantities have been inserted, luminosity can be tested. Subsequently, more gas can be inserted or removed via the vacuum.

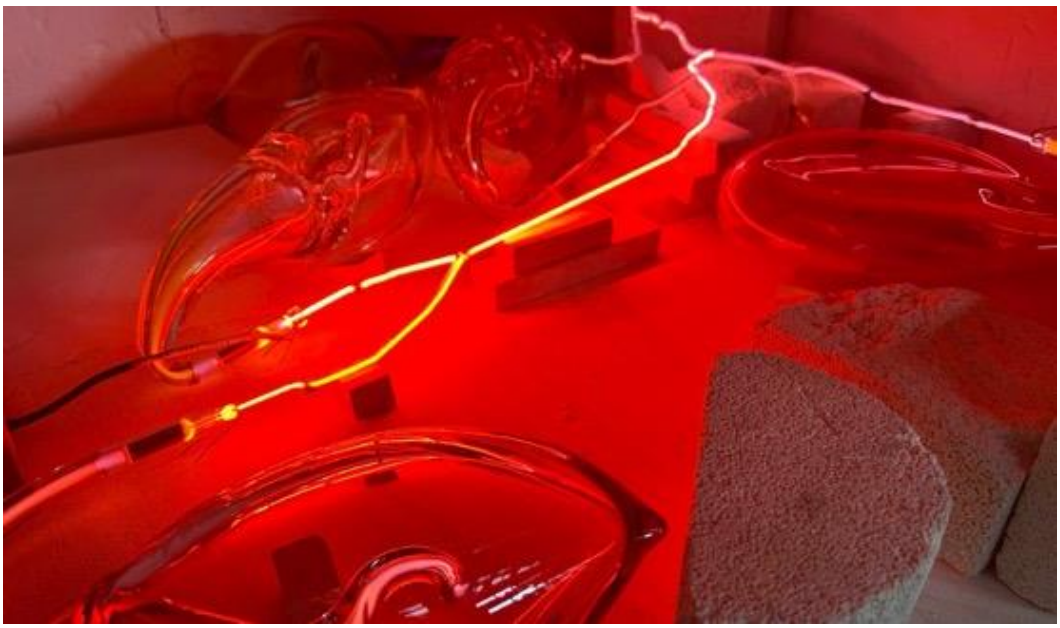


Figure 79 Neon discharge exhibiting variable behaviours depending on volumes and distance from transformer, 2024.

Four connections to high-pressure gasses allow me to introduce neon and/or argon, krypton, and xenon into the manifold.[273] My procedure is to introduce neon first, at low pressures (5–30 Torr). Neon is the most easily perceived gas at these pressures. [274] For this project, the colour also offers a metaphoric connection to blood circulation (Figure 79 Neon discharge exhibiting variable behaviours depending on volumes and distance from transformer, 2024.. I connect the transformer to the electrode wires to witness how each object appears; luminosity varies with volumes and the distance from the powered electrode. At this stage, if any glass vessel appears particularly striking with the neon glow-discharge, I can remove that piece. Alternatively, I can add more gas. I can also reopen the stopcock to the vacuum pumps and re-draw a vacuum, emptying

[273] My manifold has both gas fitting referred to at T10 and CGA580 bottles connection. I can interchange bottles at the beginning of a session.
[274] Lees, *Neon Primer: A Handbook on Light Construction*. 49

the gas molecules from manifold and vessels. Hepburn describes this as “adding and slurping” gases from forms, a process best conducted in a darkened studio, as this allows the maker to see the subtle effect of the illumination.[275]

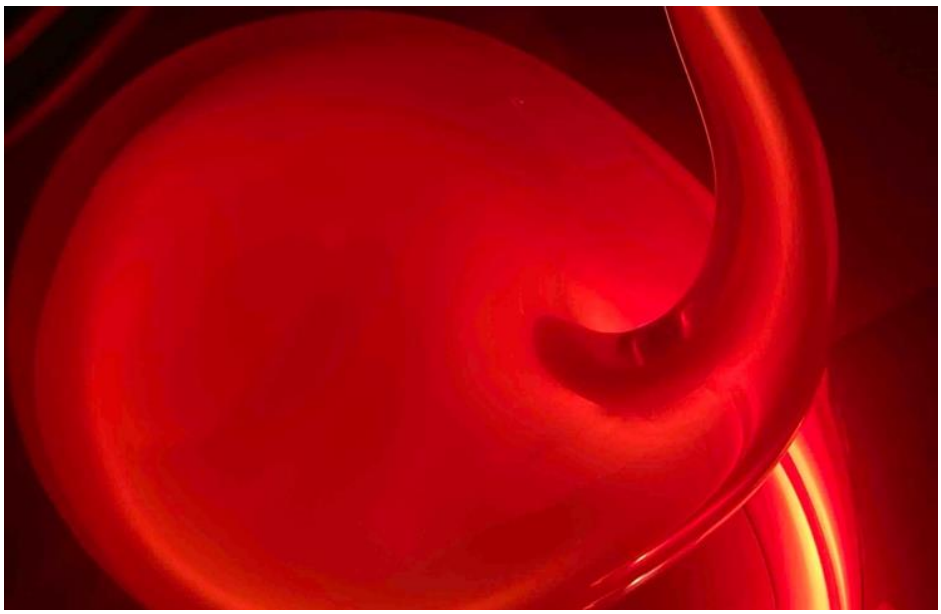


Figure 80 Low-pressure neon fill test, *Intra/twined*, 2023.

Using low-pressure neon (between 5–20 Torr) fills exhibit a soft red glow discharge plasma (Figure 80), while argon at similar pressures produces “dim violet” hues.[276] Mixes with krypton, between approximately 80–120 Torr, produce effects that sprinkle and dance around vessels (Figure 81 and Figure 82).[277] Xenon mixes at slightly higher pressures, approximately 90–220 Torr and glow bright blue-white with green sheaths around the bright meandering lines.[278] Tendrils meander or bifurcate, appearing to

[275] Slurping is a term particular to Mundy Hepburn, describing the sound made during the evacuation of the form on the manifold. I add gas from the canisters, and I can “slurp” them out by partially opening the vacuum to lower the pressure again.
[276] Lees, *Neon Primer: A Handbook on Light Construction*. 51
[277] Hepburn’s practice exemplifies these effects.
[278] Stattman PhD, 40

“walk” and “unzip” and “intercept” (Figure 83).[279] Wider volumes elicit a more diffuse glow, while constrictions provide a brightening intensity.[280]

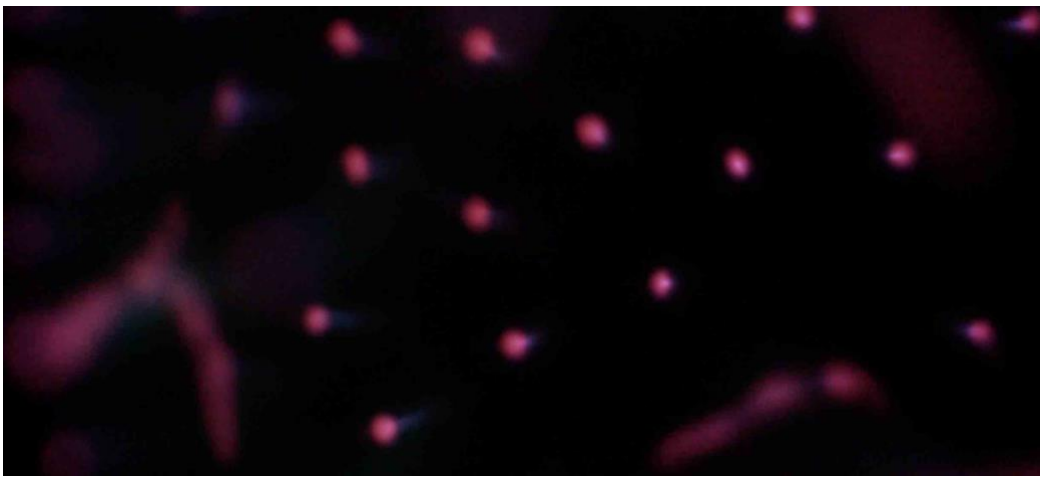


Figure 81 Krypton and neon sprinklers, video still from Peachey and Mosig, 2024.

[279] Campanell et al., “Measurements of the Motion of Filaments in a Plasma Ball.” 7
Image “UnWrapped New Mountain | Sydney Opera House.”
Artists Peachy and Mosig filmed my plasma work in my studio and an installed at Canberra Museum and Gallery, which became a small part of their *New Mountain* performances.
https://www.peacheymosig.net/project/new-mountain

[280] Kirshner, interview with the author. Kirshner described how plasmas tend to express a softer glow discharge illumination in the more voluminous spaces. There may be relationships in the constrictions, potentially due to the Corner Effect. More broadly the atoms on the interior of the glass act as constant yielding surfaces, opportunities at which electrons may interact.



Figure 82 Xenon and neon, video still from *Peachey and Mosig*, 2024.

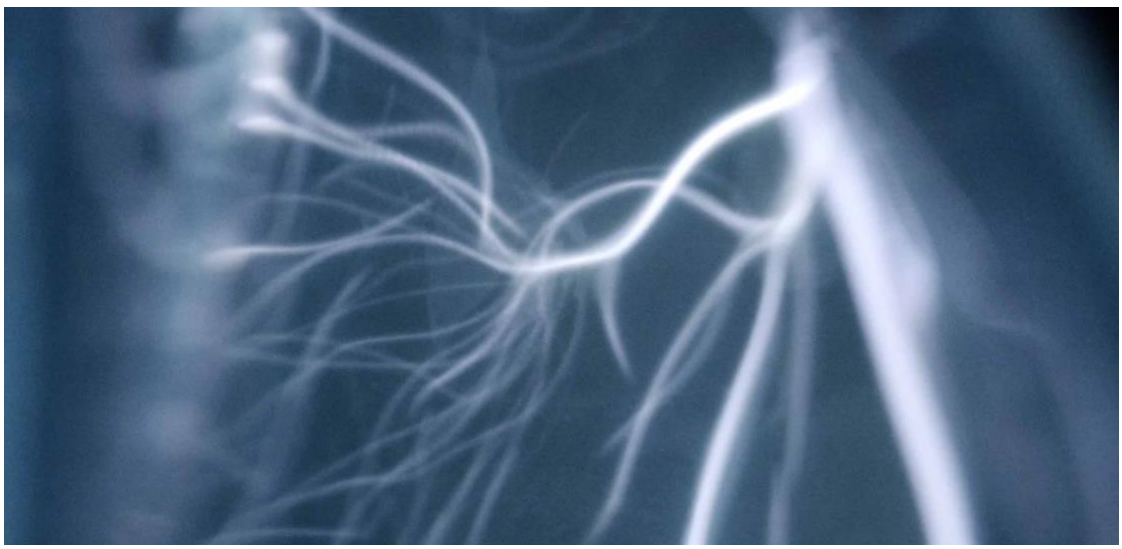


Figure 83 Dendritic xenon tendrils, video still from *Peachey and Mosig*, 2024.

During our interview, Davis and I discussed how plasma tendrils appear to interact more vividly with phosphor coatings, creating instantaneous colour transformations that reveal their behaviours as light interacts with curved, coated interior surfaces.[281] For example, phosphor powder partially dusted on the interior surface reveals the plasma discharge differently. Where it splashes against the phosphor, the light appears

[281] Davis, Daniel. Interview by author. (28.02.2025) Transcript in Appendix [3]. Davis interview discussion on interior surfaces.

pink-red and velvety, whereas against the clear glass at the front of the vessel, the discharge appears blue and sharply focussed (Figure 84).

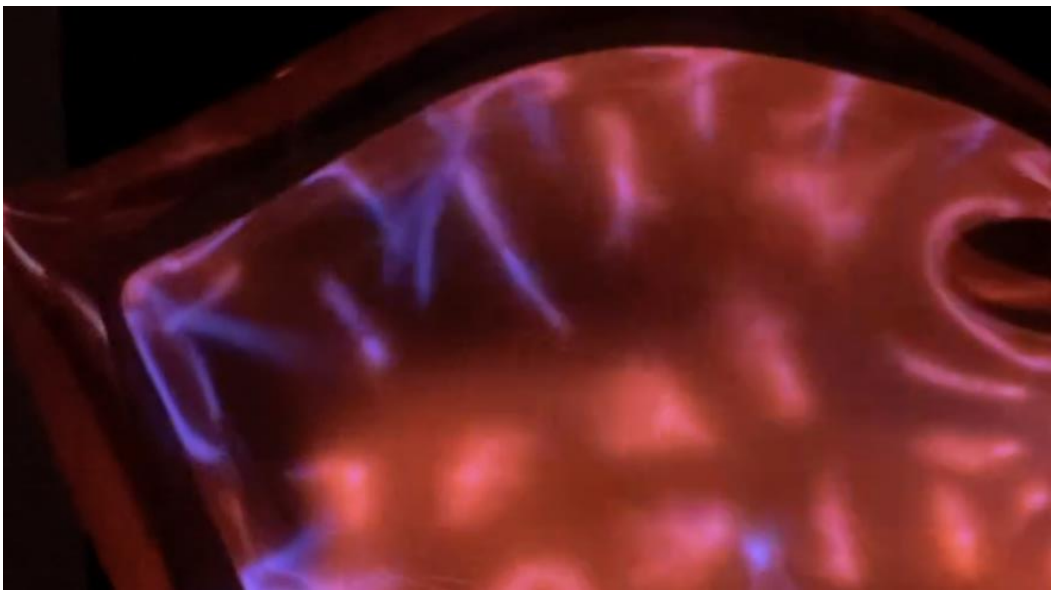


Figure 84 Red phosphor powder dusted on back interior surface, 2023, demonstrating colour variation in xenon and neon discharge. Discharge appears pink-red against phosphor, blue against clear glass front.

The endless combinations of pressures, mixes of non-reactive gases, and specific transformer capabilities all contribute to luminous effects within these objects.[282] During our interview, McAlney spoke of his interest in cataloguing these effects, despite Hepburn's warning that this might lead to obsession.[283] Within my own practice, it is not about creating the perfect geometry or architecture to create specific patterns or effects from the plasma behaviours, but rather to elicit responsive discharges that can be influenced by the observer.

[282] *Mix* is a term which is used due to the language of the filling process being akin to a recipe. Where the approach to inserting the inert gases back into the forms. Yet precisely because these inserted gases are inert, it renders the term invalid. As these elements have a complete outer shell of electrons. They are stable atoms that do not need to become a compound to exist as a stable element or compound. Technically these gases do not mix, but share the same internal volume of space, each atom individually going through the process of excitation to release photons of light.
[283] McAluney, interview with the author.

Strattman and Kirshner separately shared the reality of the visual appearance of discharges changing over time, due to chemical reactions from trace contaminants on the vessels' interior surfaces, which affect the light.[284] Laboratory technician Gary Coyne describes the distinctive colours given off by various atoms or molecules (Figure 85).[285] I generally avoid these molecules as they cause the electrodes to perish through chemical processes such as oxidation. However, there is the potential to use these constituents within electrodeless techniques described as capacitive illumination. Capacitive illumination is discussed further in Chapters 4 and 5, where I employ a method to create installations with suspended and moveable components, made luminous without direct wired connections or electrodes.[286]

[284] Kirshner, interview with the author.
Strattman, Wayne. Interview by author. (08.12.2023) Transcript in Appendix [11]. Both Kirshner and Strattman speak about change as a constant in these vessels, that pieces change, sometimes in good and sometimes in bad ways over time.
[285] *Gary S. Coyne The Laboratory Companion A Practical Guide To Materials, Equipment, And Technique Wiley Interscience (2005)*. 449
[286] "Wayne Strattman's Plasma Light Art- Luminous Glass Sculpture." 125, a form of plasma illumination where there is no electrode that comes into contact with the gases as they are excited into the luminous plasma state

Gas	Negative Glow	Positive Column
Air	Blue	(Reddish)
Nitrogen	Blue	Yellow (red gold)
Oxygen	Yellowish white	Lemon
Hydrogen	Bluish pink (bright blue)	Pink (rose)
Helium	Pale green	Violet-red
Argon	Bluish	Deep red (violet)
Neon	Red-orange	Red-orange (blood red)
Krypton	Green	—
Xenon	Bluish white	—
Carbon monoxide	Greenish white	(White)
Carbon dioxide	Blue	(White)
Methane	Reddish violet	—
Ammonia	Yellow-green	—
Chlorine	Greenish	Light green
Bromine	Yellowish green	Reddish
Iodine	Orange-yellow	Peach blossom
Sodium	Yellowish green (whitish)	Yellow
Potassium	Green	Green
Mercury	Green (goldish white)	Greenish blue (greenish)

Figure 85 Spectral variations in discharge tube with anode and cathode. From Coyne, *Laboratory Companion*, 449.

3.3.6 Sealing and separating

Once a desired outcome is achieved through testing with the transformer, the object is removed from the manifold, and its contents are encased within a sealed envelope of glass. To remove objects from the manifold, I heat those small glass tubulations of the electrode using a small fishtail torch (Figure 86). As the contents within are below atmospheric pressure, when the glass heats and softens, it sucks inward, and as I pull the vessel away from the manifold it seals itself closed (Figure 87). This action of sealing the object and can no longer be manipulated by the manifold. There is now an encasing glass membrane containing carefully controlled and calibrated atmospheric conditions within.



Figure 86 Separating filled glass piece from manifold, 2024. Video still by WEFT Production.

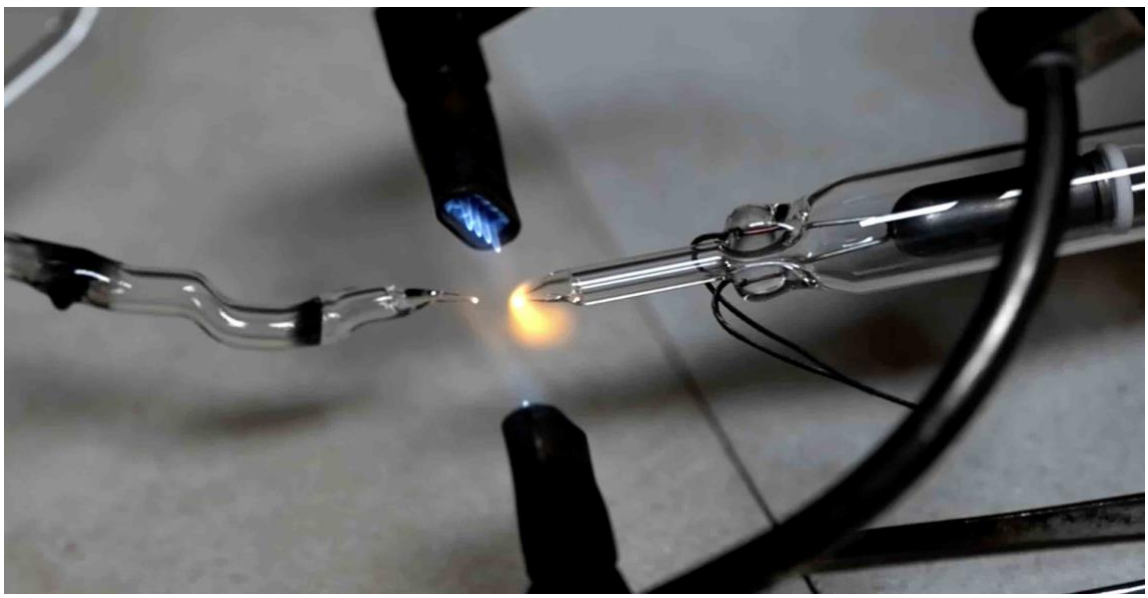


Figure 87 Detail of sealing process: nipping off soft-glass piece from manifold, 2024. Video still by WEFT Production.

As plasma is a charge-carrying state of matter (due to the freed electrons and ions), the surfaces of the vessel are contrastingly charged, and the plasma and the vessel assert their influence upon each other via their interplay. Professor Vadim N. Tsytovich, an expert in non-linear plasma physics, provides an analysis of the complex interactions at

the surface of a vessel, where there "are many physical and chemical processes which occur close to the surface" that contribute to discharge effects, influencing temperature and charge gradients.[287] As such, the glass vessel in plasma illumination can provide meaning through form while its electron-rich surfaces inherently contribute to the effects of the plasma's behaviours.

3.4 Tripartite Process: Electromagnetic Activation

Ionisation requires the application of energy (electricity) through a high-voltage transformer, which results in excitation, eliciting plasma's luminosity. This part of the tripartite process represents the intersection of artistic vision with electro-magnetic principles to produce plasmas luminous phenomena. I have mentioned that I experience the tripartite process as leaky, tangled and non-linear; an example of this is that electromagnetic activation is necessarily employed throughout the previous atmospheric manipulation stage, to test for luminosity before the vessel is removed from the manifold.

As the blown-glass vessels I produce use single electrodes or no electrodes, they require specialised transformers rather than transformers from the neon trade. The more open circuit created with these transformers and the vessel is influenced by the

[287] Tsytovich, *Lectures on Non-Linear Plasma Kinetics*. p13 printed *1995* "A low-temperature plasma can usually be confined by walls; in that case surface phenomena due to plasma-wall interactions are very important. There are many physical and chemical processes which occur close to the surface of the wall and this makes the system much more complicated than a magnetically confined plasma… However, the presence of many processes which can occur simultaneously and the big role played by collisions because of the low temperature open many channels for the development of turbulence and self-organisation processes… Recently they have been explained as being self-organised dissipative structures. Striations are localised regions with higher temperatures and lower densities surrounded by regions with lower temperatures and higher densities. Recent research has shown that if the plasma in a gas discharge is subjected to strong radio-frequency radiation there appear many different structures in it. The formation of these structures is related to the ionisation by strong radiation."

surrounding environment, affording responsive relationships with viewer-participants through human conductivity.[288]

In our interviews, Ristau described this specialised transformer configuration as "breaking the circuit", alluding to an open configuration,[289] while Hepburn described it as follows:

> The plasma light is running at high voltage and it's seeking ground because the energy always wants to equalise and mellow out the waves so when there's heavy energy coming out of the light you come near it, you're denser than the surrounding air so you attract the electricity to you, and it goes through you and to ground. That's the circuit.[290]

The transformer effectively extends the circuit and exerts its influence into the surrounding environment or through the "complex conductor" of the observer's body (Figure 88).[291] This has led me to view these plasma physical systems, including the conductive observer, as an entangled and somewhat leaky circuit akin to the body's circulatory system.

[288] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 119-125 Strattman's Chapter 6 on Transformers and Electronic Power Supplies provides exacting details on the interplay between the object and the transformer.
[289] Ristau, interview with author.
[290] Hepburn, interview with the author.
[291] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 129

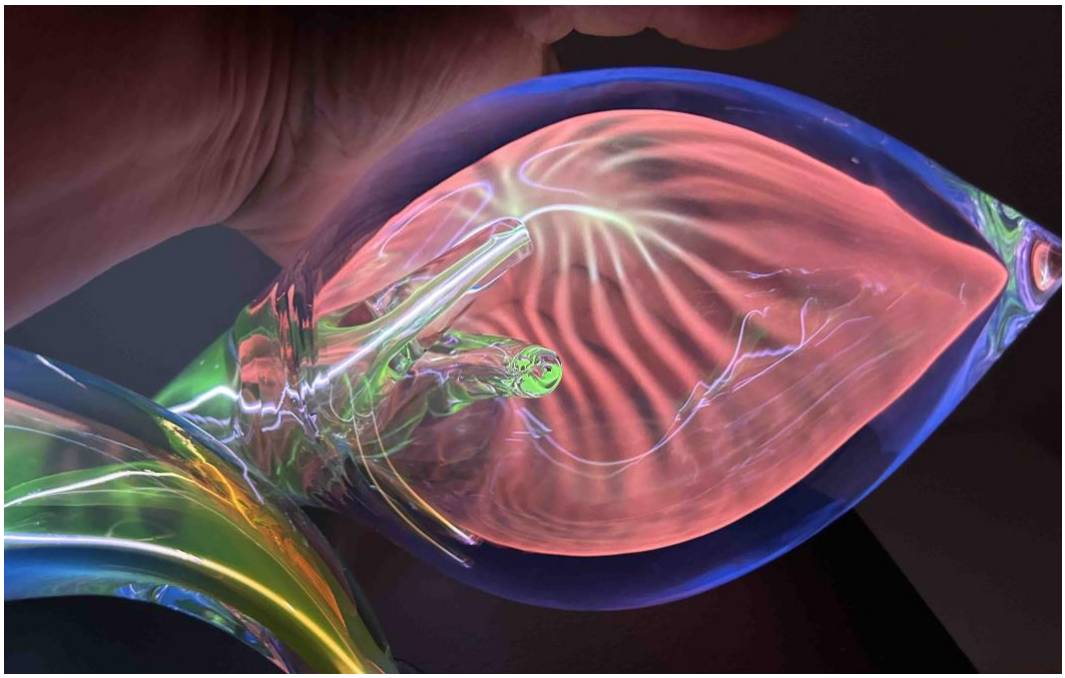


Figure 88 Testing body as conductor with *Chambered Vessel*, 2024.

Transformers are paired with vessels, calibrating their volume, scale and the gases' resistivity. Makers tend to use the same transformer during testing as when the object is exhibited. Changing transformers often results in varied luminous plasma behaviours within the glass (Figure 89 Figure 88). These transformers are produced by only a few suppliers. Because of this, plasma practitioners have started to develop and innovate in this area. Of the four devices I used, the plasma driver used most within my projects is the Neoniser 21, which I pair with a power supply from the medical industry, making it compatible with both Australian and international voltages.[292] I have also used the small Tech22 neon transformers, including the Midget Tech 22 transformer, which can be wired for single electrode vessels. (Following the Tech22 wiring diagram, one of the two wires for creating a traditional neon circuit gets re-routed as a grounding wire to an earth wire through a wall plug, enabling the transformer to be connected to the single

[292] My reservation about relying on these transformers was due to the passing of their fabricator, Bob Iannini, the inventor who ran the company *Amazing*1 for many years. Echol's *Taming Lightning* online store now has a fabricator who produces a comparable product.

electrode.)[293] I use transformers produced by Hepburn, who explained during our interview that his "entire adult life has been devoted to learning how to do all the things that it takes to make beautiful gas discharge lights, high frequency plasma type, cold plasma, wiggling filamentary arcs."[294] I also use a transformer produced by Strattman that draws on Feigen's engineering expertise.[295]



Figure 89 Comparison of transformer effects (left to right: Neoniser 21, Hepburn transformer, Tech 22 Midget), 2024, neon-xenon fill, 180 Torr, pale, blue-tinted glass with uranium veneer.

Hepburn describes the uncanny nature of interaction with plasma vessels, saying that "aesthetically and experientially, it's very weird, you turn toward the thing, and the thing turns towards you and you're like wait what? And you put your hand near it, and it lights up and changes, makes wonderful patterns depending on the mixture" (Figure 88).[296]

[293] The Tech 22 Midget has a small screw setting that enables the voltage output to be changed.
[294] Hepburn is one of those rare plasma practitioners who could be described as self-sufficient. A Renaissance plasmatician; he is capable of performing the whole tripartite process; constructing, innovating and tinkering together every aspect of the tripartite process for a plasma practice.
[295] Excitingly there are a number of new transformers now available.
https://strattman.com/about-strattman-design-plasma-light-technologies/
https://www.wardpowerelectronics.com/
taminglightning@gmail.com
https://weinmayer.at/en/videos/
[296] Hepburn, interview with the author.

Due to these specialised transformers, the resulting luminous phenomena respond to external influences, including human proximity, demonstrating plasma's capacity to make visible our typically imperceptible electromagnetic presence and conductive bodies.

3.4.1 Gas-Specific Behaviours and Interactions

When I first began experimenting with gas mixtures, the practitioners' responses to questions about their gas mixtures initially seemed cryptic. Rather than acting as subterfuge, these enigmatic answers revealed the complexity of the many competing factors inherent to a plasma practice.

Within the plasma objects, transformers create what Davis describes as “sheaths of charge”, which are seen as visually distinct regions of luminosity, resulting in arcs or dappling light.[297] The transformers also elicit “sites of current potential,” where electromagnetic fields discharge more energy closer to the electrode which enable ionisation of the heavier gases, that are lower on the periodic table.[298] Davis spoke of ionisation potentials, which describes how readily a gas will ionise when energy is applied. Larger atoms appear lower on the periodic table, yet they ionise more easily due to the increased distance between the nucleus and the outer electrons. In visualising the position of non-reactive gases on the periodic table, the gases higher in that column require more energy to change to the plasma state.

The non-reactive gases employed in my practice exist in curious states of mixing but not mixing. Justin Walk described plasma oscillations as “collision-less” and “collective”, as they exhibit a “large ritual array of possible vibrating states, different

[297] Davis, interview with the author.
[298] Davis, interview with the author.

from all other states of matter".[299] These physical insights led me to consider how these non-reactive gases function relationally. Although chemically inert, they create complex interactive effects when transformed into their plasma state.

During our interview Davis articulated the mechanisms of Penning mixes: "where a trace amount of lower ionisation potential gas dramatically affects the overall striking voltage of the mixture."[300] For example, adding small amounts of argon (which requires less energy to ionise) to neon allows those freed electrons to impart their kinetic energy to the neon atoms without ionising them. Davis describes how partially excited neon atoms maintain long-lived metastable states that subsequently transfer energy to the argon atoms (or other mixes), ionising them at lower voltages than either gas would require individually. The mechanisms of Penning mixtures offers a complex insight connectivity at a minute scale.

In my practice, I use Penning mixes, inserting neon with small measures of xenon (1–15 Torr) to total pressures of 150 –200 Torr, producing curving, dendritic expressions of excitation. For example, Krypton mixed with other gases creates distinctive "sandbars" or "butterflies," luminous effects appearing as chicken-foot patterns tinkling on glass interiors.[301]

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[299] "BBC Radio 4 - In Our Time, States of Matter." (April 04, 2014) Audio 15:00

[300] Davis, interview with the author.

> "...with a slight addition of a lower ionization potential gas, [for example xenon, lower down the column of the 'Noble gases' on the periodic table] you can drastically lower the striking voltage for that mix, is because, with electrons colliding with the higher ionization energy gas the neon in this case they impart kinetic energy to those gas molecules, but not enough to ionize them. And they form what are called metastable states and those metastable states have really long lifetimes, we're talking on the order of like seconds, which is really amazing because normally whenever you know an atom gets excited, you know, immediately de-transitions and then gives off light..."

[301] Hepburn, interview with the author.
"BBC Radio 4 - In Our Time, Kinetic Theory."

A Paschen curve is a graphic visualisation of variable ignition voltages, relative to pressure and distance from an electrode.[302] Lower-pressure conditions require less energy to excite a gas into its luminous plasma state because the "mean free path," the distance between the atoms or molecules, has been increased.[303] Davis describes how inversely, at high pressures, an electron's path (the distance between collisions or interactions) requires high electric fields or more thermal energy for ionisation.[304] As pressure decreases, the mean free path increases, allowing ionisation at lower voltages until reaching its minimum. Beyond this point, voltage requirements increase again as fewer collisions occur between electrons and gas molecules. These multifarious subatomic actions and their resulting plasma behaviours are influenced and affected by every aspect of the tripartite process.[305]

Making work while expanding my knowledge of plasma illumination has allowed me to better comprehend the nuances of how pressure, surface interactions with vessel architecture, Penning's mixture, and Paschen curves describe the complex interactions within luminous plasma objects. The pattern of repeating the tripartite process within my studio, while comprehending its minutiae, offers an experimental pathway through creative practice. This application of a diffractive methodology permits multiple experiences, ways of thinking, and processes to exert their influence on my work.

[302] Davis, interview with the author.
[303] Biswas and Mitra, "High-Frequency Breakdown and Paschen Law." 377
[304] Davis, interview with the author. Where Davis speaks of Pashen curves and ignition potentials.
[305] Davis, interview with the author.
"There are higher fields and lower conductivity, and lower and lower current density in that diffuse streamer, fan or glow discharge. So, there is higher fields, lower current density and lower conductivity, and those higher fields allow the gas with the higher ionization potential to be excited. Which is why you see the neon preferentially. In a similar way in lightning in the streamer fan, you see predominantly ultraviolet emission and in the leader in the leader channel, you see predominantly infrared emission."

3.5 Paired Systems*: Intra/twined* Vessels

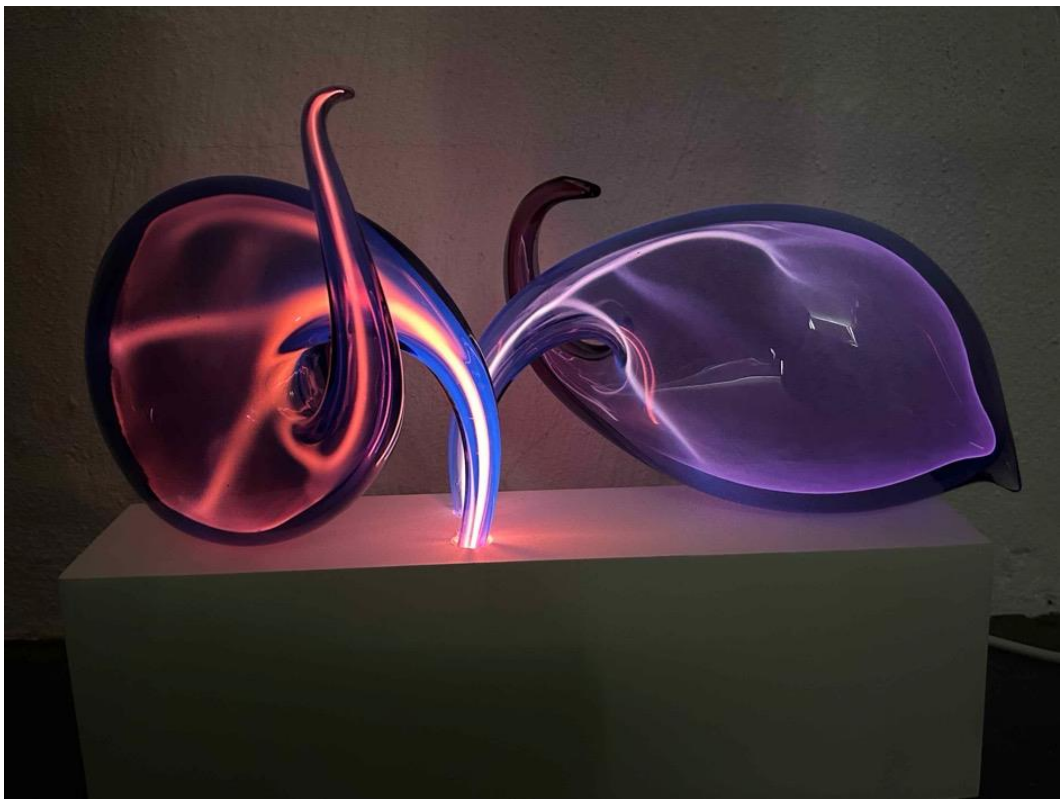


Figure 90 *Intra/twined* (work in progress), 2023, blown glass, ionised gas, electrode and transformer in base.

I will now discuss these influences during the making of the *Intra/twined* vessels. Developing the *Intra/twined* vessels enabled me to pair abstracted vascular forms comprising of individual plasma chambers (Figure 90). These separate plasma objects assert their influence on each other despite the glass membrane that separates them. Envisaged as paired objects, they provide further evidence for plasma's capacity to make visible electromagnetic connections between objects and a viewer-participant.

After blowing the vessels, I encased between 50-180 Torr of mixed non-reactive gases. I initially illuminated these two glass forms using a single shared transformer, testing the responsive relationship between the objects and furthermore with the viewer-participant. The adjustable voltage output of the Midget Tech22 transformer allowed

me to elicit slow-moving discharges or (to increase the energy output via an adjustable potentiometer) to elicit more fast-moving or erratic discharges.[306] When selecting a higher power output, touching these objects imparted an electrical buzzing sensation as the plasma vessel is over-charged. In this state, a faint blue coronal discharge (a form of plasma discharge) can also be seen where touch occurs outside of the vessel. Coronal discharge is accompanied by the smell of ozone (that fresh smell after a lightning storm), as chemical reactions cause oxygen O_2 to become O_3 for a short time.[307] This over-charged state will eventually burn out the transformer. When re-adjusting the transformer to avoid external coronal discharge, the vessels' internal ionisation elicited soft glows with meandering dendritic lines.

When these vessels are installed in a paired configuration, viewer-participant proximity draws more current into the closest object, creating more active and vivid light tendrils in that form (Figure 91). Conversely, the untouched paired piece dims due to reduced electrical conditions. Although each vessel contains similar gas pressures and combinations, the vessels react differently based on their distances from their transformers and slight variations of form, producing varied luminous effects. My artistic intention in eliciting these changing luminous effects and altering their intensity through interaction is also metaphorical: proximity and interdependency influences changing energetic and luminous expressions.

[306] The Midget Tech 22 transformers, has a small screw setting that enables the voltage to be changed.
[307] "Ozone Equipment Manufacturer and Ozone System Integrators Corona Discharge Ozone Generators - How They Work? Ozone Integration Experts."

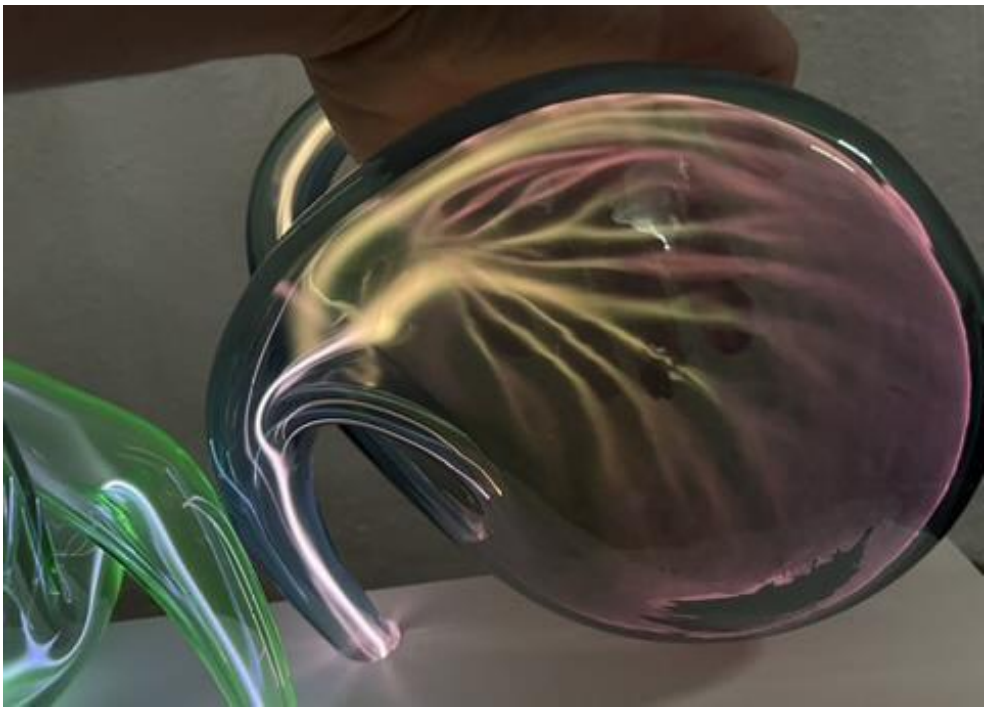


Figure 91 *Intra/twined* (work in progress), 2023: viewer-participant proximity draws more current into closest object.

I fabricated bases for the *Intra/twined* objects that could house the electronics while including small holes for air flow. I then prepared holes in the top of the bases, through which I could lower the electroded section of the object, before connecting them to the transformer. The single transformer configuration, although poetic, was problematic due to the tendency to burn out the transformers. I decided to change the configuration to two smaller transformers housed within the base. The interactive plasma discharges remained similarly responsive, in that the viewer experience is similar. I secured the electrical and glass components with silicone inside the base, before affixing a non-conductive (acrylic) sheet to the underside of the base, to prevent contact with the electrical componentry.

The *Intra/twined* objects allowed me to experiment with vessels that echo each other yet individually change their luminosity in response to electromagnetic interaction. As I paired these single tinted objects with their fluid and reaching tendrils, I began to

understand these forms as transitional. They bridge the single chambered stylised heart vessels of *Between Movement and Stillness* with the interconnected *Chambered Vessels*. When interacting with the *Intra/twined* objects, I can sense how the dendritic branching plasma behaviours unfold. Their brilliant emphasis reaching into the elongated tendrils demonstrate how the glass forms enhance the discharge dynamics. I saw the electric fluid dynamics of the plasma shift from one form to another, influenced by the changing electromagnetic conditions affected by the viewer-participant's proximity.

3.6 Chambered Vessels: Internal Architecture Illuminated



Figure 92 *Chambered Vessel Pair,* 2024, installation view, Canberra Museum and Gallery. Photo by Brenton McGeachie.

By incorporating what I had observed in the *Intra/twined* objects, my intention was to emphasise and make visible differentiated plasma behaviours within *Chambered Vessels* (Figure 92). Although the form of the *Chambered Vessels* references historic gas-discharge illumination, by adapting traditional glassblowing methods, they take

their formal cues from vascular references. I combined a colour palette inspired by fleshy tones, paired with the lurid glow of fluorescing Geissler tubes. By adapting areas of the tripartite process of production, I hybridised glassblowing methods to create novel, interconnected chambers.

I developed my own interpretation of the Italian glassblowing technique *Incalmo*, which is traditionally used for banded colour application, combining a cup and a tube of equal diameter.[308] Rather than using this method for decorative purposes, I created complex hollow interior architectures that resemble valve-like chambers of a heart, or scientific glassware, such as distillation devices.

While blowing these vessels, I worked on the internal asymmetrical form, with internal tubes that narrow to tiny apertures. Meanwhile, my assistant prepared a cup-like structure. By heating areas selectively and lining the components up while hot, we pressed them together into an interconnected vessel with varied internal structures (Figure 93– Figure 96). The form was then finessed using vessel-making techniques, paying attention to create a reduced diameter of tubing, onto which an electrode could later be attached (Figure 97).

This making practice aligns with Ingold's description of how such processes are "not the imposition of preconceived forms on raw material but the drawing out or bringing forth of potentials immanent in a world of becoming."[309] This confluence of material practice acknowledges historical lineages of glassblowing while extending it into fluid contemporary glassblowing practices.

[308] "Incalmo | All About Glass."
[309] Ingold, Making.31



Figure 93 Harriet Schwarzrock and Matthew Curtis preparing, heating, and measuring individual forms to be pressed together into one object, Australian National University, 2023. Video still by author.



Figure 94 Testing connection of glass forms, Australian National University, 2023.

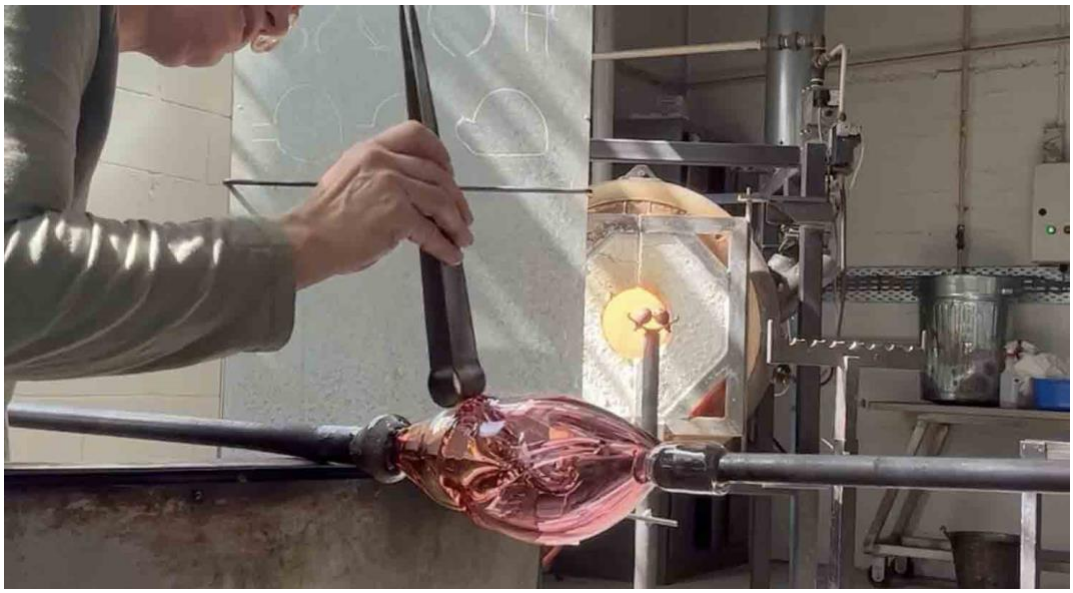


Figure 95 Joining of blown glass forms, Australian National University, 2023.



Figure 96 Separating blown glass form from blowpipe, Australian National University, 2023.



Figure 97 Adapted *Incalmo* technique showing attachment to punty before annealing, Australian National University, 2023.

After beginning to test the production of these vessels at the Australian National University (ANU) Glass workshop from 2022, I undertook field research in 2023, visiting the University of Massachusetts, Amherst. This provided a pivotal encounter that deepened my appreciation of the making of gas-discharge illumination. During my visit, scientific glassblower Sally Prasch showed me around her laboratory, and I was able to handle delicate Geissler tubes that still contained their altered nineteenth-century atmospheres. The experience of holding these vessels revealed the incredible skill of the maker along with the delicacy of these objects (Figure 98).



Figure 98 Sally Prasch displaying an original Geissler tube at the glassblowing laboratory, University of Massachusetts, Amherst, 2023.

Prasch indicated that Geissler tubes demonstrate intricate iterations of glassblowers' skill and ingenuity outside of producing scientific glassware. This practice, much like the imaginative "frigger" pieces known to have been created in glassblowing factories, are distinct from the everyday objects produced.[310] Prasch has written about the intersection of teaching creativity and skills, noting that "[I] have always included scientific glassblowing and artistic techniques into the class."[311] Doing so allows the

[310] Moore, "Agents of Incongruity: Glassmaking Embraces Nonsense to Monsters, Wonder and Dread." p.44 Tom Moore writes "There is evidence that 19th Century glass factories sanctioned something akin to play, whereby efficient workers were given occasional free access to materials and facilities. "End of day" glass objects, also known as "friggers" in England and "whimsies" in America are usually ornamental novelties, sometimes intended to boast the skill of the maker."
[311] Issuu, "GASnews Winter 2023."

glass vessel to be appreciated simultaneously as a functional object and a creative artefact of skilled fabrication.

I experience working with hot glass as a fluid process where material potential unfolds through action. Making with furnace-blown glass allows me to strategically manipulate wall thicknesses and to create varied volumes that fluidly distort vessel forms, as opposed to laboratory glass making that results in even wall thickness and tube diameters. This project required creating and joining interconnected bubbles and vessels with relatively uniform wall thickness while ensuring secure and accessible points for subsequent electrode attachment. Through experimentation, these blown-glass objects transitioned from bubble to vessel to interconnected chambers, with the increasing complexity of their interior structures offering sites of interactive potential for plasma behaviours.

Technical innovations during vessel formation result in Klein-bottle like forms, becoming the internal membranes of the *Chambered Vessels*, generating complex continuous interior surfaces.[312] My process references a rich tradition of glass vessel making, from the exactitude of scientific methods for creating multi-chambered apparatus to asymmetrical blown glass vessel making in the hot glass studio. Hybridising these approaches allows me to press one open chamber into another, forming asymmetrical interconnected organ-like chambers, referencing circulatory vascular valves and chambers. The fluidity of this process, with its responsive decision making and iterative adjustments, resulted in complex internal forms that were well joined for later vacuum integrity. During the process, I ensure that the internal components do not touch the larger bulbous vessel. Glassblowing enabled me to create internal chambers while achieving flowing forms with curvaceous lines and visual tensions. In addition to the form, I made decisions based on how I imagined the

[312] "Klein Bottle | Nonorientable, Multiply-Connected, Self-Intersecting | Britannica."

plasma behaviours would be affected by the internal architecture of the form. I capitalised upon plasma's fluid behaviours, pulsing and trickling throughout the vessel.



Figure 99 *Chambered Pair* (work in progress), 2023, blown glass.
Figure 100 *Chambered Pair* (work in progress), after cold-working punty removal, 2023, blown glass.

Once cooled, these interconnected vessels were coldworked (punties removed) and electrodes attached ready for plasma illumination processing (Figure 99 and Figure 100).[313] Processing these complex forms followed similar principles to the *Intra/twined* vessels yet required additional time to evacuate their complex interiors. The internal constrictions revealed lags, as pressures are not immediately equalised throughout the manifold and vessel, causing bounces in the pressure gauges. While evacuating the constricted volumes and filling these vessels, fluctuating gauge readings are alleviated by making incremental adjustments. As inert gases are re-inserting the contents pass

[313] The removal of the punty requires me to grind and polish off the glass using traditional studio glass working techniques and tools. These grinding methods use diamond abrasives and water to cool the objects. Note the importance of taping closed the opening where the electrode will be attached, ensuring that water and grit do not enter the object.

through small openings into the connected glass forms through interconnecting tubulations (Figure 101).[314]



Figure 101 Vessels connected within kiln for bake-out, 2024.

During test illumination while processing I used a Tech22 transformer. This transformer elicited dramatic plasma behaviours due to relatively higher voltages, this elicits vibrant visual plasma-discharge effects and leaves a tingling and buzzing sensation when touching the work.[315] A combination of the unique morphology and the relatively higher

[314] I considered Strattman's "flow through" filling technique, Which I had seen demonstrated during a PAA event in Boston at Strattman's studio. Where the manifold configuration positions objects between pump and gas canisters, enabling more precise pressure reading.
Ristau, interview with author. Here Ristau described implementing this process of flow through processing, with capacitance manometers- pressure gauges, to read pressures at both ends of the system.

[315] I describe working with this transformer as spicy.

pressure of the gases within the forms caused these transformers (over time) to burn out, (disappointingly) recalling the short-lived virgin tubes of Geissler.



Figure 102 *Chambered Vessel Pair* (detail), 2024, plasma illumination, ionised gases within two interconnected blown glass chambers, transformer, base, 24 x 36 x 25 cm.

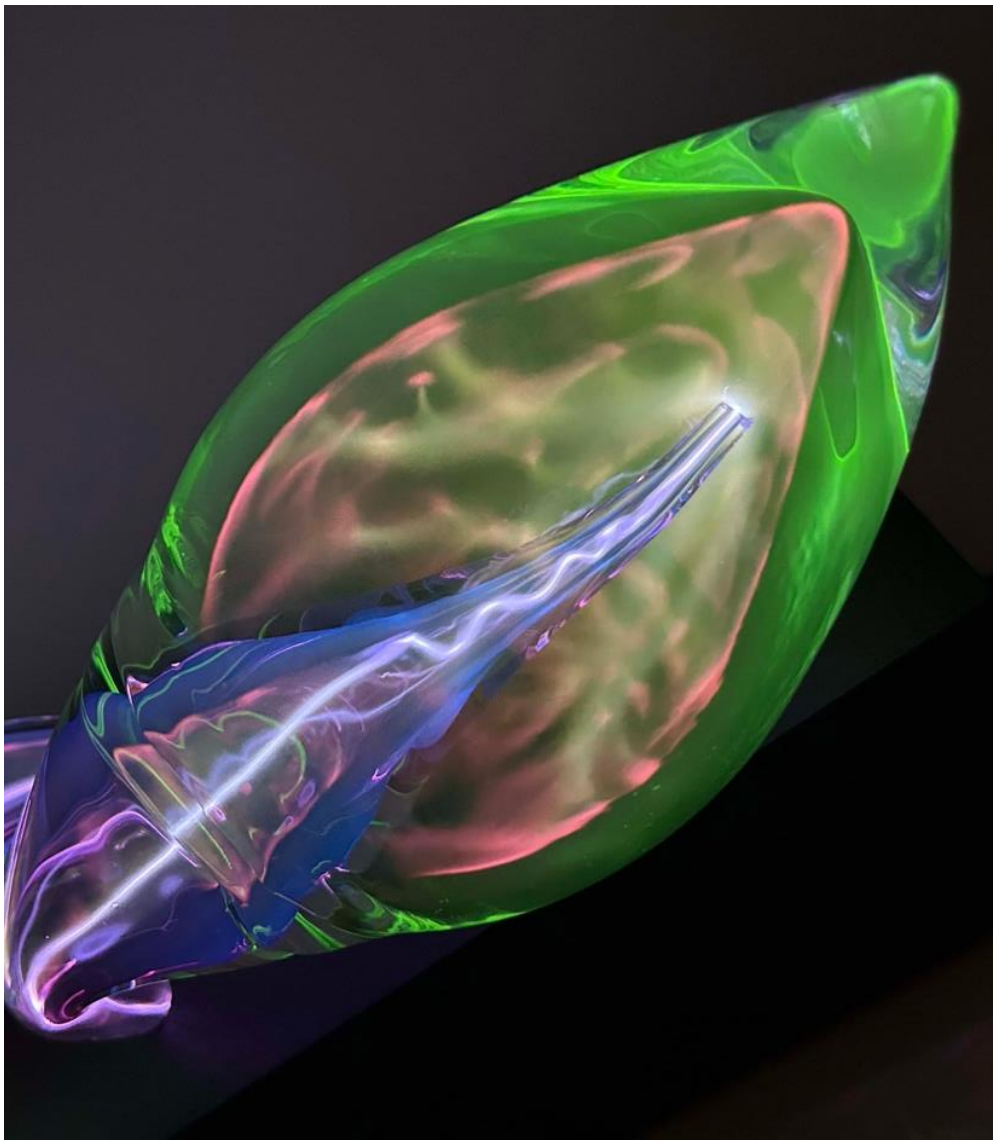


Figure 103 *Chambered Vessel Pair* (detail), 2024, plasma illumination ionised gases within two interconnected blown glass chambers, transformer, base, 23 x 44 x 13 cm.

When these plasma objects are filled with gas (80–120 Torr) and then ionised and excited, complex interior architectures produce diverse registers of light from glow discharge to arcs. Lightning-like expressions become spiralling lines dissipating into fluid dappling, spreading out from the point source (the smallest aperture within the

vessel) to splash against the walls of their interconnected chambers (Figure 102 and Figure 103).[316]



Figure 104 *Chambered Vessel Pair*, 2024, two interconnected blown glass chambers with ionised gases, transformer, base, installation view at Canberra Museum and Gallery. Photo by Brenton McGeachie.

By experimenting with the valve-like constrictions of these objects during glassblowing, these interconnecting forms influence plasma behaviours, where the excitation of the same gas mixture appears differently throughout the interior of the vessel. Narrow arcs of plasma diffractively spill into widened chambers, seemingly pulsing and trickling throughout these forms. I wonder if these objects make visible the Paschen curve, showing discharge behaviours that alter in relation to the distance from the power supply.[317] Again, I constructed and arranged these *Chambered Vessels* as paired objects, powered by transformers secured in their bases. Similar to the *Intra-twined*

[316] I ultimately installed the more reliable Neoniser21 during the *Materiality But Not As We Know It* exhibition at Canberra Museum and Gallery. I have more options now, of larger more reliable transformers produced by both Mudy Hepburn and Wayne Strattman with Jeff Feigen, which will be installed during the exhibition at The ANU School of Art and Design.
[317] Davis, Daniel. Interview by author. (28.02.2025) Transcript in Appendix [3]. Discussion on Paschen curves.

Vessels I wired up separate plasma drivers (Figure 104, Figure 105). When exhibited in darkened spaces, the interplay between the forms, as well as between their interconnected chambers, demonstrates how the plasma is affected by the glass vessels' construction.



Figure 105 *Chambered Vessel Pair*, 2024, two interconnected blown glass chambers with ionised gases, transformer, base, installation view at Canberra Museum and Gallery. Photo by Brenton McGeachie.

While working in the kiln with these objects, I repeatedly adjusted the glass tubes, heating them to accommodate connecting the asymmetric vessels for atmospheric manipulation. I observed how the connective tubes within the kiln appeared to have grown ever more vain-like (Figure 106). During testing for luminosity, the tubular networks illuminated and pulsed. These responsive and luminous actions became the impetus for the next body of work, *Entangled Vessels*, which is discussed in Chapter 4. The productive spaces within these *Chambered Vessels*, as well as connecting tubes between objects, demonstrated varied qualities of making visible connectivity and revealing relationships that directly informed the subsequent bodies of work.



Figure 106 Testing for illumination, vessels connected within kiln for bake-out, 2024.

3.7 Outcomes and Reflections



Figure 107 *Chambered Vessel* (work in progress, studio), 2024, blown glass, ionised gas. Photo by Cassie Abrahams.

Eliciting plasma illumination within blown glass requires critical engagement with materials. I initially framed my studio experience of plasma illumination as an interconnected process of leaks and tangles. With methods bleeding into each other and continuously influencing one another, I find resonance with Ingold's flux, which emphasises continuous flow and transformation.

A diffractive methodology allows me to attend non-linearly to the individual parts of the tripartite process. Historical contextualisation and contemporary science, approached through studio practice, assisted to conceptualise physical phenomena and their mechanisms at a studio and subatomic level. The reapplication of these insights influenced each object, this recombination created patterns of difference and interference that align with Haraway's methodology. This diffractive approach has altered my practice and the expected outcomes of my practice now make visible relationships and acknowledge waves of influence.

At this point of my candidature, I returned to my central research question: how might novel glassblowing techniques affect plasma's luminosity? By exploring complex internal architectures through adapted *Incalmo* techniques, I demonstrate distinct plasma behaviours within single vessels (Figure 107). Constricted areas concentrate illumination while wider chambers create softer glowing effects, making visible relationships between vessel geometry, glass colour and plasma. The progression from stylistic heart forms through to paired *Intra/twined* objects to complex *Chambered Vessels* demonstrates how decisions made in the moment of glassblowing influence subsequent plasma behaviours. This work makes visible how the vessel contributes to discharge effects, providing complex internal surface areas, apertures and volumes. Each blown-glass component builds upon previous studio insights creating ever more nuanced internal architectures.

I refined techniques for warm-welding electrodes by introducing a pre-heating stage, allowing electrodes to be welded onto increasingly complex blown glass vessels. I refer to traditions in which carefully crafted glass apparatus transforms invisible matter into perceptible phenomena. Systematic experimentation with gas mixtures provides direct evidence for how variations in atmospheric conditions and compositions affect plasma's visual properties. I interpret relationality at a subatomic scale, through Penning mix dynamics where trace amounts of different gases create complex interactive effects. By developing specialised mounting bases to house transformers and wired connections, I enable safe viewer-participant interaction while preserving plasma's electromagnetic sensitivity.

Gathering information from practitioner interviews and applying it to elucidate phenomena extends the vocabulary of plasma illumination, creating accessibility for makers, artists and curators. These interviews translate the equations of physics enabling me to consider techniques that may affect plasma's luminosity and reveal differing discharge effects. I hope the documentation of my leaky and tangled practice acts as a model of plasma practice that others might build upon. The object-based outcomes demonstrate how carefully crafted glass vessels with controlled atmospheric conditions transform invisible phenomena into perceptible experience through material engagement. The seemingly disparate yet interconnected aspects of this practice reinforce that objects are created in the productive space between maker, matter, and energy.

Chapter 4: *Entangled Vessels*—Manifold and Capacitance as sites of Circulation, Containment and Connectivity



Figure 108 *En/tangled* (detail), 2024, neon and argon plasma in borosilicate tubing. Photo by Cassie Abrahams.

This chapter provides an account of the development of my *Entangled Vessel*s; a series of illuminated glass sculptures made from manipulated borosilicate laboratory tubing. The artworks depart from the *Chambered Vessels* in technical approaches as well as in

their relationship to the manifold on which they are produced, my body, and the circulatory systems the forms reference (Figure 108).

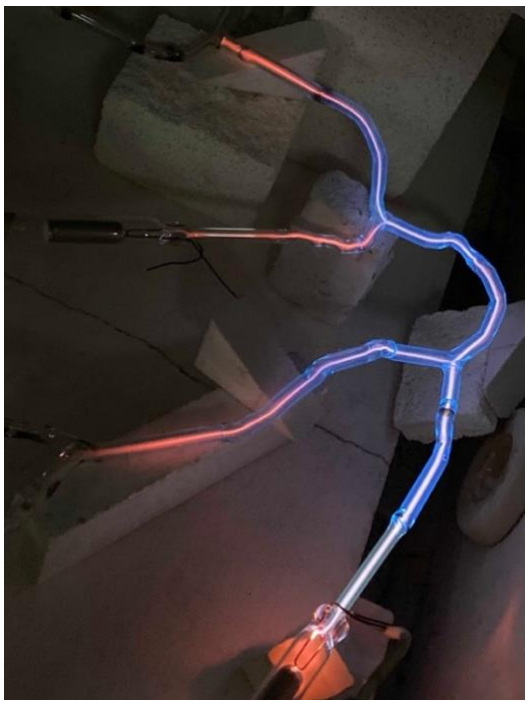
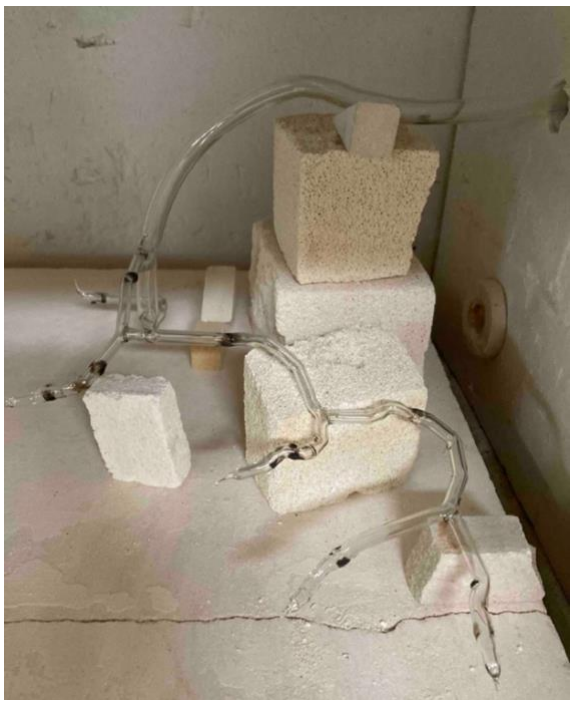
Reflecting upon the dual etymology of plasma, referring to both light and blood, my experiences with blood plasma donation during the COVID pandemic allowed me to practice connection. Despite our physical distance in that period, plasma donation played an essential connective role to others as a medical treatment. The experience of my blood leaving the body in tubular flows, through an extended circulatory process, informed my illuminated plasma tendrils as conduits of connectivity. The artworks also reference historic examples of circulatory diagrams to visualise circulatory flow.

While producing the previous *Chambered Vessels* series, I had become intrigued by the extended tubular connections between artwork and manifold (Figure 109). I experienced the manifold, the site of the second part of the tripartite process (of atmospheric manipulation), as a conduit of connection and an object its own right ((L): Figure 110 and

(R): Figure 111).



Figure 109 Vessels connected within kiln for bake-out, 2024.

(L): Figure 110 Illuminated manifold extension during atmospheric manipulation, 2023.

(R): Figure 111 Manifold extension after atmospheric manipulation of the glass vessels, 2023.

The deliberate shift in my making methodology recognises mentorship as a generative catalyst. The mentoring I experienced fostered experimentation in making, conceptualising, and observing plasma phenomena, revealing deeper material knowledge through the integration of adapted glassmaking methods and experiential learning. An artist residency at the Corning Museum of Glass enabled me to experiment with borosilicate laboratory glass in my sculpture for the first time, where I employed skills gained from interviews and mentorships. The new techniques and material understanding expanded my skills and influenced my decision making in developing the *Entangled Vessel* objects and installations.

Working with borosilicate glass allowed me to experiment with capacitive illumination, untethered from a direct power source. These glass vessels encase a low-pressure

neon glow when moved into the radiating field of a plasma transformer.[319] Borosilicate glass is lighter than furnace blown glass, permitting innovative installation strategies, such as suspending components within suspended installations. Borosilicate's robustness allows the viewer to handle components of the work without the risk of breakage, enabling responsive encounters. This chapter outlines the development of these objects and installations as physical systems, while Chapter 5 discusses their exhibition strategies and presentation to test the engagement and relational capacity of this medium.

4.1 Tubular Forms: From Vessel to Connecting Conduit

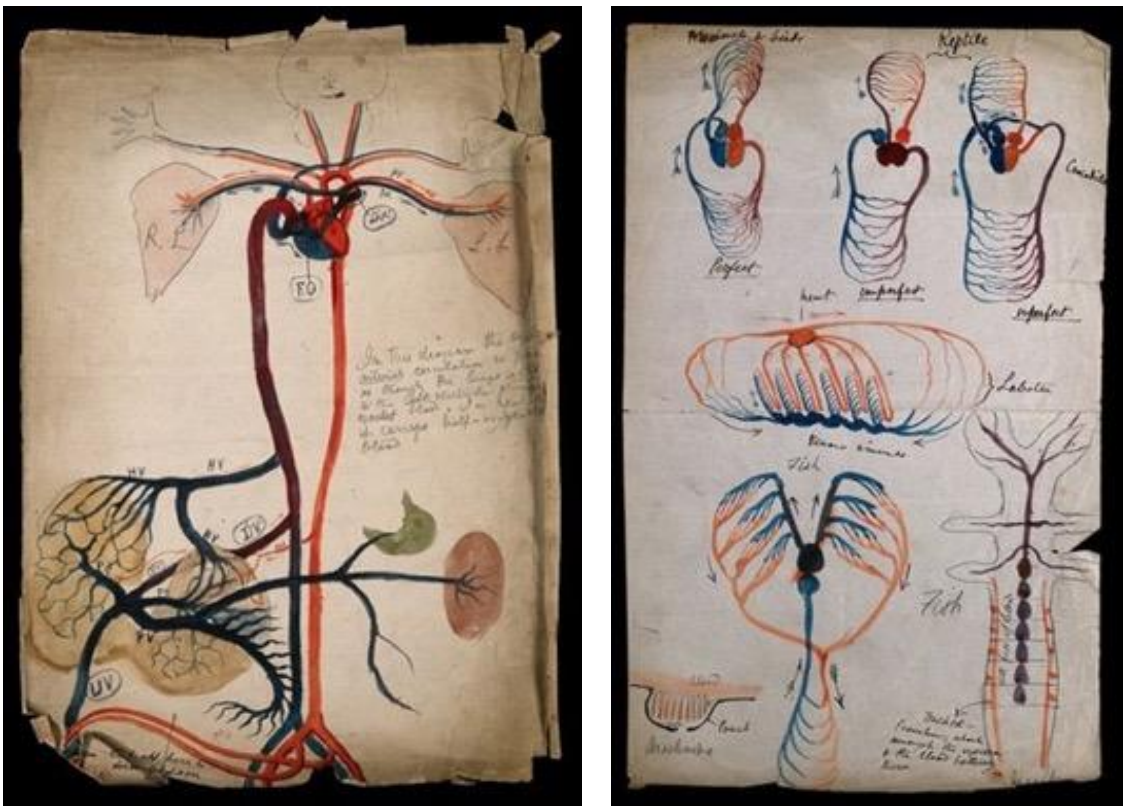


Figure 112 Watercolour Drawing by J.C. Whishaw, The Circulatory System: Diagram Showing the Heart, Arteries, Lungs and Major Organs, with a Cartoon-Style Face and Hands (ca. 1853).

Figure 113 Watercolour Drawing by J.C. Whishaw, Circulatory Systems: Seven Diagrams, Indicating the Heart and Circulatory Systems of Mammals, Birds, Reptiles, Lobsters, Fish and Arachnids (1852/1854)

[319] Burm, "Plasma." 25

Historical representations depicting blood flow influenced the development of Entangled Vessels. Illustrations of J. C. Whishaw's nineteenth-century watercolours are early examples of a circular, rather than a dendritic, system of circulation (Figure 112 and Figure 113).[320] Whishaw depicts vascular pathways, represented as an interconnected and capillaried loop, illustrating how blood travels through convoluted pathways in a tangled cycle of exchange. In contrast, a 1980s era educational model of *Transparent Woman* (Figure 114) reverted in some instances to representing the veins and arteries as dendritic forms with terminal ends, rather than interconnected circuits.[321]

[320] Wellcome Collect., "The Circulatory System." Wellcome Collect., "The Circulatory System."
[321] Wellcome Collect., "Being Human."
Transparent Woman (Anatomical Figure) Unknown designer, Plastic, wire, c.1980 (restored in 2006), Stiftung Deutsches Hygiene-Museum Dresden "Press the buttons on this 1980s anatomical model to see different organs light up around the body. The aim is to teach anatomy, but such figures can also reinforce ideas about what is 'normal'. There is no scope in a single model to represent differences – this is a generic 'woman' rather than an individual."



Figure 114 *Transparent Woman* (detail), Wellcome Collection, London, 2024, displayed in their permanent *Being Human* exhibition.

I began to interpret branching and dendritic structures in my work as illustrative of exchange and discharge, revealing the transfer from one system to another. I see the dendritic or branching form describing a meshing, an edge, a meeting, between root and earth, nerves and flesh, river and estuary, even between electricity and air in lightning. The iterative development of the *Entangled Vessels* combines branching structures with circular looping vessels, allowing me to visualise and test the actions of plasma's flow within variations of luminous borosilicate objects informed by circulation.

4.2 Plasmapheresis; Plasma, Blood, Content Warning

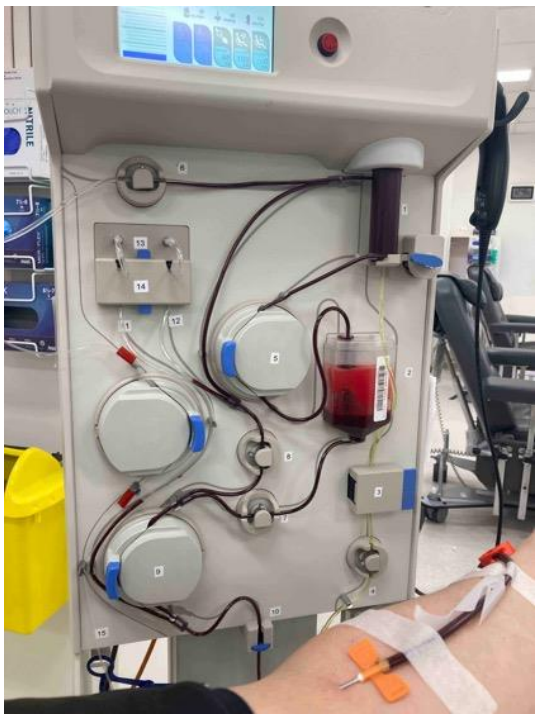
During the COVID-19 pandemic, my experience of donating blood plasma through plasmapheresis offered a powerful metaphor for connection at a distance.[322] This medical process involves a complex mechanical manifold that extracts blood, separates plasma, and returns red cells through the same needle (Figure 115 and Figure 116).[323] Shane Sergent and John Ashburn define plasmapheresis as follows:

> Plasmapheresis is a therapeutic intervention involving the extracorporeal removal, return, or exchange of blood plasma or its components. This procedure operates through either centrifugation or filtration using semipermeable membranes. Centrifugation separates blood components based on their specific gravities, while membrane plasma separation filters them by particle size. [324]

When donating blood plasma, I experience the boundary of my body as blurred, my circulation temporarily extended, as I notice the tubes that carry my blood, still warm, laying on top of my skin. These sensations test the edges between this machine's flexible fluid manifold and me. This medical machine, with its flexible manifold components, separates my apple-juice-coloured plasma from my blood before returning it, isolating, separating, and recombining otherwise contained matter. The action of witnessing my blood flow through tubes, filtering, returning and redistributing my plasma, assisted me in visualising circulation as a metaphor for interconnectivity within my practice.

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[322] As an artist, plasma donation was one of the few necessary and useful tasks that I could engage in during the Covid lockdowns.
[323] "What Is Plasma? | Lifeblood." Accessed December 20, 2024. "Return" is the term used during plasma donation to describe when the flow changes direction, back into the body during a Lifeblood plasma donation. Toward the end of the process, the return also contains extra fluids to compensate for the donation.
[324] Sergent and Ashurst, "Plasmapheresis."



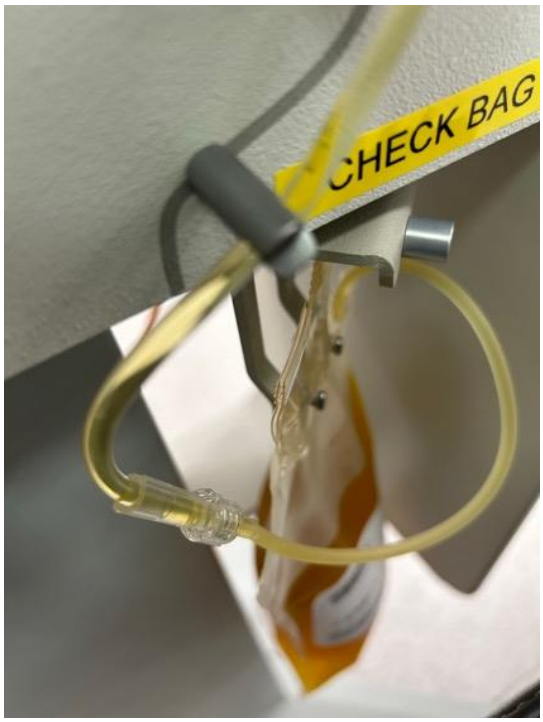


Figure 115 Plasmapheresis Lifeblood, 2023. My blood being filtered before its return into my body, Canberra

Figure 116 Plasmapheresis donation, 2023 Apple juice coloured plasma dripping into the donation bag. Lifeblood, Canberra

4.3 Manifold as a Flexible System: Ed Kirshner's Method

My experiences donating blood plasma, where my body connects to a flexible fluid manifold during plasmapheresis, resonate with the innovative flexible manifold that Kirshner employs for plasma illumination. Within a luminous plasma practice, the manifold mediates the second tripartite process: glass preparation for atmospheric manipulation. Once the glass vessel is sealed onto the manifold, heating the vessel accelerates gas molecules, enabling the vacuum to remove atmospheric impurities and to establish very low pressures.[325] Kirshner's innovations combine a rigid borosilicate glass manifold, including metal valves and gauges, with flexible medical-

[325] Feigen, Interview with the author. The heat increases molecular activity which can more easily be sucked out via the vacuum. An alternative method employed by Feigen uses getters. These are specialised sponge like metals, that once activated by heat, draw impurities into their surface.

grade silicone tubing. These flexible connections allow glass objects to attach to the manifold without the frustrations of welding intricate glass tubulations together and avoiding re-contamination from exhaled air in the blow hose.

During our interview, Kirshner detailed his signature processes. He begins by assembling vessels in a kiln using low-fired enamels as “solder” rather than direct heat welding, to achieve vacuum-tight seals around joins and electrodes. Once constructed, the vessel is cleaned using the oven bake-out process. The vessels are then cooled and backfilled to atmospheric pressure with argon gas, temporarily sealed with a silicone plug for a future session of introducing non-reactive gases.

When refilling these objects, he attaches a flexible silicone connection between the tubulated glass object and his manifold. Kirshner emphasised that annealing temperatures should NOT be attained while pumping out the interior of the vessel, as this can create stress within the glass vessel. Rather than working inside the kiln, the object is placed on a non-conductive surface beside the manifold. The surface is also fireproof, as a hot torch is needed later in the process to seal off the glass tubulation from the manifold. This innovative process allows Kirshner to “tune” his plasma object with its transformer, avoiding interference from the kiln's metal (Figure 117). [326] Working outside the kiln greatly reduces electromagnetic shielding from the conductive surfaces, which would interfere with the transformer and alter the object’s delicate luminosity. Considering Kirshner’s methods helped me to understand how the Faraday cage effect shields or alters the distribution of charge, which affects the behaviours of the plasma within a vessel within a metallic kiln (Figure 117).

[326] Kirshner, interview with the author. Regarding Faraday cages, filling outside the kiln limits this effect, which influences the plasmas subtle luminous effects. The kiln behaves as metallic membrane which attracts and distributes charge differently.

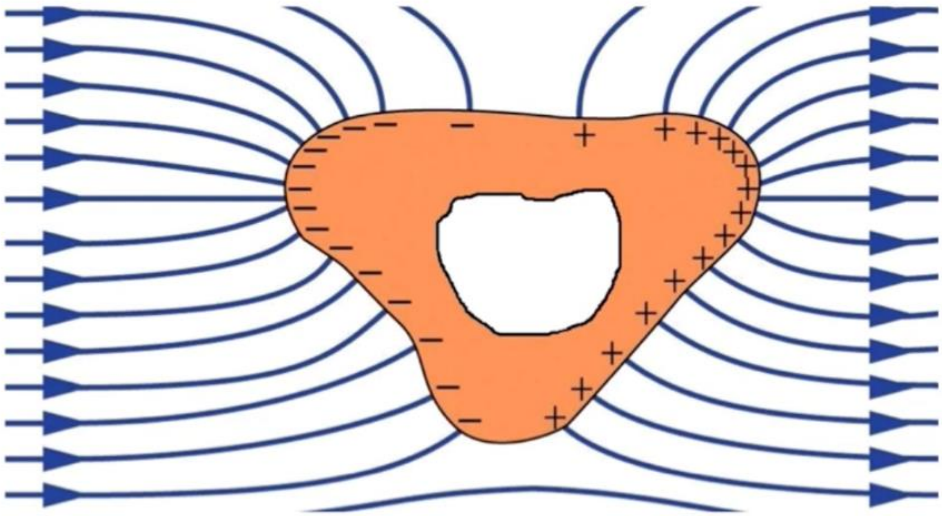


Figure 117 *Faraday Cage*. Video Still: visualising distribution of electric charge (+-) influenced by a conducting shell or Faraday cage, or kiln. UNSW physics video, time stamp 1:50



Figure 118 Ed Kirshner with Bernd Weinmayer and Jaime Guerrero, *Vase with a Bowl of Chaos* (detail), n.d. constructed blown glass, ionised gases, transformer.

Kirshner describes this intricate process of adjusting the gas mixtures and testing by adjusting the connected transformer, as "tuning the forms until they 'click'" to achieve

effects informed by his interest in video feedback interference and his fascination with chaos theory.[327] This “click” denotes the moment when the signature bifurcating tendrils of plasma appear within the internal rims of his forms (Figure 118).[328] Departing from the traditional rigid borosilicate manifold, Kirshner’s innovations highlight the manifold's centrality as the site for creating specific conditions for his delicately tuned plasma illumination and how the materials used influence the plasma behaviours. Although Kirshner's flexible manifold innovation resonates with my experience of plasmapheresis, my current investigation focuses on exploring the glass manifold as a contributor and as part of the *Entangled Vessels*. During this chapter, I focus attention on developing skills to use borosilicate glass, which I selected for its robustness and because it offers a conceptual link to the manifold as a conduit for plasma illumination.

4.4 Borosilicate Tubing and Texture with Peter Minson

The properties of borosilicate glass, characterised by thermal resistance and a lower COE (30–33), create unique possibilities for developing experimental plasma physical systems.[329] Interviewee Lemaire’s approach to using borosilicate glass highlights its potential for endless reuse and repair, an essential consideration in a more sustainable practice.[330] Unfortunately, in Australia, scientific glassblowing is a diminishing trade. The history of these collected tubes creates another link to scientific and laboratory methods. By collecting and repurposing glass from dismantled scientific labs, I also harness conceptual and material continuity between scientific and artistic applications while reducing environmental impact.[331] I have secured borosilicate glass from laboratories and suppliers that are closing; this form of recycling involves substantial

[327] Kirshner, interview with the author.
[328] https://www.aurorasculpture.com/plasma-videos?pgid=jngi9b7n-4c16c580-7508-449e-849c-602c11e7ae31
[329] Crook & Fishman, *The Neon Engineers Notebook*. 226
[330] Lemaire, interview with the author.
[331] Austroads, “Increasing the Use of Recycled Glass in Transport Infrastructure.” Sadly, in Australia, glass for recycling essentially ends up as road base.

cleaning, along with rigorously testing the compatibility of glass before joining and welding glass tubes together.

Borosilicate is manipulated in a process called flameworking, using specialised torches with extremely hot, blue-white flames that combine propane with oxygen. During heating, the glass becomes plastic as it brightens to an orange hue. This heated orange spectrum (a phenomenon called black-body radiation) is central to a glassblower's experience, as makers read the heat through this orange spectrum for the plasticity it generates within the material.[332] Conversely, glass is a poor conductor of heat.[333] When reheating tubes or rods of glass during flameworking, one can hold the glass a short distance away from the hot flame, allowing for precise handling that enables complex laboratory apparatus or sculptural work to be realised.

Despite borosilicate's superior thermal shock resistance, this glass is more susceptible to trapping small bubbles or pinholes. Great attention must be paid to maintain vacuum integrity across multiple connection points. Dust and cracks (or small imperfections from breaking tubing using a diamond or tungsten file) can introduce contaminants that become points of weakness, forming pinhole leaks that compromise atmospheric manipulation.[334]

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[332] BBC, "BBC Radio 4 - In Our Time, The Photon." Susan Cartwright
Senior Lecturer in Physics and Astronomy at the University of Sheffield, with Melvin Bragg. 12 February 2015. Audio. 08:11 Where black body radiation is described.
[333] Klemens, "The Thermal Conductivity of Dielectric Solids at Low Temperatures (Theoretical)." 119
[334] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 70 Flame worker, artist and educator Colton Baker; https://www.instagram.com/sqwishyglass/ Squishy; introduced me to a scientific glassblowing join, during my residency at Corning Museum of Glass. Called the Jesus weld, where rather than making a hole and welding a tube to the hole, instead thinned out bubble sections can be heated and brought together, when the whole join is heated, the slight increase to the diameter of the tube from positive air pressure, air is inserted, thins out the bubble section of the connecting membrane, causing the membrane to stretch and peel open, creating a vacuum tight tubular join.

Although I have transferable skills from glassblowing, I am not trained in flameworking borosilicate. I experience working with this tubular form of glass as more akin to welding or drawing, as the tubular glass can be joined and bent in space. It can also be manipulated with less urgency than I am accustomed to with glassblowing. Working with selected mentors during developmental field work expanded my technical skills, with their individual approaches influencing my practice.

Multigenerational flame-worker Peter Minson introduced me to altering tube thickness, surface texture, and colour application. Working at a traditional flameworking bench, he works seated in front of a mounted torch ((L) Figure 119). Together we created textured surfaces by rolling heated sections in powdered and fritted glass. We added trails of glass onto the surface, thickening the glass walls unevenly but maintaining smooth interior surfaces ((L) Figure 119(R) Figure 120 and Figure 121).





(L) Figure 119 Peter Minson demonstrates techniques to thicken and alter the glass walls while ensuring no folds or undercuts, 2023. Binalong Australia.

(R) Figure 120 Detail of sections of uneven thicknesses in an inflated borosilicate tube.

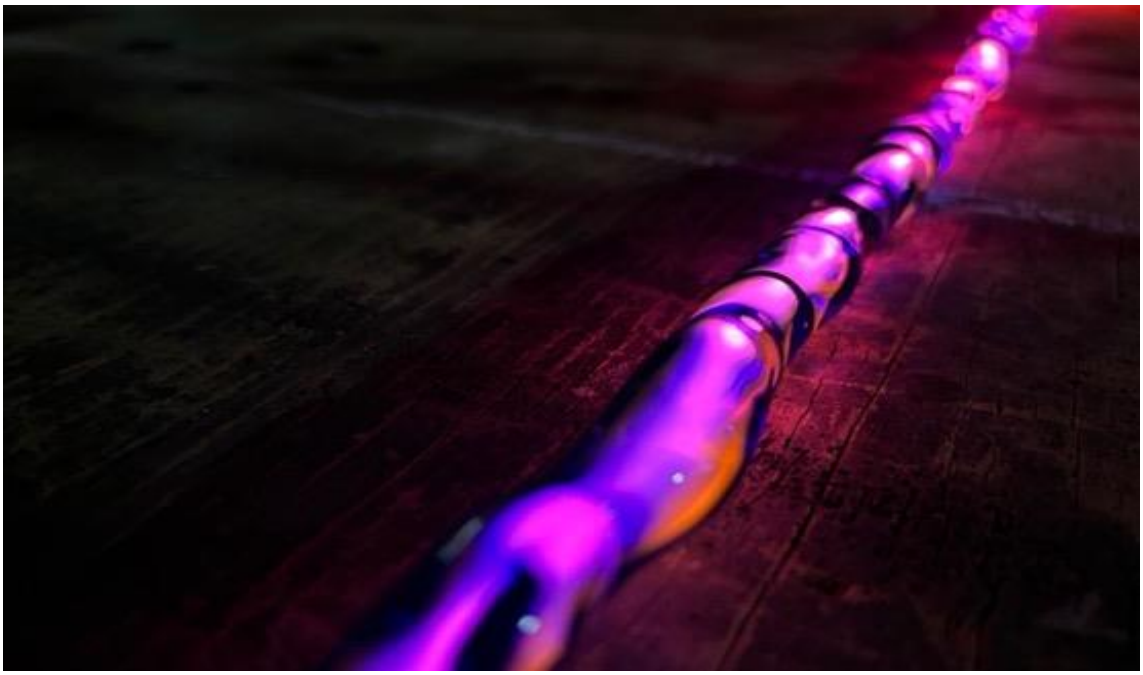


Figure 121 Neon fill (25 Torr) 2023 inside of blue borosilicate glass tubing manipulated by heat.

4.5 Bridging Techniques with Steven Cole: Creating Three-Dimensional Conduits



Figure 122 Borosilicate tubing organic bridging welds, 2022.

A key technical development required for the development of the *Entangled Vessels* was to achieve junctions or bridging joins, enabling a tube to bifurcate and rejoin the vessel elsewhere. I imagined how these tangled geometries, once luminous, would encourage the plasma illumination to take alternate paths depending on the position of the observer. I envisioned that these joins may appear as if they had grown, allowing me to realise complex vascular tangled objects (Figure 122). The difficulty in achieving these joins lies in maintaining vacuum integrity across complex interconnecting welds. The examples of scientific glassblower and plasma artists Bernt Weinmeyer and Eric Franklin exploit perfect joins, allowing the plasma matter and its light to follow varied pathways within a single object ((L): Figure 123) and ((R): Figure 124) .[335] My intention differs from these exemplars, as I imagined suspended vascular tangles in installations, harnessing the glow of capacitive illumination within moveable components, an installation method I return to in Chapter 5.

[335] "Weinmayer Glasarbeiten | Wir Machen Kunst Aus Glas," accessed September 27, 2025, https://weinmayer.at/en/. "Iris van Herpen | Weinmayer Glasarbeiten."
A. Moret, "Eric Franklin: The Body Electric," *Installation Magazine*, April 9, 2013, https://installationmag.com/eric-franklin-the-body-electric/.





(L): Figure 123 Bernt Weinmeyer and Iris van Herpen collaboration, *dimensionsim*, 2020–2021, 80 x 90 x 80 cm. Photo by David Uzochukw.

(R): Figure 124 Eric Franklin, *An Anatomical Study of the Human Body Considering the Mind and Body as One Entity*, 2006–2008, flameworked borosilicate glass, krypton, wood, 198.12 x 91.44 x 60.96 cm, Roberts Family Fine Art Collection. Photo by Brad Carlile.

Most borosilicate torches require heat generated from a hotter gas and oxygen mix. In contrast to using the bench-based flameworking approach, I had found I could gently bend the borosilicate tubing standing over a ribbon burner, a torch from the neon trade ((L): Figure 125(R): Figure 126). These torches burn gas with air and are designed to bend neon tubing (soft glass). I would cool those bent sections before cutting them up to weld and join them together, creating tangled vascular networks. My intention was to achieve yielding or flowing lines, building shapes, through addition and distortion, rather than using the neon practice of following a template to a predetermined pattern.

I iteratively joined, constructing interconnected components, before annealing to relieve any thermal stress at their welds.[336]





(L): Figure 125 Softening borosilicate tubing, 2024. Photo by Cassie Abrahams.

(R): Figure 126 Bending borosilicate tubing, 2024 video still WEFT Productions.

Working with second-generation neon mentor Steven Cole in Melbourne, I tested techniques for creating complex organic junctions in glass. Although Cole works predominantly with soft glass, his enthusiasm to assist me to push my boundaries saw us adapting neon traditions for splicing and joining using borosilicate glass.[337] The process involved carefully heating tube sections, creating controlled bubbles that are subsequently punctured with a hot torch, leaving mounded openings. By cutting, measuring and bending sections we would bridge two holes, to create T-junctions and bridges. This joining process relies on simultaneously heating the multiple glass rims that are pressed together ((L): Figure 127 (R): Figure 128). By heating four rims concurrently complex tubular bridges can be pressed together and sealed.

[336] *Gary S. Coyne The Laboratory Companion A Practical Guide To Materials, Equipment, And Technique Wiley Interscience (2005)*. 488 "After placing the entire piece in the oven, bring the oven's temperature up to 565°C, hold that temperature for about 15 minutes, and turn the oven off. It is best to leave the piece in the oven until it reaches room temperature, at least three to four hours or simply overnight."
[337] Soft glass, soda lime, 96 COE compatible with most studio furnace glass.





(L): Figure 127 1&2 Cole's diagrams for preparing join by blowing out bubbles, 2023.

(R): Figure 128 Sketch of working with Cole to refine branching and bridging joins, 2023.

Cole describes the next part of this process as "breathing the glass welds together." A flexible blow hose is attached to the form, through which the maker can insert controlled air through the tube while heating the joins.[338] The glass tube shrinks inward and thickens when heated with the torch, then one can then gently breathe into the glass (through the connected blow-hose) to re-inflate the softened and thickening tube to the desired diameter. When joining glass, the aim is to maintain regular tube diameter whilst ensuring that both tubes flow or join without distorting the shape or introducing stress-creating undercuts of glass. This attention to detail creates homogenous, smooth interior surfaces, avoiding irregularities which compromise the vacuum integrity, essential for plasma illumination.

Cole shared another skill for removing pieces from the manifold, demonstrating his generosity and material knowledge. With careful preparation, he applies the principle

[338] Cole demonstrated and expressed this "breathing together" during intensive periods of mentorship in 2022 and 2023.

that an electrode can be “nipped off” or removed after the tripartite process of atmospheric manipulation. Once a vacuum tube is reheated with a torch, the propensity is for the glass to suck inward on itself due to the low internal atmospheric pressure.[339] Cognisant that I wanted the electrodes removed after the piece was tested for luminosity, Cole prepared a section of tubing with a slightly narrower diameter (yet with a thicker wall thickness) allowing for this section or electrode to be removed (Figure 129).[340] This method of nipping off enabled me to develop electrodeless objects for installations, creating capacitively luminous forms.



Figure 129 Steven Cole, 2023. Showing a tubular constriction (to the left) allows for the removal of electrode after atmospheric manipulation and testing for light. The narrower sections of tubing can then be heated to remove the electrode from the component.

4.6 Masterclass at Strattman Design and Corning residency

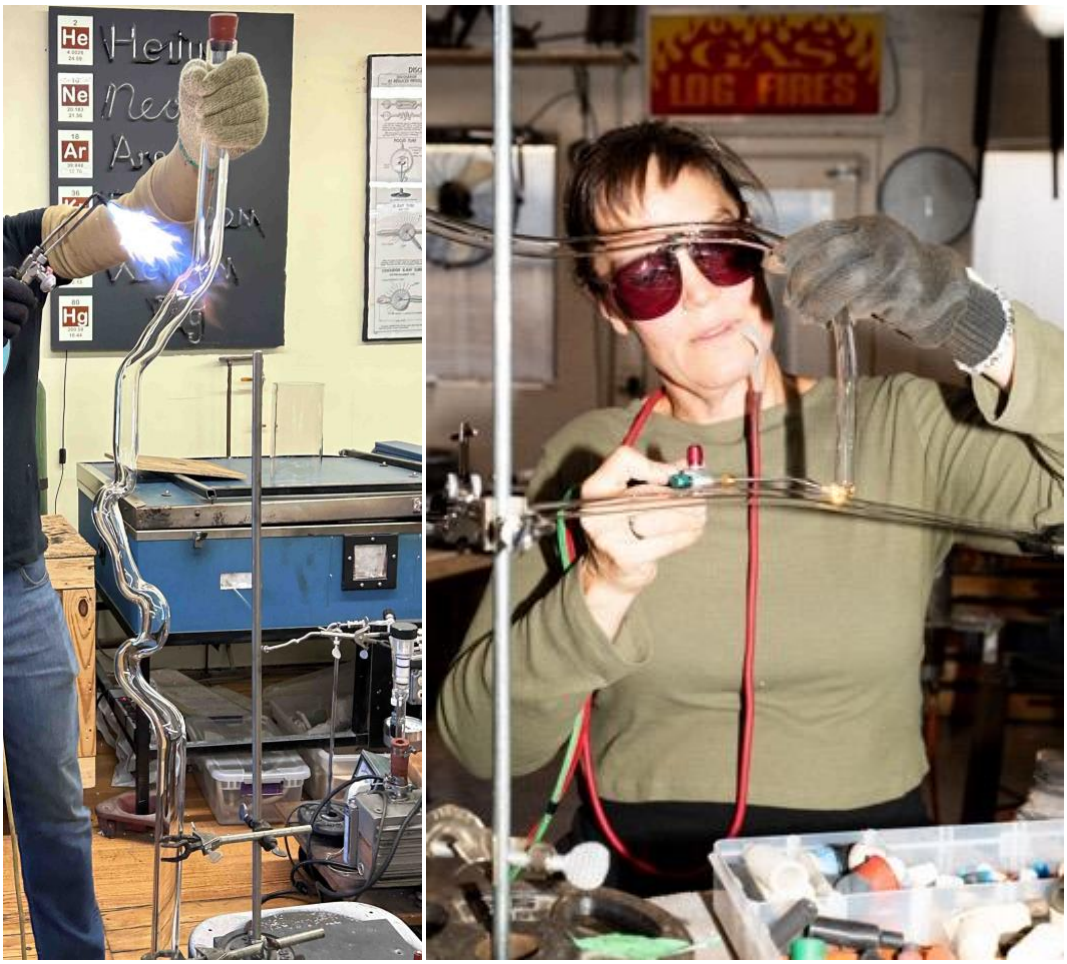
Attending an immersive masterclass with Strattman redefined my understanding of plasma through technical, historical and conceptual mentoring, alongside targeted skill development using borosilicate glass.[341] In this section, I will expand upon the glass manipulation techniques Strattman introduced to me. I will return later in this chapter

[339] Nipping off, describes the moment when a tube is removed from the manifold using a torch to heat and seal off the object.
[340] I was able to process my capacitive strand for installation work using this nipping off technique.
[341] “Workshops.” Essentially during this class I had the additional insights Feigen, providing me with rich technical and material insights, imparting profound practical knowledge of electrical phenomena.

to discuss the concepts and tests he and co-participant and interviewee Feigen shared, which assisted my visualisation of electrical fields for use in capacitive illumination projects.

Strattman's standing approach to glass manipulation hybridises glassblowing, flameworking, and scientific glass-forming methodologies. When creating sculptural objects, we secured the glass in counterweighted retort stands with clamps ((L): Figure 130(R): Figure 131). Bringing the torch to the material alters the relationship between body, tool, and glass. Like other materials, when heated, borosilicate glass pools and tends to drip, thus the glass is periodically reoriented to accommodate the influence of gravity. When a maker is working in an upright standing position with the work secured in clamps, one hand can support and manipulate the glass above the heated section while the other hand operates the torch. This method establishes a direct relationship between maker and material, where material and body are in flux.[342] While working, I became attentive to the movement of the material, allowing the tubes to yield, accommodating a morphology of venous structures. Through repeating these skills, this form of manipulation, of drawing with the glass in space, I experienced the tactile feedback of the material softening; my body informs outcomes through material engagement rather than purely visual prompts. This heightened awareness of making as a relationship with materials developed my understanding that process and phenomena are sites of material and energetic interaction.

[342] Ingold, *Bringing Things Back to Life*, 8.



(L): Figure 130 Feigen in Strattman's workshop 9-12 February 2023. standing manipulation of a glass tube, using a hand-held torch, during masterclass.

(R): Figure 131 Welding a join with specialised miniature propane and oxygen (Smith Little) torch for precision heating, 2024. Photo by Cassie Abrahams.

My artist residency at the Corning Museum of Glass, begun directly after the Strattman masterclass, providing an intensive period of implementing the techniques introduced during my mentorship.[343] Experimentation accelerated the evolution of my tubular vessel forms during the residency. As I iteratively bent and manipulated borosilicate glass, reflexive, knot-like forms became tangled loops, suggestive of circulatory systems. I worked daily over the torch, teasing out movement and irregularity from tubes of assorted diameters. I experimented with bifurcating and connective

[343] "Harriet Schwarzrock | Corning Museum of Glass."

expressions of forms. Möbius-like geometries initially emerged; these conceptually single-sided forms, when produced from a tube, further challenge perception of what is inside or outside. I applied coloured borosilicate glass, melted on the surface, like drawing with a hot crayon while flameworking (Figure 132 and (L): Figure 133).[344] I implemented, manipulated, and adapted tubular joining, shunting and bypassing strategies- suggestive of flow, exchange and interconnection. The objects I produced were informed by circulatory metaphors heightened by my practice of blood plasma donation. Manipulating these looping and interconnecting pathways began to echo the manifold, as the connecting apparatus in the tripartite process of plasma illumination ((R): Figure 134).



Figure 132 Corning Artist residency work in progress, red borosilicate glass melted into the surface of the manipulated glass tubing, 2023.

[344] *Etymonline*, "Mobius - Etymology, Origin & Meaning of the Name," accessed October 5, 2025, https://www.etymonline.com/word/Mobius.



(L): Figure 133 Borosilicate glass mobius (work in progress), Corning Museum of Glass Studio, 2023.

(R): Figure 134 Borosilicate work in progress at the Corning Museum of Glass Studio, 2023. Photo by Allison Burrell.

4.7 Manifold as Conduit

After the Corning residency, I prepared borosilicate vessels for plasma illumination and atmospheric manipulation, with the manifold mediating this complex process (Figure 135 and Figure 136).[345] The manifold's interconnected arrangement of tubes and gauges, creates multiple zones separatable by valves, capable of interconnecting yet separating distinct processes from one another, affecting the outcomes through recombination.

[345] This follows the traditional kiln processing methods, rather than implementing the flexible tubular processing of Kirshner.



Figure 135 Manifold iteration number two, 2023; with borosilicate glass welded onto the manifold extension inside the kiln, connected via a hole that perforates the side of the kiln. (The kiln door is wide open out of the image on right.)

As the tubular networks I produced became more elongated and complex, I relocated my manifold equipment beside a larger kiln to accommodate the bake-out of these components (Figure 136).[346] Manifold redesign responded to my increasing understanding of the tripartite process, demonstrates how seemingly separate components and activities influence and interact within the physical system's ongoing performance.[347]

[346] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 75
[347] Karen Barad, Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning. Duke University Press, 2007. https://doi.org/10.1515/9780822388128.



Figure 136 Preparing to remove objects from the manifold, with Pearl, 2024.

Barad's "agential realism" informs my understanding of these multiple sites of interaction at the manifold, positioning matter as iterative interactivity rather than fixed substance. In their book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, Barad discusses the seminal quantum mechanical concepts articulated by Niels Bohr.[348] Bohr described how, contrary to the understanding of the objectivity of the scientific method, the interactions between the observer and matter definitively affect an experiment. Extending Bohr's observation, Barad's hypothesis reveals that all contributing agents are positioned within an "intra-active" relationship, in which they influence and thus contribute to phenomena.[349] I began to understand my manifold as not simply a neutral tool but an active participant in creating plasma phenomena. Reiterated through the interviews, the influence of the maker affects the outcomes of the plasma illumination through varied treatment of the

[348] Barad, *Meeting the Universe Halfway*, 114.
[349] Barad, *Meeting the Universe Halfway*, 97.

materials, equipment and methods within the tripartite process. My understanding of eliciting plasma appreciates this interactive and intra-active nature of phenomena, which in this practice is influenced by manifold, matter, maker and energy.[350]

Employing Barad's agential realist reading of an apparatus, where "apparatuses are the material conditions of possibility and impossibility of mattering; they enact what matters and what is excluded from mattering", has affirmed and extended my experience of plasma objects as extensions of the manifold.[351] The resulting objects are, and were, sections of the manifold through which their atmosphere was altered. Similarly, the effects of the maker, as well as those of the viewer-participant, assert their influence with the luminous plasma behaviours of this extended physical system, in both obvious and subtle ways.[352] This framing of the manifold with indistinct boundaries provided me with physical experience through which I could momentarily grasp the ongoing influences contributing to plasma illumination phenomena.

Barad's analysis of Bohr and Rovelli's interpretation of Heisenberg reiterate that the experimenter is no longer a distant or impartial observer of quantum phenomena but also becomes part of their dynamics. This understanding has profoundly influenced my practice. Within an arts practice, my role as maker in flux with materials is evident. By extension, my understanding of the viewer has shifted from impartial participant to active and agentic viewer-participant who influences the ongoing behavioural quality of luminosity within these objects. My experimental and experiential practice extends into relational engagement, where viewer-participants' presence, interaction and proximity visibly affect the object's luminosity.

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[350] I use the term interactive here celebrating Kamila Mróz Thesis and the more entangled description Intra-active used by Barad, *Meeting the Universe Halfway*.
[350] Mróz, "Interactive Light – the Use of Plasma Discharge in Noble Gases as a Medium of Applied Art."
[351] Barad, *Meeting the Universe Halfway,* 148.
[352] Barad, "Diffracting Diffraction," 168.

4.8 Capacitive Illumination and Voltage Differential

The objects I create are made luminous through electromagnetic activation; for this, I am reliant upon specialised transformers. Capacitive illumination describes the propensity of a gas-discharge object, encasing very low atmospheric pressures of gases, to glow parasitically in the powered field of a specialised transformer (Figure 137).[353] This glowing illumination can be elicited through proximity to another plasma vessel or via a specially fabricated capacitive base. Rather than adopting the term "parasitic," I use "symbiotic" to describe this luminous relationship.

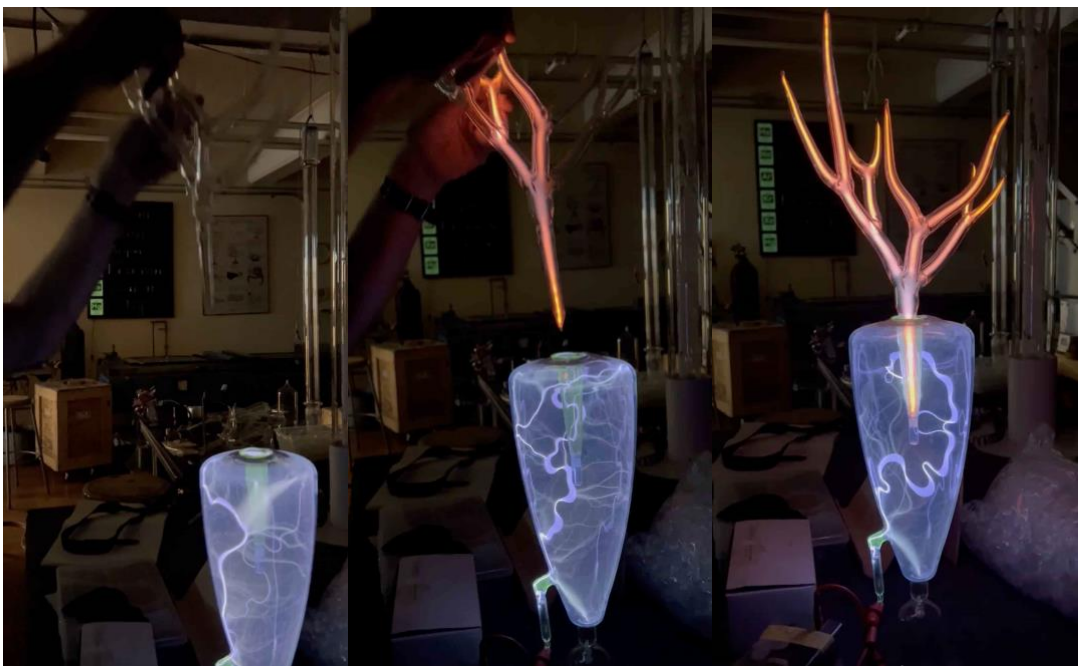


Figure 137 Video stills of capacitive illumination demonstration at Strattman's studio, 2023, featuring his artwork series *Emergent*. Bringing the neon element into the electromagnetic field (generated by the transformer and extended by the powered piece) elicits plasma excitation in the capacitively coupled or symbiotic component.

[353] McAluney, interview with the author.
Parasitic was a term that McAluney spoke of during our interview to describe a capacitive plasma vessel becoming luminous within the powered electro-magnetic field of a transformer, or a vessel attached to a transformer.

The masterclass that I attended with Strattman was tailored for Feigen and me to expand our practices, and I experienced it as a totally immersive learning environment.[354] Considering what role proximity plays in influencing the behaviours of plasma illumination required a better understanding of the role of voltage differential. We discussed the application of high-voltage electrical energy in eliciting luminosity, and Feigen emphasised the importance of understanding plasma as a radiating phenomenon rather than simply calling it light.[355] Radiation is a key concept for understanding and employing capacitive illumination, where prepared plasma tubes become luminous when brought into electromagnetic fields.

We experimented with directly powering a vessel by attaching its electrode to a transformer; this vessel extends the transformer's field due to the low-pressure conditions within it.[356] When a capacitive element is brought close to the connected tube, it illuminates at a further distance from the transformer. As Strattman states:

> Because high-frequency power supplies produce high voltages, their field can capacitively couple to other conductors and other gas-filled tubes around them. ... a sculpture with separate tubes—one directly energized, and a completely separate one with no electrode, lighting up because it's within the high voltage field. This near-field lighting ability drops off quickly with distance. [357]

I began to visualise the low-pressure space within the capacitive vessel as a path of least resistance for potential gradients to flow. As low-pressure gases ionise more easily, sufficient radiating energy exists within that space, to excite the gas into luminous plasma while voltage differential attempts to equalise.

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[354] "Workshops Strattman 2023." With studio assistant Cary Rapaport and Jeff Feigen. Feigen also invited me to his studio, making visible other studio plasma practices.
[355] Butler et al., "Nomenclature, Symbols, Units and Their Usage in Spectrochemical Analysis," 1456.
[356] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 125-128.
[357] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 127.

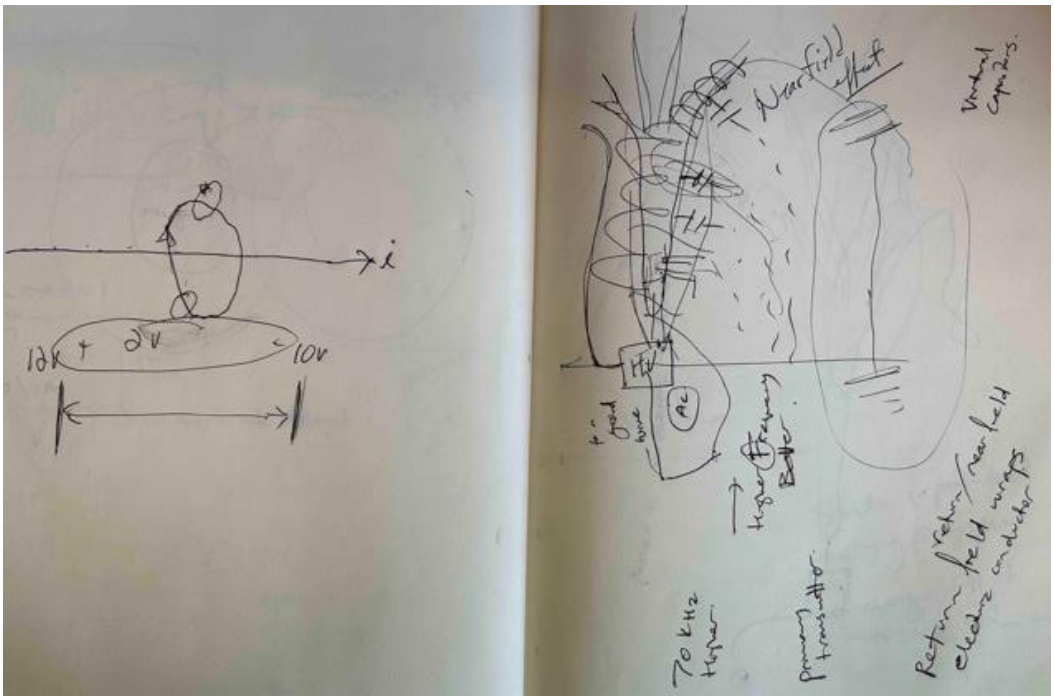


Figure 138 A Strattman assisted sketch (2023) during workshop.

While discussing capacitively illuminated configurations, I hurriedly sketched (with Strattman's tweaks added), allowing me to visualise interconnected electrical concepts within these high-voltage fields, where changing electrical conditions and near-field lighting effects influence capacitive plasma illumination (Figure 138).[358] Feigen and I interacted with Strattman's artworks that employ capacitive lighting, making visible the physical principles of voltage differential and the near-field effect. Interacting with these components evidences the sophisticated borosilicate fabrication techniques used to achieve the precise finish to his artworks. They embody the capacitive principles through objects rather than theory (Figure 137). These visual and sensory examples of mentoring and experimenting with the artwork demonstrated

[358] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*.127 Strattman "shows a sculpture with separate tubes tubes—one directly energized, and a completely separate one with no electrode, lighting up because it's within the high-voltage field. This near-field lighting ability drops off quickly with distance."

complex principles, allowing me to integrate explanations more effectively in my practice.

4.9 Fields of Potential

Despite the material solidity of glass, the physical boundaries of the vessel do not hinder the electromagnetic field in a capacitively luminous object. Within my work, the voltage gradients of a transformer's electromagnetic field can be made visible through capacitively illuminating a plasma vessel. Artist and researcher Dr Emily Morandini's PhD thesis *Modulating Earth and Sky: Extended Electronic Circuits in the Arts* provides a poetic material framework for creating, illustrating, and activating circuits.[359] Her research demonstrates how electronic circuits and systems extend beyond their earthly and material components to include surrounding electromagnetic fields, making visible (and audible) typically imperceptible electromagnetic relationships. Her concept sketch inspired by Richard Feynman's *Lectures on Physics* (Figure 139) illustrates data on the distortions of electromagnetic conditions around an earthed conductor.

[359] Emily Morandini, "Modulating Earth and Sky: Extended Electronic Circuits in the Arts," PhD dissertation, University of New South Wales, accessed January 5, 2025, https://unsworks.unsw.edu.au/entities/publication/09536840-341d-4206-9f57-70c8b379b551.

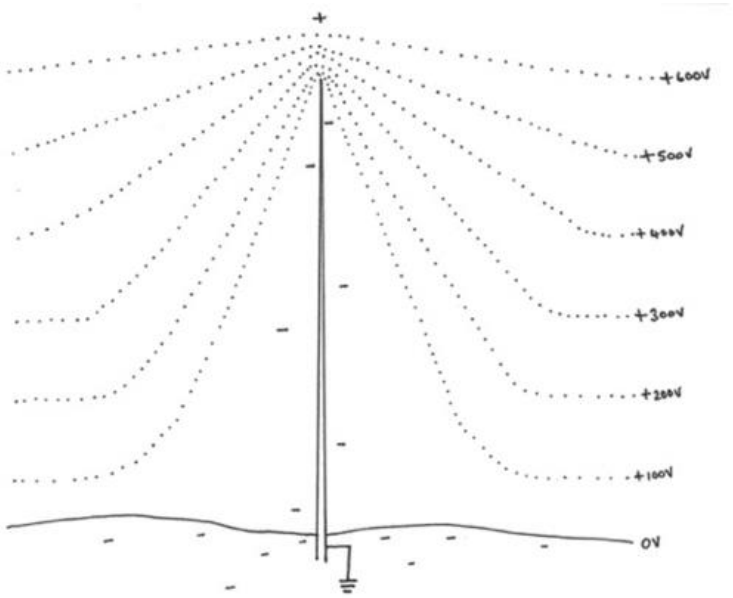


Figure 139 Emily Morandini. Concept sketch of the atmospheric electric field distorting over an earthed conductor. Illustration inspired by Richard Feynman's Lectures in Physics, Vol 2., 196

Similarly, I can consider that the low-pressure environment within my capacitively luminous plasma vessels acts as a conductor, a conduit, a path of least resistance, capable of wicking away voltage gradients external to the tube. The changing electric conditions within the vessel produce luminous glow as a byproduct as low-pressure gases ionise and excite. These principles were harnessed in the video work *Encounter with the Halo Field* (2009) by Haines and Hinterding (Chapter 2) and have also been demonstrated through Richard Box's installation *Field* (2004) (Figure 140), composed of 1301 fluorescent tubes, installed and earthed under high-tension cables, an installation that makes the extended electromagnetic field visible.[360] For me, this documentation of the site-specific installation *Field* echoes the visualisation presented by Morandini of atmospheric field distortion (Figure 139).

[360] Hinde, "Field by Richard Box."



Figure 140 Richard Box, *Field,* 2004. Video stills from documentation of the 2004 installation of this work.



Figure 141 Testing capacitive symbiotic tangles of neon, suspended above a blown glass plasma vessel, 2024.

By harnessing capacitive illumination, capacitively coupled vessels as objects and installations become symbiotically luminous within extended electromagnetic fields, making visible radiating energy without direct wired connection.[383] At home in my studio, I began to experiment with symbiotic components suspended over more voluminous plasma objects (Figure 141).

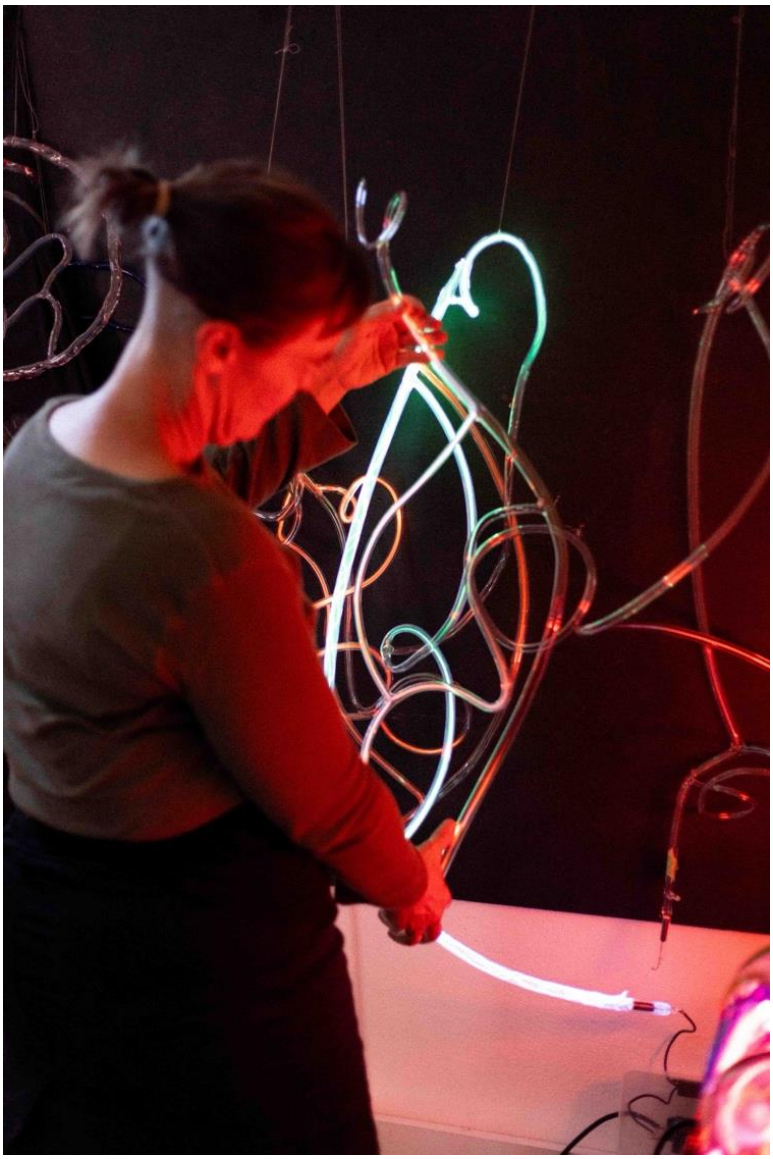


Figure 142 Capacitive studio test, 2024. Photo by Cassie Abrahams.

By pairing an electroded *Entangled Vessel* connected to its transformer with a symbiotic capacitive tube, I could achieve entwined suspended compositions. The symbiotic vessel would flicker in relation to the near field of the powered object. Furthermore, the influence or proximity of the viewer-participant changes the conditions within the extended physical system, affecting luminosity (Figure 142).

Transposing neon principles to my plasma installation practice required me to reconsider resistance and impedance within these objects.[361] Unlike the larger volumes of the blown glass *Chambered Vessels,* these *Entangled Vessels*, with their extended tubular structures, have increased electrical resistance. This is partially due to the length of the tube; their implicitly increased surface areas, the increased distance from the electrode, and the composition of the gas mixtures all contribute to the resistivity of the component, qualities that impede the effectiveness of the transformer and affect the quality of light.[362]

A more resistive combination of gases requires a more powerful transformer to ionise the plasma throughout the form. In this more tubular work, rather than dendritic branching arcs of lightning-like discharge, the dynamics can result in spiralling tendrils, like modern telephone cables meandering up the tube, until the current drops and the sheath-like green glow discharge become dominant (Figure 143).

[361] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 119-121.
[362] Crook Fishman, "Neon Engineers Notebook." 187.

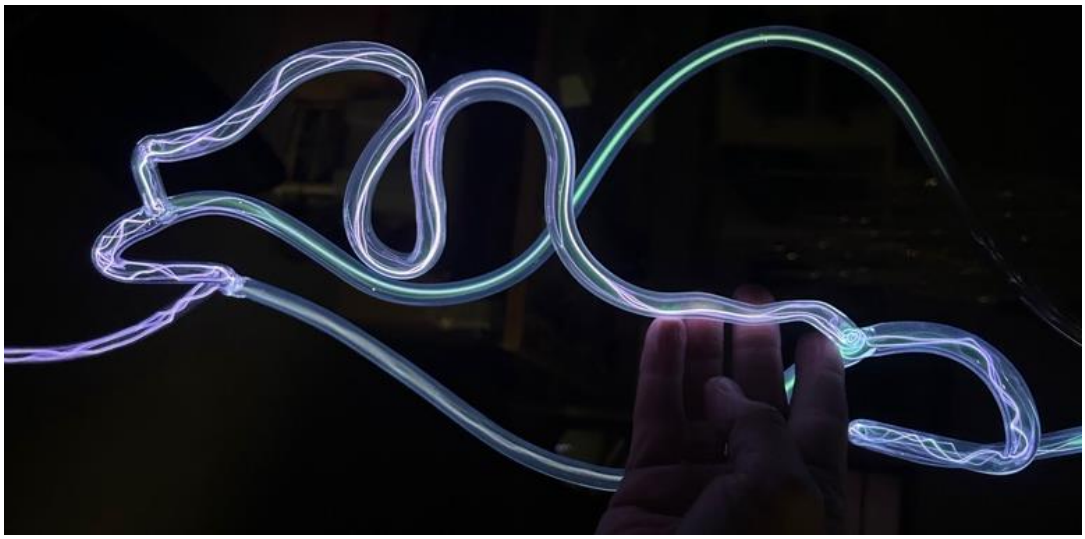


Figure 143 Borosilicate glass, xenon, neon, transformer, 2024. Although xenon has a lower ionisation potential, is a more resistive gas and requires a more powerful transformer to excite the plasma through the length of the tube.

Strattman describes the human body's capacity to "conduct electricity like a bag of salty water. The conductivity across and through your body, however, is not uniform. It depends upon your body and even your emotional state."[363] Similarly, I began to consider the body as symbiotic conductor, affecting the luminous outcomes of the plasma within. I considered how voltage gradients combined with viewer proximity to elicit capacitive luminosity more effectively. This confluence assisted me to visualise how tubular components might function as conduits of connectivity within installations. What intrigued me more than constantly glowing elements was establishing conditions, where the capacitive symbiotic objects appeared clear in their gas state but would illuminate as viewers approached. In my studio I tested how the flickering excitation of the symbiotically capacitive objects offers heightened engagement, piquing the curiosity of the viewer-participant as clear tubes become luminous on their approach, making visible invisible systems of connectivity.

[363] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 129.



(L): Figure 144 *Sinuous Möbius Pair* Detail ,2023. Borosilicate glass, electricity to ionise gases using direct electrode connection and capacitive illumination, (2023) photo Suki and Hugh.

(R): Figure 145 Detail *Nearly, Barely, There,* 2024. Long exposure image of direct and capacitive illumination.

I devised strategies for suspending objects in proximity to one another, enabling larger scale installations and intimate experiences which both harness capacitive illumination. I suspended eerie blue strands, with xenon or krypton gases, connected to their transformer, paired with low pressure capacitive neon tubes, which become vibrant red, echoing the historic representation of red arterial blood and blue venous fluids ((L): Figure 144(R): Figure 145). I began by sketching, arranging, and testing larger suspended experiments. Producing installations of these objects, I increasingly relied upon the viewer-participant to assert their influence, by enticing participants to physically move objects in ongoing luminous, symbiotic, and capacitive moments of engagement.[364] Testing smaller objects as models led to the ongoing series of movable *Symbiotic* objects discussed in Chapter 5. The following chapter details the installation and testing of these series of works in multiple settings.

[364] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*.129, where Strattman writes about the body as conductor.

4.10 Reflections

The shift in my practice from producing voluminous plasma vessels to interconnected entangled conduits uncovered new perspectives of connectivity through plasma-illuminated glass. By practising strategies to realise luminous vascular tangles, I considered the entangled energetic relationships explored by artists such as Haines and Hinterding, Richards, and Mróz discussed in Chapter 2, investigating connections between bodies, technologies, and energetic fields that typically remain imperceptible yet fundamentally shape our experience of our material world.[365]

Extending circulatory metaphors has expanded how I perceive connection in conjunction with my practice of blood plasma donation. The flow of blood plasma within our own circulatory system and its transferral to other bodies as treatment reveals an act of fluid connection. The development of forms and techniques, such as bridging and capacitance, were catalysed by targeted mentorships with contemporaries. I adapted laboratory glassmaking techniques to incorporate moveable plasma vessels in sculptural installation works.

Influenced by Barad's term “intra-active,” which expresses an agentic relationship where elements affect each beyond the hierarchy of cause and effect, the technical development and conceptualisation of the manifold as an intra-active agent reinforces the position that material, maker, and energy application all influence plasma illumination outcomes. [366] This conceptual implication raised broader questions about the manifold's influence beyond its function as materially productive apparatus. The

[365] Mróz, “Interactive Light – the Use of Plasma Discharge in Noble Gases as a Medium of Applied Art.” 60. Describes the multiplicity of interacting with the work, beyond interaction into a more complex and nuanced relationship. “My goal is to provoke the viewer to want to enter into a relationship with the energy of the work, to try to touch the light— to forget about the existing boundaries and let oneself be carried away by the magic of combining noble gases and electricity.”
[366] Barad, *Meeting the Universe Halfway*, 141.

objects produced through the tripartite process are part of the manifold's physical system. When removed and installed elsewhere, they become part of another system yet echo their origin.

Neither strictly scientific nor exclusively intuitive, material experimentation, conceptual development and collaborative knowledge-making combine in my practice of leaks and tangles. My objects and installations shift from static displays to dynamic systems as viewer-participants influence the spaces between objects, becoming conduits, conductors, and connectors that expose this medium's responsive potential.

Rather than exploring neon signage's even lines of light, my exploration encompasses a responsive and evolving approach to plasma illumination. I harness capacitive illumination to bridge theoretical understanding with perceptual experience, informing installation strategies that make visible the observer's presence. I reimagined these capacitive elements as symbiotic rather than parasitically luminous vessels, expressing their shared proximal luminosity.

The next chapter discusses how these objects are exhibited and explores their physical systems as installations in multiple settings to diverse audiences. These endeavours have shifted and extended my practice toward eliciting excited matter and embracing unstable illumination. New forms and approaches to making foster immersive and responsive encounters that respond to the maker's influence, the presence of participant observers, and the responsive properties of matter itself.

Chapter 5: Properties of Plasma—From Responsiveness to Relationality



Figure 146 *Intra/Pendant Looped Möbius*, 2024, borosilicate glass, neon plasma capacitive illumination, transformer mounted within wall shelf, 40 x 35 x 11 cm. Photo by Suki & Hugh Gallery.

Within my studio practice, I became attuned to how individual materials and methods influence each other during the tripartite process to produce plasma-illuminated objects. This chapter is concerned with the composition and exhibition of these objects, reaffirming how interconnectivity is made visible through the ongoing interactions with this medium. In his book *Helgoland*, which begins with Werner Heisenberg's breakthrough quantum revelations, Carlo Rovelli elucidates his relational interpretation of quantum mechanics, describing objects as nodes of interaction that reveal phenomena as the result of relations. He writes: “Instead of seeing the physical

world as a collection of objects with definite properties, quantum theory invites us to see the physical world as a net of relations."[367]

These nodes, and their entanglement, describe phenomena not as connections between two objects but rather as what Rovelli calls "a dance for three that weaves the world," inviting his readers to appreciate that phenomena rely upon interconnectivity.[368] Within plasma physical systems, sites of proximal interaction between viewer-participant or intersecting strands of illuminated glass reveal themselves as regions of heightened luminosity (Figure 146). Through these observations, my creative practice with plasma shifts from appreciating its responsiveness to embracing this relational perspective.

This chapter focuses on the installation and observation, rather than on the studio production, of eliciting plasma. Through installation strategies, I deepen my understanding of this medium's relationality. Through experimentation, by initially pairing objects, then suspending multiple pieces, and later incorporating mobile and movable components, I employ various installation strategies to explore the luminous potential and the interaction between objects and the viewer-participant.

During this project, I installed plasma physical systems across diverse settings, which included open-studio events with hands-on engagement, a Makers Forum seminar at ANU that encouraged interactive presentations of work in progress, and an exhibition at Suki & Hugh Gallery that showcased experimental tubular works from my *Entangled Vessels* series.[369] My work was then curated into *Materiality But Not as We Know It*, a

[367] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics*. 70.
[368] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics*. pages. 86, 87, 88
On page 88 Rovelli writes; "Entanglement is therefore far from being a rare phenomenon that occurs only in particular situations: it is what happens generically in an interaction, when this interaction is considered in relation to a system that is external to it."
[369] Suki Hugh Gallery, "Matthew Curtis & Harriet Schwarzrock | PAIRED."

group exhibition at Canberra Museum and Gallery, offering valuable experimentation with larger-scale installations. [370] This was followed by an intimate interactive installation for the *Artefact* exhibition at the Classics Museum at ANU, where I created participatory symbiotic objects in response to museum artefacts within a museological context. [371] These opportunities demonstrate how variables in installation settings, such as darkness, the ability to install work suspended from a wall, or from a ceiling, and even the influence of the building materials used in the exhibition space, all affect plasma behaviours. Through experiments with installation setups, I demonstrate how plasma can extend beyond individual vessels to become proximally engaging artworks. Further opportunities included presenting papers at an AAANZ conference, Ausglass, Cambridge, and Medical Humanities symposia at the ANU; being interviewed on the *Taming Lightning* podcast (hosted by Echols II); and co-teaching masterclasses at Melbourne for the Ausglass conference and Pilchuck glass School in the USA.[372] These formal settings allowed me to discuss the implications of my research and to forge valuable connections within the field.

Ongoing experimentation with capacitive illumination, where plasma is activated symbiotically through electromagnetic fields rather than direct electrical connections, supports a relational reading of this state of matter. Through testing, I created subtle and delicate luminous encounters, resulting in objects and installations where the plasma state becomes heightened at intersecting sites of connection. These investigations allowed me to harness new possibilities for proximally activated art that invites viewer-participant engagement, changing the luminous quality of plasma through electromagnetic influences.

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[370] Canberra Museum and Gallery, "MATERIALITY BUT NOT AS WE KNOW IT."
[371] "Artefacts Exhibition | School of Literature, Languages and Linguistics."
[372] "The Medical Humanities in Australia." Looking at Bodies, Sex and Gender in the Health and Medical Humanities" From the 5th to 6th June 2024.

5.1 Testing Plasma's Responsiveness in My Home Studio

My testing methods blend studio experimentation with installation configurations and viewer-participant engagement. My home studio serves as a laboratory for exploring plasma's responsive and relational qualities. Bi-annual open studio events offer ongoing opportunities to observe diverse audiences interacting with my work.[373] These interactions reveal patterns of engagement that guide my decisions for creating movable components or capacitive strategies. In my darkened studio space, multiple plasma vessels are illuminated. On a table within this room small, capacitive objects are available for visitors to pick up and move around the space. By moving these objects close to the powered objects, viewers elicit their symbiotic brightening glow.

Studio open days have informed how I invite people to engage with plasma. These interactions allow me to determine how much space is needed for viewer-participants to feel comfortable picking up and setting down the *Symbiotic Objects*. Similarly, these open day events inform how much technical or scientific information viewer-participants require or desire before they embark on their own exploration and experimentation. In my studio, viewer-participants can also experiment with their perception of light through interactions with small diffraction grating lenses, which allow observation of the spectrum of light radiating from the plasma objects. This activity provides a means of experience of additive colour, to contemplate plasma's granularity. I love that in my studio my work can make wizards out of children and children out of wizards.

[373] Queanbeyan | Arts Trail." Craft Des. Canberra, "2025 Craft + Design Canberra Open Studios + Organisations Open Day Program."

I witness involved audience engagement, evidenced though extended experimentation, where I see people move the capacitive *Symbiotic Objects* throughout the space. I hear squeals of delight, noises of disbelief, utterances of "wow," or giggling delight as transparent objects become luminous. Sometimes, the experimentation is almost trancelike, where audience-observers move their bodies incrementally and deliberately to witness how the behaviours within the plasma objects change. At times, this experimental curiosity and engagement result in complex conversations about matter and energy; at others, viewer-participants are thrilled to feel like they are magicians. Every year, there are repeat visitors who return to play, experiment and express wonder in the "plasma vault" or "wizard room."[374] Visitors often return, bringing friends or family to interact (and play) with the objects.

Viewer-participants often spend several minutes manipulating individual objects compared to a reported median gallery viewing time of static artworks of 17 seconds.[375] My experience also aligns with research indicating that primed and engaged audiences spend more time with artworks.[376] I observe that this extended engagement is also fostered by the darkened space enveloping these luminous forms, affording uninhibited and engrossed interaction. We do not just experience ourselves reflected in these objects; we experience our agency through changing luminosity. Even when I struggle with the complex, tangled nature of this practice, the viewer-participants' reactions, curiosity and wonder far outweigh the challenges of my leaky and tangled tripartite process.

[374] My partner Matthew Curtis and I alternate using these descriptions.
[375] "Spending Time on Art." 231.
[376] Brieber et al., "Art in Time and Space." Context Modulates the Relation between Art Experience and Viewing Time." *PLoS ONE* 9, no. 6 (2014): e99019. David Brieber, Marcos Nadal, Helmut Leder, Raphael Rosenberg

5.2 Makers Forum: Participant-Driven Engagement

Early in my candidature, I was co-convener of Makers Forum at ANU.[377] This space fostered an experimental, judgement-free environment where fellow academic researchers could directly engage with and respond to works in progress. During my seminar presentation, the space was darkened, and I placed a collection of objects on a table, including several directly powered plasma objects and a group of smaller, moveable capacitive tests. By leaning in towards the work, viewer-participants were encouraged to touch these objects, to engage with the movable components, or to rearrange them, discovering how and where they became luminous. Employing this strategy of inviting interaction enabled me to observe the objects being handled, with initial tentative engagement leading to more intuitive experimentation.

The perspective of displaying moveable plasma artwork for interaction, whether for a private audience, a small gallery, or a museum, raises questions about permission to touch the works. During my interviews with both Echols II and Lemaire, we discussed strategies for these permissions.[378] Each practitioner held unique perspectives; Echols II spoke of navigating the gallery or museum's expectations and adjusting the levels of permission, through education, to manage interaction with this type of artwork.[379] Naturally, this includes ensuring that the objects are safe, well-installed, and straightforward for gallery staff to illuminate and monitor, with specific arrangements tailored depending on the space. I agree that these interconnected requirements vary between gallery spaces, shaping the viewing or participatory experience of the observers.

[377] With Dr Lindsay Kelly and Dr Julian Laffan, 2022, 2023. Australian National University, School of Art and Design.
[378] Lemaire, interview with the author.
[379] Percy Echols II, interview with the author, 02 November 2023, full transcript available in Appendix 4.

By contrast, Lemaire adopts an almost black box approach to the technology. Although she shares every aspect of practice with students, she refrains from discussing or revealing the mechanisms at work in her own exhibitions. Discouraging touch, her works are fabricated and presented so that the primary engagement with the work is visual. Proximity sensors (PIRs) switch the work on only when the viewer approaches.[380]

These discussions highlighted the importance of communication, whether through written instructions or verbal invitation. The installation and its location partially determine the level of engagement, whether in a private setting, gallery, or museum. My approach when exhibiting my work has been to allow viewers to come as close as they dare (this is dependent on the institution's protocols). When viewer-participants touch the work, I prefer it to be respectful and curious. With the capacitive *Symbiotic Objects*, I treat the work with the same care I use with a smartphone; ordinary interactions are encouraged, dropping these small robust objects is the only risk.[381] Depending on the exhibition, I give viewers agency to touch and move objects. I hope viewer-participants enjoy interactions with the *Entangled Vessels*, where suspended components might touch, making the tinkling sound of borosilicate laboratory glass while becoming

[380] Lemaire, interview with the author. Proximity triggered [PIR] power boards are not available in Australia. I have worked with local artist Brian McNamarra and in discussion with Percy Echols II to wire up PIR sensors to individual pieces. My partner Matthew Curtis has assisted me with wiring PIR sensors inline in extension cords and power boards, which are "tested and tagged" for electrical safety during gallery installations.

[381] I clarify with the gallery that I am comfortable with viewer-participant engagement. I provide extra capacitive *Symbiotic Objects,* in case something goes astray.

luminous with proximity. Even the hummmm of a fan, the squeals of transformers, or the buzzing tingle of powered pieces contribute to the multisensory experience.[382]

Late in 2023, participating in a shared critique for research candidates at the School of Art and Design in Canberra, I installed the objects in a small, darkened room, including some of my newly developed suspended *Entangled Vessels*. Observers were encouraged to move transparent components, which appeared to be empty ampules, around the space. These capacitive symbiotic objects, filled with low-pressure neon gas, glowed red within the shared electromagnetic fields of other powered devices. It was surprising that it was such an uninhibited experience, invited by a dark space. Despite the rigorous questioning of process and methods, it was hard to keep focus, as play and wonder was part of the academics' experience. This participatory approach accentuates a co-creative process of curiosity and discovery, with exploratory movements influencing the plasma's behaviour in ways that reinforced engagement and interconnectivity as a core to this practice.

Harnessing darkness within this installation space invited a certain level of inhibition and created a buzz of activity and involvement. Darkness facilitated noticing more subtle luminous behaviours, as on approach tendrils of arcing light meander toward the viewer-participant, or dappled sprinkle of light converge to the point of touch. I noticed how some viewers felt uncomfortable handling objects, while others were delighted. This prompted adapting installation strategies to include suspended capacitive

[382] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 128. regarding the "squeal," Strattman writes; "When two or more pieces are powered by separate power supplies, another situation can arise in which the separate fields are close enough to interfere with one other. This may result in audible squeals resulting from beat frequencies, which are differences between the pairs of energizing frequencies. Though the two power supplies are running well above audible frequencies, the difference between their frequencies may fall into an audible range. The only solutions for this are to separate the tubes so there is no appreciable overlap, or to possibly run both tubes on the same power supply so that their frequencies are identical. An alternative-and perhaps less desirable— solution is to put an electrically conductive grounded surface between the two tubes to shield them from each other and ground their overlapping energy fields."

components in *Entangled Vessels*, which glow through proximity rather than requiring visitors to move the objects around the space. I observed how engagement and interest were strongest with flickering, pulsing, or changeable illumination, rather than static light-engaging intrigue. I began to explore how partial, uneven, and unstable luminosity could reveal otherwise invisible connectivity.

5.3 Generous Encounters: Speculative Objects at Suki & Hugh Gallery

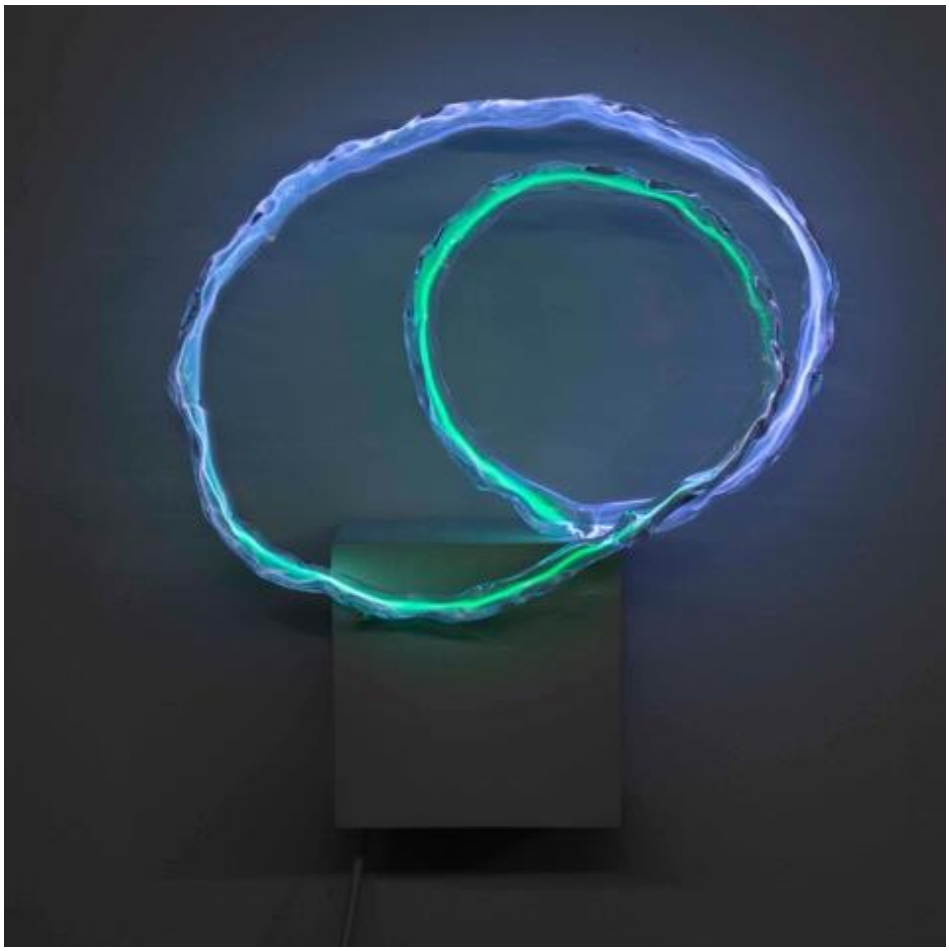


Figure 147 *Möbius*, 2023, borosilicate glass, electrodes, ionised gas, high voltage transformer, 43 x 39 x 20 cm. Photo Suki & Hugh Gallery.

In an exhibition at Suki & Hugh Gallery in September 2023, I presented the interactive and moveable components created during my Corning Museum of Glass residency.[383] Visitors to this private gallery setting could directly engage with the work through touch and proximity. This unconventional decision on my part, along with generous curatorial support, allowed me to observe plasma's responsive behaviours, highlighting how the *Entangled Vessels* foster participatory encounters that go beyond traditional object–viewer interactions.

The experimental *Möbius* object inspired by themes of circulation and connectivity was installed using a transformer housed within a wall plinth. This object is connected to the transformer via its electrode which is also concealed in the wall plinth. Due to the continuous enclosed space within this tube, when ionised and excited, this object displays varied luminous behaviours depending upon the distance from the transformer. As the piece is filled with low-pressure neon and xenon, the spectral lines closest to the electrode express a bluish-white xenon arc, while the interconnected volume furthest from the electrode glows green (Figure 147).[384]

Similarly, the *Sinuous Möbius Pairs* (entangled plinth-based objects) reveal similar arcing discharge behaviour. These pairs harness capacitive illumination. The one green-blue form has an electrode connected directly to a transformer at the base. It is paired with a transparent red-glowing symbiotic companion, with no direct electrical connection, emitting neon's characteristic red spectral light (Figure 148). As a viewer's hand approaches these objects, tendrils of light are drawn further around the form, revealing the observer's influence (Figure 146, Figure 148).

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[383] Suki Hugh Gallery, "Matthew Curtis & Harriet Schwarzrock | PAIRED."

[384] *Green Plasma in Xenon-Nitrogen Mixture*. I can only speculate on that glow; considering that it is either related to complex chemistries or bremsstrahlung. Carl Willis discusses green plasmas in this demonstration, discussing chemistry. Bremsstrahlung is discussed in section 1.13, describing the potential glow of the electrons themselves giving off their energy as they are bent in space.

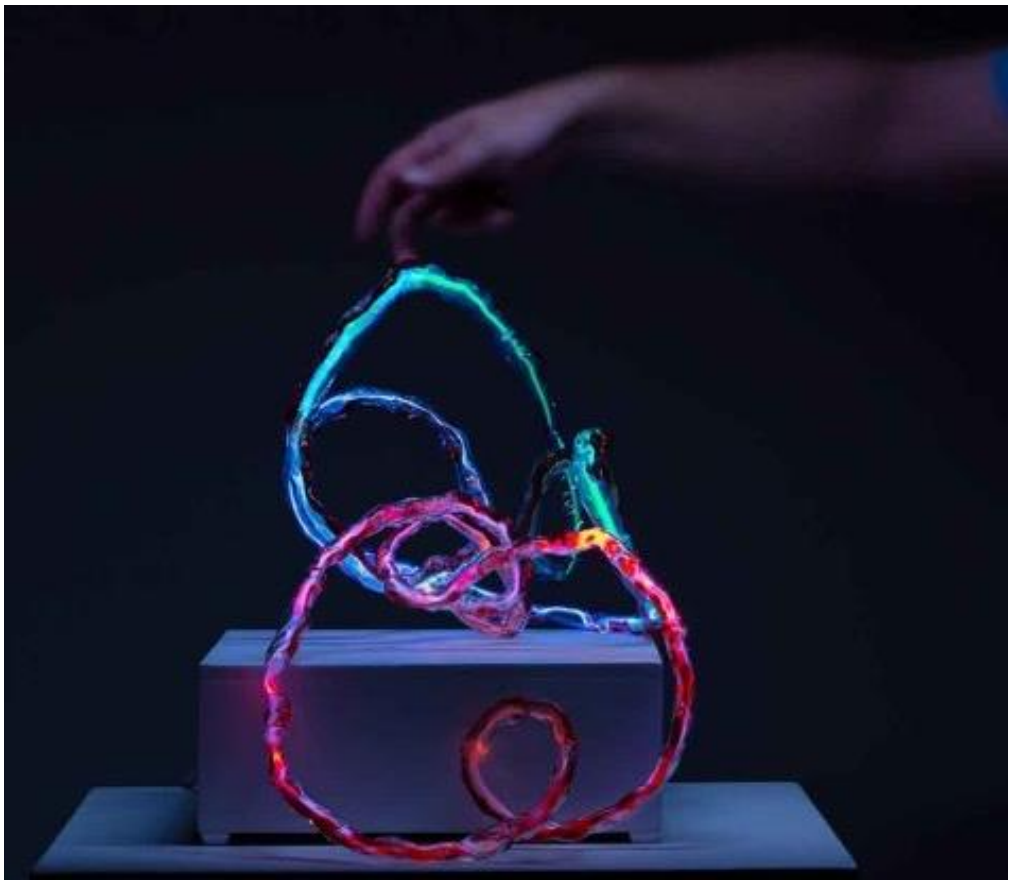


Figure 148 *Sinuous mobius pair II*, 2023 borosilicate glass, electrodes, ionised gas, high voltage transformer, 44 x 35 x 35 cm, variable. Photo Suki & Hugh Gallery.

This exhibition allowed me to experiment with suspended arrangements of objects. *em/brace entwine* consists of two borosilicate tubes, each with electrodes, wired to each other in sequence. One cable from the transformer connects to the first piece, further connected to the second component (Figure 149). This setup began to reveal divergent possibilities for the path the plasma light takes, influenced by the viewer-participants' proximity.



Figure 149 *em/brace entwine*, 2023, flameworked borosilicate glass, electrodes, ionised gas, high-voltage transformer, nylon thread, 72 x 48 x 15 cm (variable). Photo by Suki & Hugh Gallery.

I then installed speculative arrangements of works, where one tangled strand of plasma was suspended against a wall from a nylon thread, while connected to its transformer placed on the floor directly beneath. A paired object was also suspended from the same fixture on the wall. This symbiotic tangle of glass tubes glows capacitively in the field created by the powered object. With this capacitive (or indirectly powered luminous) configuration in mind, I exhibited several pairs of suspended objects, each featuring an electroded form, connected to its transformer, paired with a symbiotic component. For example, in *em/brace oblique* and *em/brace bridging*, the whiter-brighter piece is connected directly to the transformer, while the red component is

filled only with neon and glows symbiotically red (Figure 150, Figure 151). As the viewer approaches the light shifts and meanders through the twisting bridges of glass. The arrangement of the two forms, influenced by one another reveals that these paired objects become “a dance for three” in concert with the proximity of the audience-observer.[385]



Figure 150 *em/brace oblique* (2023) borosilicate glass, electrode, ionised gas, high voltage transformer, nylon thread. 70 x 60 x 17 cm dims. variable. Photo Suki & Hugh Gallery.

[385] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics.* 87-89. This short section of Chapter 5 *The Dance for Three That Weaves the Relations of the World* speaks of the correlated nature of entanglement.

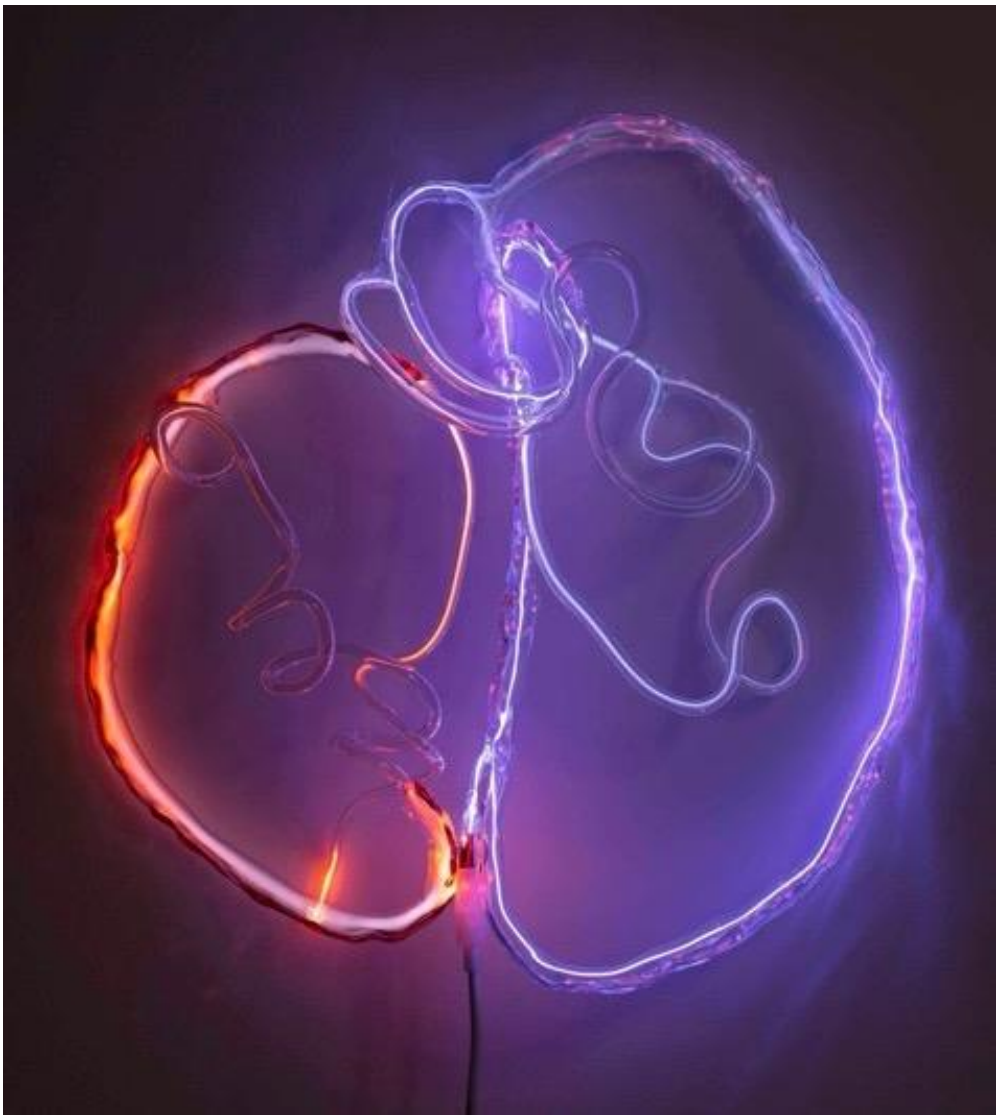


Figure 151 *em/brace bridging* 2023 borosilicate glass, electrodes, ionised gas, high voltage transformer, nylon thread, approx. 58 x 58 x 20 cm. Photo Suki & Hugh Gallery.

I also installed *A Frenetic Stillness*, a work that harnesses multiple components, made capacitively luminous by a horizontal tube of plasma, connected to a specialised transformer (Figure 152). Again, the suspended capacitive elements, with their shifting luminosity, flickered due to tight curves of the strands, and brightened on the audience-observers' approach. Unexpectedly the building materials in the gallery space also influenced the luminosity in the suspended installations. For example, concrete walls provided contrasting grounding characteristics, and the timber framework of a wall with

metal studs fundamentally altered how much current was drawn through the transformer. The surroundings became conduits affecting the quality of illumination. This architectural influence demonstrated what I had considered but not expected to experience so overtly: that the plasma physical system is directly influenced by its surrounding environment.

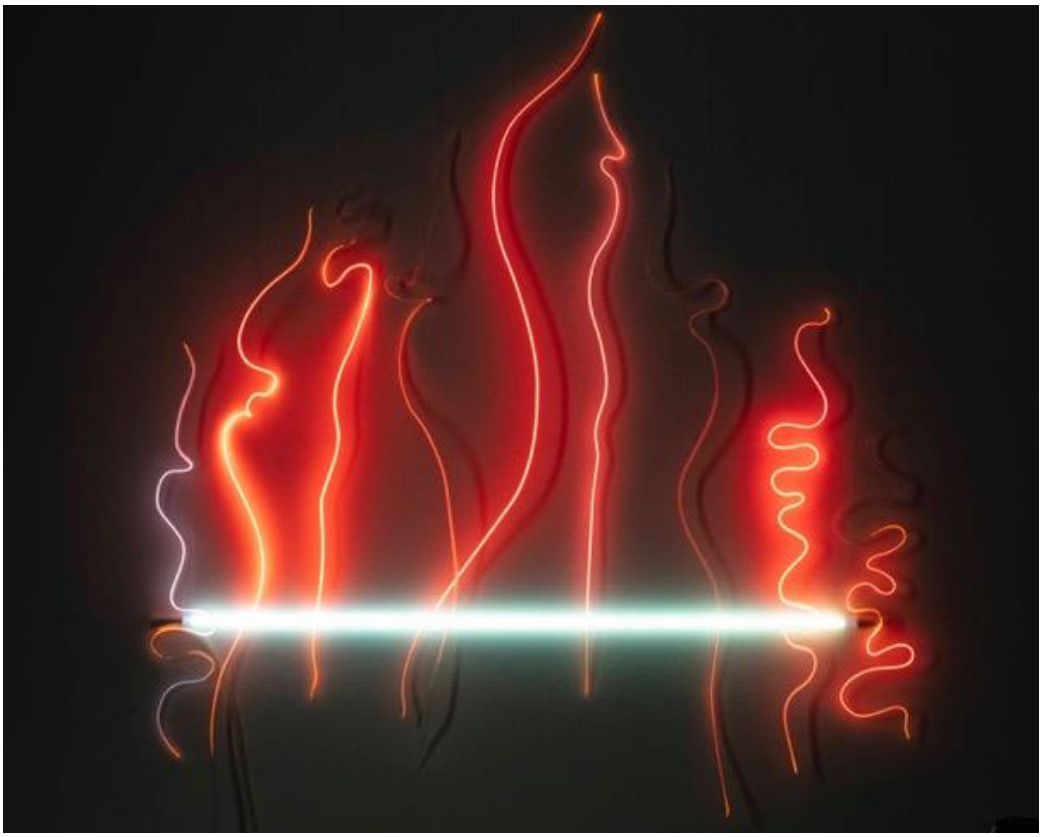


Figure 152 *A Frenetic Stillness,* 2023, borosilicate glass, electrodes, ionised gas, high voltage transformer, nylon thread, approx. 230 x 120 x 11 cm. Suki & Hugh Gallery.

The testing in my studio differed greatly from the installation in the gallery, and this led me to consider how I might better suspend the paired entangled vessels for future installations to avoid some architectural influences and to give viewers opportunities to navigate the work in the round. A particularly significant aspect of this exhibition involved creating and refining the small capacitive objects that visitors could carry throughout the space. These participatory, luminous, symbiotic objects contain only

trace amounts of neon gas that capacitively glow red when brought near larger powered works. This direct engagement invited viewers to influence these objects through re-arranging the electromagnetic assemblages. Movement and proximity determined how these objects would become luminously activated, offering heightened viewer-participant engagement. These intimately scaled objects were the first iterations of the ongoing series of *Symbiotic Objects*, which will be further discussed in relation to the Classics Museum exhibition later in this chapter.

Through generous curatorial support at the Suki & Hugh Gallery and the engaging visitor interactions, these symbiotic objects revealed their role as conduits not only for light, but also for showing a connection between the audience-observer influencing the work. The gallery directors shared visitor feedback, where attendees described their participatory and proximal experiences with the objects as “magical” or “alive”.[386] Several visitors at the opening event told me how the glow made them feel “connected” to the artwork. These reactions indicate that plasma's electromagnetic responsiveness fosters connection through engagement that purely visual encounters cannot demonstrate. The Suki & Hugh exhibition demonstrated significant artistic potential lies not in plasma illumination's visual spectacle but in its ability to make the often-unstable interplay of matter and energy visible through the viewer's presence and influence.

[386] Susan Foxlee and Sam Cooper gallerists of Suki & Hugh gallery, conversation with author during deinstallations of exhibition.

5.4 Canberra Museum and Gallery Installation: *Nearly Barely There*



Figure 153 *Nearly Barely There* [1-7] 2024, bent, spliced and flame-worked borosilicate glass tubing. neon, argon, krypton, xenon, electrodes, transformers, ionised inert gas, metal frame, nylon thread, 240 x 150 x150 cm dims. variable. Home studio test hang, photo Cassie Abrahams.

Curator Virginia Rigney's exhibition framework for *Materiality But Not As We Know It* (2024) at the Canberra Museum and Gallery positioned contemporary artists as working "beyond the conventionally private space of the studio into the expanded field of

interactions".[387] This exhibition provided me with a crucial testing ground for my most ambitious plasma installation. Each artist in the exhibition was assigned a space, lit and painted to suit their installation. Most of my work was installed within a darkened contained room, where viewer-participants could see subtle luminosity and experience how their proximity affected the plasma's illumination.

The darkened space displayed a collection of paired *Chambered Vessels*, each powered by a transformer secured in their bases. The objects were exhibited on plinths and wall-mounted boxes, their tangled extension cords largely hidden. Visitors could approach and get as close as they felt comfortable. As I have discussed the outcomes of the *Chambered Vessels* in Chapter 3, I will mainly focus here on the suspended installation of entangled vessels *Nearly Barely There* (2024) (Figure 153).

[387] Rigney. Virginia, *Materiality but Not as We Know It*. Catalogue essay



Figure 154 *Nearly Barely There* (detail), 2024 bent, spliced and flame-worked borosilicate glass tubing (neon, argon, krypton, xenon), electrodes, transformers, ionised inert gas, nylon thread, home studio test hang. Photo by Cassie Abrahams.

While developing these elongated and fluid entangled vessel forms, I incorporated twisted bridging formations that create visually distinctive luminous pathways which

make visible the plasma behaviours through these three-dimensional structures (Figure 154). These involutions, reminiscent of shunting blood vessels, became vivid sites of flickering luminosity.



Figure 155 *Nearly Barely There*, 2024. Installation at Canberra Museum and Gallery, photo Brenton McGeachie.

The installation *Nearly Barely There* featured entangled borosilicate glass strands, creating a three-dimensional network of tubular forms, suspended from a circular frame (Figure 155). The installation comprised seven pairs of suspended glass

elements, each pair consisting of one component with an electrode. These tubes contained mixed non-reactive gases at relatively high pressures (150–200 Torr), which pulsed and flickered, glowing with blue, white, and green tendrils of plasma when illuminated. The objects were suspended by nylon threads wound around the tubular glass then secured to the frame. The electrode was suspended approximately 10 cm from the frame, each individual transformer and their power supply positioned on top of the frame, housed in a non-conductive box. Once all the electrode vessels were suspended equidistantly, the transformers were connected and silicone sleeves covered the electrodes with its high-voltage wire connection. After installing these seven pieces, I began to suspend a capacitive component near each powered piece. These capacitive or symbiotic tubes, filled with low-pressure neon gas at 15–30 Torr, have the potential to glow red in the powered electromagnetic field that the connected piece provides.

The configuration of seven interconnected pairs suspended from a single frame posed unprecedented technical challenges, most of which did not become apparent during the extensive test hang I conducted in my home studio.[388] The tubular shapes with their increased surface area relative to volume, created higher electrical resistance. Each tube with an electrode was tuned and adjusted for optimal performance. However, as the transformers were positioned closely to one another, they interfered with each other's operation. To mitigate this, I spaced the transformers within their insulating electrical (junction) boxes as far away from each other as the frame would allow. I secured electric cables and ensured that the frame was grounded via an earth wire. I replaced several transformers as they burnt out from running too hot. Initially, I experienced the technical issues as distressing and unprofessional; I felt that I was failing to produce a finished artwork. Again, this experience re-confirmed how gallery

[388] Strattman, *The Art of Plasma Creating Lighted Sculpture with Gas, Glass & Electricity*. 128 Strattman refers to the proximity of tubes affecting luminosity.

conditions substantially influence the way plasma-illuminated physical systems function and glow.

The installation consistently defied predictable illumination, possessing its own influence between materials as a relational physical system.[389] This lively materiality resonates with the concept of "vibrant matter," a central premise in Jane Bennett's book of the same title, describing the interconnected agency of even seemingly inanimate objects, acknowledging the agentic potentiality of materials.[390] Installing *Nearly Barely There* (2024) challenged my conception of myself as an artist. This suspended installation shifted my role from that of trained object maker to one of ongoing negotiation. I became artist performing as technician or conjurer, attending to technical issues: failing transformers, altering installation configurations, adjusting the capacitive suspended pair to become luminous with viewer-participant approach. Rather than making finished artworks, I engaged in ongoing experimentation, recalling the dance of three discussed by Rovelli.

The installation also revealed practical considerations for future large-scale plasma works, including the need for modular electrical systems and motion or PIRs, which allow the mains power to only power the transformer when someone is in the room. After the exhibition at Canberra Museum and Gallery, I reinstalled this piece in my studio with significant modifications. I inverted the components to take advantage of thermal updraft within the vessels, a finding that capitalises on the upward movement of heat.[391] By positioning the transformers on the ground and plugging them into a power

[389] I had experience with feedback and interference with transformers previously, but the effects in this installation defied my expectations.
[390] Jane Bennett. "Vibrant Matter." *CSPA Quarterly*, no. 14 (2016): 7–11.10
[391] Discussed with Strattman during the masterclass.

board with an inline PIR, I created a situation in which the transformers only turn on when someone is in the room viewing the work.[392]

The following iteration of harnessing capacitive illumination led to the installation *Lightly Tethered*. I threaded an extension of the transformer's insulated high-voltage wire through the suspended capacitive objects, connecting it to only one component. Instead of powering a higher-pressure plasma vessel, one low-pressure neon component is illuminated. The intention is that the extended cable leaks voltage, creating a relational luminous dynamic (Figure 156 and Figure 157).[393] On approach, this configuration appears mostly transparent, a diagonal sweep of components building in crescendo, with only the furthest component pulsing red. The subtle and delicate luminosity depends almost entirely on viewer proximity, drawing more current through the tubes that touch the cable, making them glow (Figure 158). When one walks past the components of the tangled cascade of *Lightly Tethered*, only those closest to the person ionise and flicker with light, while a tinkling glass sound rings throughout the suspended moving forms.

[392] When experimenting with proximity sensors [PIR] with artist Brian McNamarra we had the interesting experience, that the objects themselves were being sensed by the PIR sensor, which has resulted in having to shield the sensor from the work.
[393] For this installation I have used the transformer designed and built by Strattman and Feigen based off the PVM400 by Amazing1.



Figure 156 *Lightly Tethered,* 2026, bent, spliced and flame-worked borosilicate glass tubing, electrode, transformer, high voltage cable, ionised neon gas, nylon thread, home studio test hang.



Figure 157 *Lightly Tethered* 2026, bent, spliced and flame-worked borosilicate glass tubing, electrode, transformer, high voltage cable, ionised neon gas, nylon thread, home studio test hang.

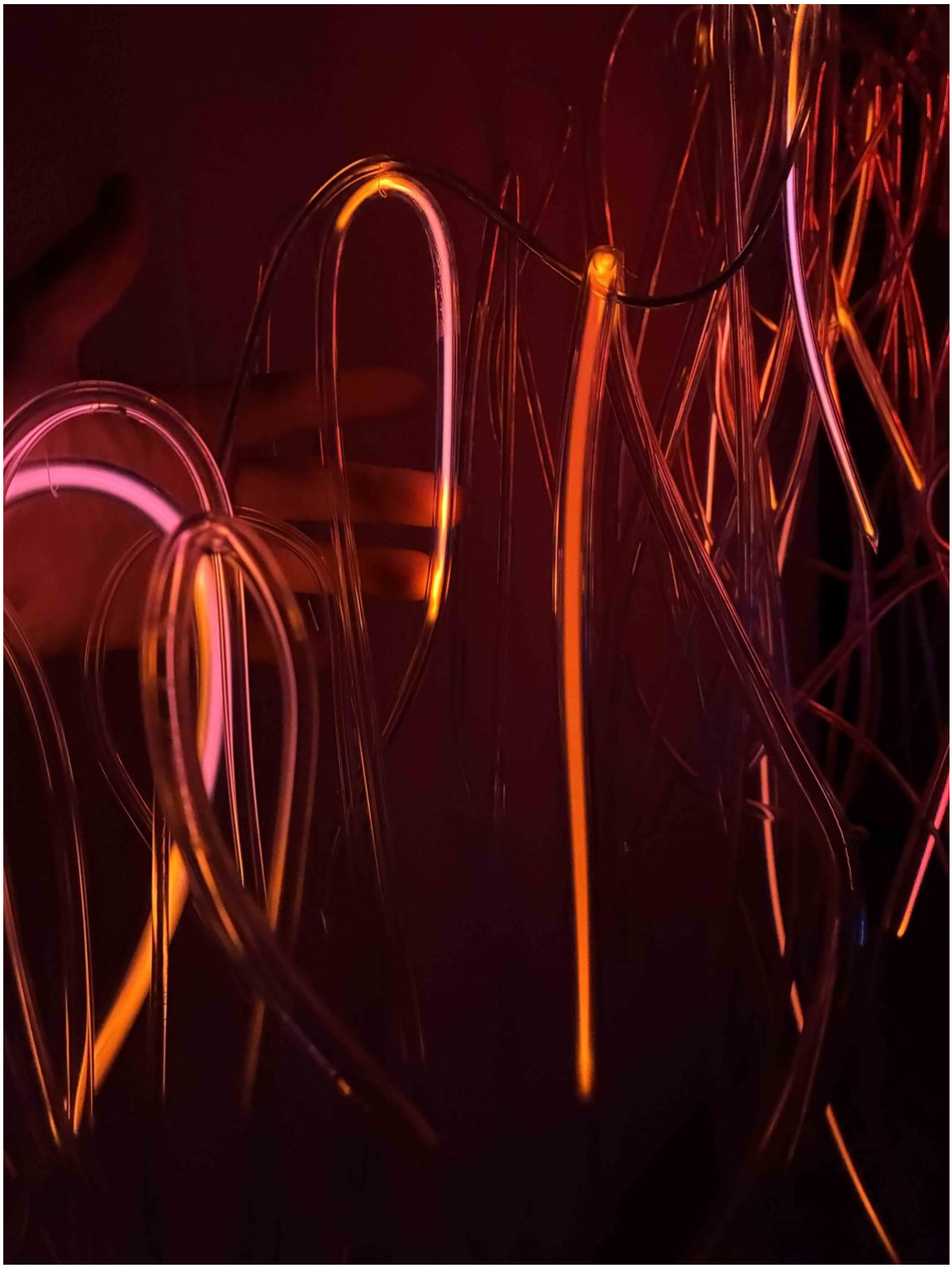


Figure 158 *Lightly Tethered* 2026 detail.

The suspended capacitive and symbiotic conduits sway with air currents and viewer proximity, forming a dynamic, constantly shifting arrangement that harnesses the medium's luminosity through relational engagement. Moving one's body near the object altered the direction of the luminescent plasma flow, echoing Rovelli's claim that “one part of nature manifests itself to any other part of nature”, in which luminosity is co-produced with the viewer-participant, the maker, or the environment.[394] The installation's technical challenges demanded that I embrace change and uncertainty. Unlike static artworks that maintain fixed relationships with viewers, the iterations of *Nearly Barely There* and *Lightly Tethered* create encounters where intersecting points of luminosity emerge through ongoing interactions.

5.5 Classics Museum: Spiralling Symbiotic Objects

An invitation from Dr Georgina Pike Rowney and Dr Julian Laffan to participate in the *Artefacts* (2024–2025) exhibition offered a unique opportunity to create artwork responding to an object from the Classics Museum collection at ANU.[395] Each participant in this project responded to different items from the collection, the artists and researchers included Aidan Hartshorn, Julian Laffan, Rob Nugent, Susie Russell, and myself. I selected an eighth-century BCE *Bronze Spiral Brooch* (accessioned 1980.12), where the continual twist of forged metal highlights the skill of the maker.[396]

[394] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics*. 67.
[395]“Artefacts Exhibition | School of Literature, Languages and Linguistics.”
“Classics Museum | School of Literature, Languages and Linguistics.”
[396] Catalogue number





(L): Figure 159 Handling the object, 2024, photo Julian Laffan.

(R): Figure 160 Eighth-century bronze spiral brooch, accessioned 1980.12 Classics Museum ANU.

I reflected on how this historic spiral brooch resulted from precise material practices and techniques, and I contemplated how the maker might have formed this object. I examined the artefact to better understand its crafting process and the origin of its decorative pattern and their connection to spiralling forms ((L): Figure 159 and (R): Figure 160). I visualised how this brooch could have been worn, fastening a woollen cloak and providing warmth. I reflected on how the simple act of removing clothing can generate static electricity through friction, enough to make our hair stand on end or even produce a tiny spark. As discussed in Chapter 2, I was able to generate enough static electricity by wearing (or rubbing) sheepskin while holding a low-pressure, neon-filled tube to witness the momentary neon red glow.



Figure 161 *Spiralling Symbiotic Object* (detail), 2024, laboratory glass tubing, ionised neon gas, electrical potential from high-voltage transformer.

In response to the brooch, I crafted spiralling glass ampules containing low-pressure neon gas.[397] Simple plinths housed a square of copper wire mesh connected to a transformer, creating a capacitive base plate.[398] This radiating wire mesh is encased within sheets of non-conductive glass (or acrylic) to ensure electrical components

[397] "Bronze Spiral Brooch - 1980.12 | School of Literature, Languages and Linguistics." "The whole is made from a single length of bronze. The strip is quadrilateral in section at the front but rounded for the pin and clip behind. The decorative front part comprises two spirals, their centres leading back to pin and clip, their outer edges joined in a figure-of-eight. The pin runs from the back of the centre of one spiral, and the clip-hook from the back of the other. They show only a little diminution in the diameter of the wire."
The type is known as a spectacle fibula, and it probably dates to the eighth century BC. The style fits well with the Geometric style of contemporary pottery.

[398] To create an extended electromagnetic field from the transformer, I connected the transformer's wire to a wire mesh sandwiched between two glass and/or polycarbonate sheets (non-conductive materials) to create a surface onto which the capacitive objects could be placed to become capacitively luminous once the transformer is connected.

cannot be touched. As the glass vessels have no electrode attached, the plinth serves as the power supply, illuminating the moveable *Spiralling Symbiotic Object* (Figure 161). As described in Chapter 4, these capacitive objects are made luminous when the changeable matter within their glass envelopes becomes excited within the transformer-generated electromagnetic field. The borosilicate glass spirals glow when placed on or near the specialised transformer base and brighten when moved and handled.

In preparing my response for this exhibition, I reflected on plasma-illuminated objects as an extension of the manifold through which the processing takes place. Once removed from the manifold and brought close into the electromagnetic field of the transformer, these symbiotic objects enable the viewer to experiment with and influence the plasma phenomena. Artist and researcher Maarit Mäkelä suggests that

> Artefacts are essential outcomes of artistic process, but in the context of practice-led research, they have an even more important role. They function as a means of realising a thing which has to be perceived, recognised and conceived or understood.[399]

As such, the influence and perception shift from the maker to the viewer in an ongoing form of creative experimentation. Again, historic examples of Geissler tubes asserted their influence on this project. Like the brooch, they extend pure function through decorative elements. Many of the discharge tubes produced in the 1800s became objects of curiosity; with their whorls and curlicues, they were no longer strictly scientific instruments (Figure 162).[400] As mentioned earlier, I was fortunate enough to hold examples of Geissler tubes at Sally Prasch's scientific glassblowing laboratory at the University of Massachusetts Amherst. When I encountered these objects, their physical weight and lightness was a revelation, a sensation I had not anticipated. While

[399] "Classics Museum | School of Literature, Languages and Linguistics." 159.
[400] "Scientific Instrument."

I was holding the glass object, my focus was split between contemplating the skill of the glass maker and contemplating that the vessel contained a trace amount of the atmosphere from long ago (Figure 162 and Figure 163).[401]

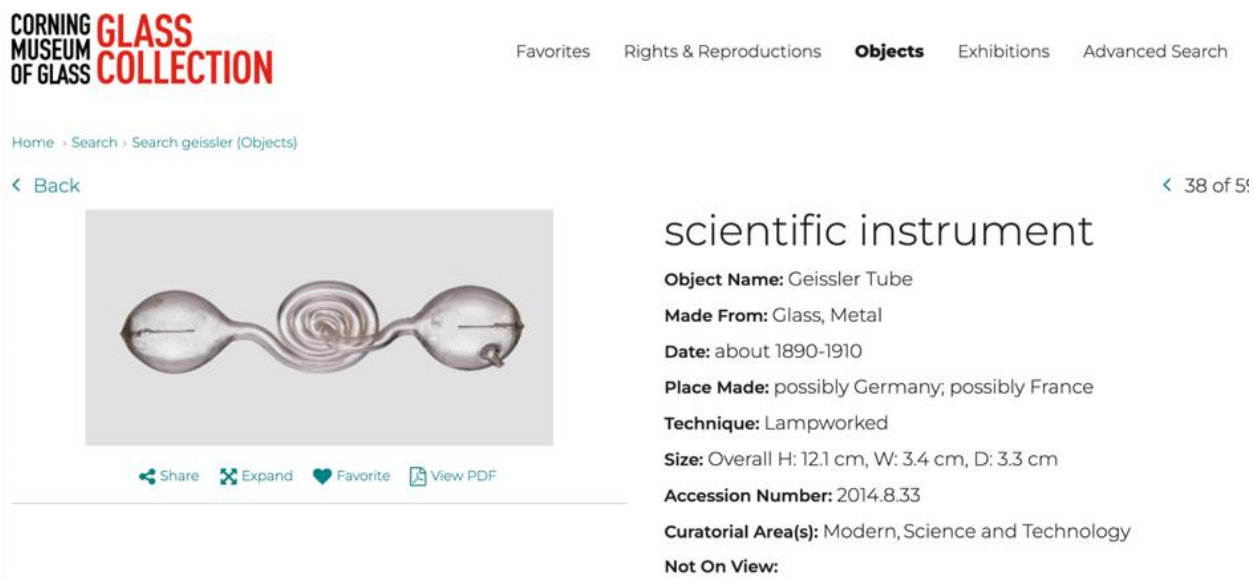


Figure 162 Possibly German, Possibly French *Geissler Tube,* about 1890-1910, Lampworked glass. https://glasscollection.cmog.org/search/geissler%20scientific%20 Corning Museum of Glass.

[401] "Sally Prasch."

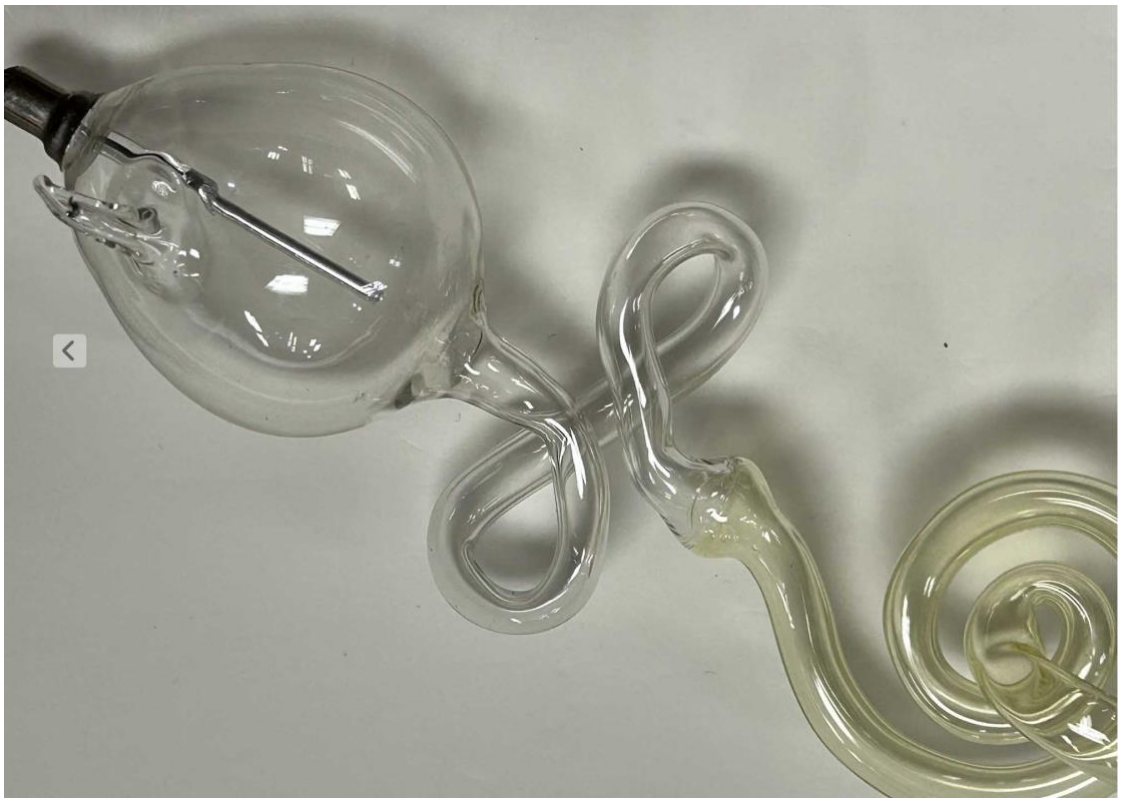


Figure 163 Handing a Geissler tube, 24 March 2023, Massachusetts Amherst Scientific glassblowing Laboratory.

Producing the objects for this exhibition demonstrated the significance of a three-dimensional form in revealing voltage differentials, a critical factor in capacitive plasma illumination. When exhibited, the more two-dimensional spiral forms sometimes remained transparent and unilluminated until an observer approached or touched them. This action drew more current into the object, causing excitation. I observed that the more unravelled and three dimensional those wilder spirals (with more height) offered a greater potential difference between the base and the uppermost point, providing more effective pathways for current flow. This visualisation echoed technical perspectives explained by Strattman and Feigen.[402] The unravelled spirals offered a more defined path for the current to flow, resulting in brighter illumination (Figure 164).

[402] "Workshops Strattman 2023."

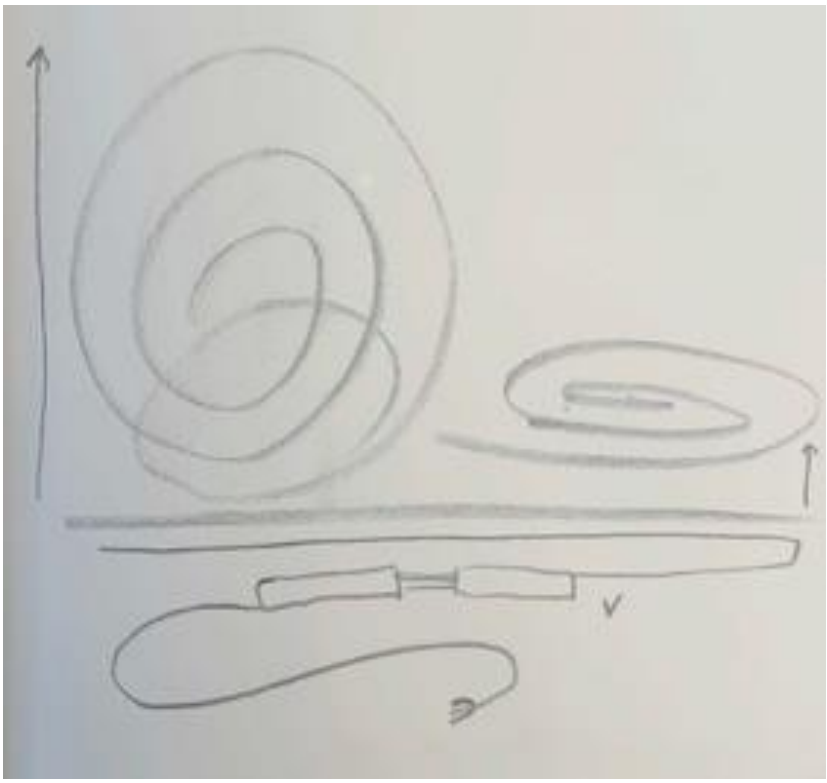


Figure 164 *Spiralling Symbiotic* sketch, visualising the larger potential gradient of a taller object.

Throughout the installation, I also noted that several of the neon-filled *Spiralling* ampules dulled from their bright red neon spectral lines to a paler pink. This pink is anecdotally linked to oxygen or nitrogen, revealing part of the history and atmospheric contents of the older glass tubes I had used.[403] Over time, the ionisation and excitation of these objects heat the glass, causing small quantities of contaminants to be released from their interior surface of the glass. [404] These molecules or atoms also ionise, and their unique spectral lines alter the perceived glow of the objects (Figure 165). This shifting luminosity further reinforced plasma's character as a relational medium. Its phenomena and behaviours emerge through engagements.

[403] Crook Fishman, "Neon Engineers Notebook." 65. "When clear red turns pink" I also think on Hepburn's advice to clean tubes with demineralised water and dry immediately with the flowing air of a hair dryer to remove contaminants.
[404] Strattman, interview with the author.



Figure 165 *Spiralling Symbiotic Object,* 2024, borosilicate glass, ionised neon gas, capacitive transformer base. Detail shows voltage gradient and colour change from vibrant neon red to pink indicative of unclean glass.



Figure 166 *Spiralling Symbiotic Object,* 2024, borosilicate glass, ionised neon gas, capacitive transformer base. Detail shows symbiotic participatory capacitive objects influencing each other.

Unlike traditional museum objects that maintain fixed relationships with viewers, these moveable *Spiralling* forms encourage intimate dynamic encounters, where even proximity may influence the objects' luminous effects. Through this project, with moveable components and shifting glowing behaviours, Rovelli's conceptualisation of interdependency enriches my understanding of influence: “things do not exist in splendid isolation. On the contrary they do nothing but continuously act upon each other”.[405] Resonant with this insight, I consider influence as a form of collaboration and connectivity. The *Spiralling* forms, where multiple components that can be moved and shifted, reveal more than decorative flair; they demonstrate dynamic fields of influence between observer and object (Figure 166).

[405] Rovelli, *Helgoland: The Strange and Beautiful Story of Quantum Physics.* p68

5.6 Plasma Behaviours: Observation, Documentation, and Presentation

Through visual documentation, one can analyse the colours of excitation attributed to the discrete spectral lines of non-reactive gases. For instance, xenon's blue-white emissions and neon's red-orange glow are readily distinguishable. However, more subtle effects throughout some forms, such as the green plasma sheaths that appear under specific conditions or the red Hepburn “sprinkles,” demonstrate how gas mixtures, or Penning mixtures, create complex plasma interactions when ionised (Figure 168 and Figure 169).[406]

An informal studio visit by Dr David Pfefferlé, at the time Senior Lecturer at the School of Physics, Mathematics and Computing, University of Western Australia, along with two of his students, refined my understanding of visible plasma discharges. We examined plasma-illuminated objects in a dark room in my studio and contemplated what we were witnessing within the vessels.[407] We initially considered the characteristic spectral lines from bound-bound radiation, which reveals specific spectral colours for each atom (Figure 168).

[406] Hirsch, “On the Mechanism of the Penning Discharge.” 1542
Davis, interview with the author. Where Davis discusses Pennings mixes.
[407] David Pfefferlé, from the University of Western Australia, was presenting at a conference in Canberra (and visiting family in Canberra, my dear PhD colleague Cath Webb suggested a studio visit to see plasma in another context). Prior to our meeting during our email introductions Pfefferlé explained that he does not specialise in the low temperature plasmas, rather mathematical models for plasma physics.



Figure 167 *Entangled* detail, 2024, borosilicate glass, ionised neon gas, transformer. Detail on left shows spectral line of xenon, blue-white, the neon red-orange glows capacitively in the background.

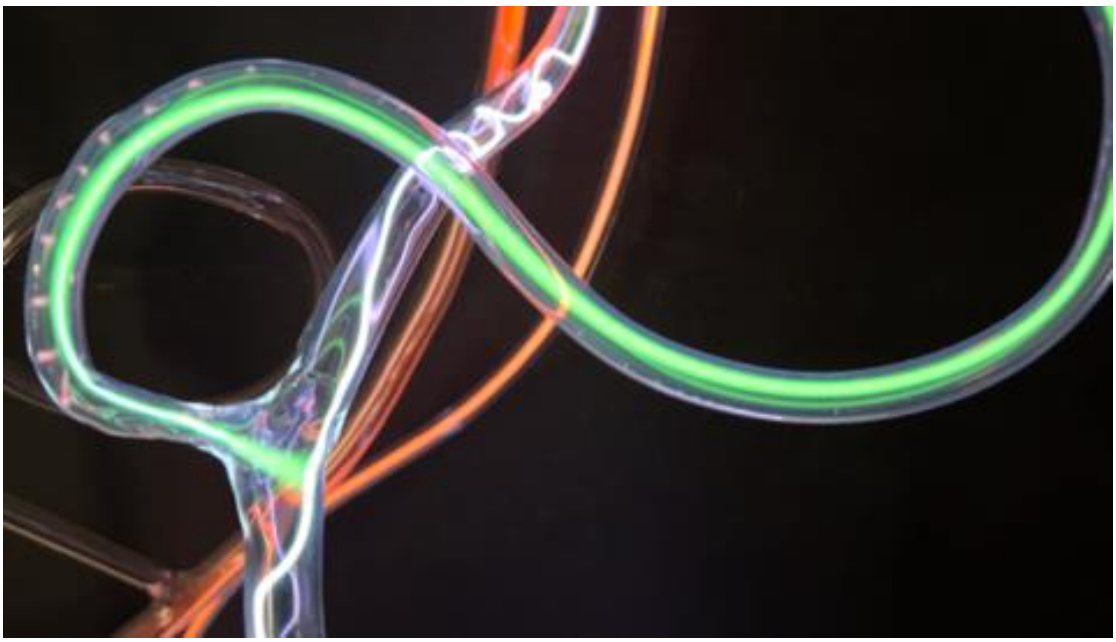


Figure 168 *Entangled* detail, 2024, borosilicate glass, ionised neon gas, transformer. Under differing conditions detail on left shows spectral continuous green plasma sheaths possibly Bremsstrahlung, around the xenon ionising, the neon red-orange glows capacitively in the background.

Under differing conditions, particularly through touching the object, we observed an eerie green glow forming sheath-like structures around xenon's spectral lines (Figure

168). Pfefferlé suggested this might indicate *Bremsstrahlung* or free-free radiation (discussed in Chapter 2), in which freed electrons bend and influence each other in space, and due to conservation of energy they release energy their as light. These actions are potentially responsible for creating the eerie glow.[408] I can only imagine this glow being like what early experimenters with discharge tubes might have observed; this green phenomenon illustrates plasma's complexity beyond simple gas identification.[409]

Throughout this research project, Toby Ehinger of Weft Productions documented my leaky and tangled tripartite process, often filming in slow motion to allow methods and plasma effects to unravel slowly on screen.[410] Ehinger documented the *Chambered Vessels* and the installation *Nearly Barely There* installed at Canberra Museum and Gallery. Much like my own videoing of demonstrations during the Strattman masterclass, documentation enables one to analyse the behaviours and discharges, contemplating the contributing tripartite influences and physics involved. For me, visually documenting plasma discharges functions like filming magic tricks or sporting performances; replay becomes a tool for refining techniques and understanding this practice's minutiae.[411] Multimedia artists Peachey & Mosig (Rachel Peachy and Paul Mosig) also filmed my plasma vessels as a visual component within a performance

[408] Kirshner, interview with the author. Kirshner also references xenon's green glow during our interview, noting that he recalled a different mechanism at play than the distinct spectral lines of atoms.
[409] This green phenomenon and its chemistry are discussed in depth by Carl Willis channel in the episode. Green Plasma in Xenon-Nitrogen Mixture. In this presentation he describes the complex chemistries involved in the green emissions associated with this combination. *Green Plasma in Xenon-Nitrogen Mixture*, 2013. https://www.youtube.com/watch?v=jv9txBM9U5E.
[410] "Tobias Ehinger - Weft Studio | LinkedIn."
[411]Mróz, interview with the author. When I asked: How do you experience Responsiveness within your plasma practice? "As a kind of magic. Although I see myself as a very rational person who strongly believes in science and understands the laws of physics that control plasma discharges, the responsiveness of plasma discharges is still hypnotizing and magical. So maybe I'm not so rational after all!"

installation.[412] Film stills from both these documentation projects appear throughout this exegesis.

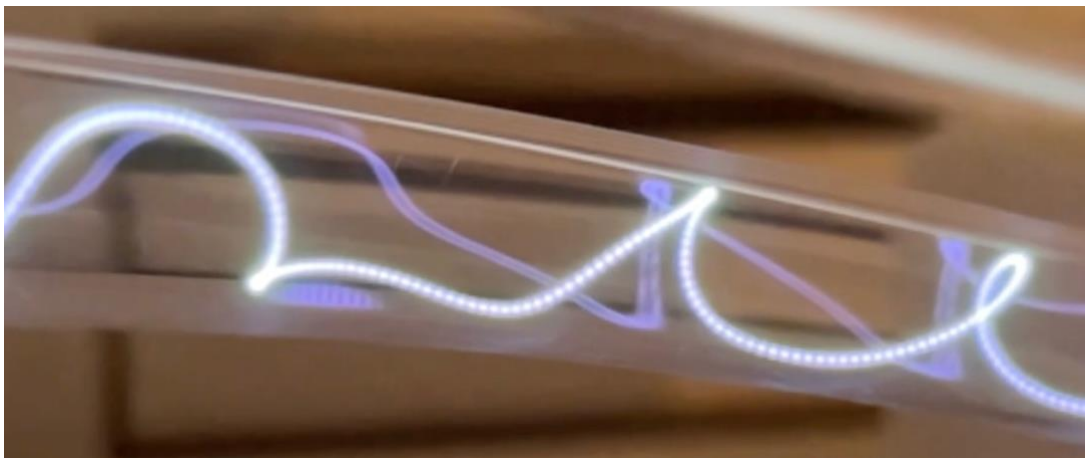


Figure 169 Krypton beads of light, and its reflection within a tube in the kiln. (2024)



Figure 170 Dendritic branching lines forming, in Xenon and neon tube. Video still Peachy & Mosig 2024.

When photons of light are filmed at close distance or slowed down, one can almost make sense of their discontinuous radiating events (Figure 169, Figure 170). Documentation also captures how the illumination is responsive, influenced by the

[412] Artists Peachy & Mosig.

audience-observer approaching these objects, making tangible the subtle relationality that this medium affords.[413]

I have been fortunate to share my research through masterclass teaching academic paper presentations, where the support documentation of imagery and film ameliorates the complexity of the tripartite process. Co-teaching has provided opportunities to disseminate my leaks and tangles approach. Leading an intensive masterclass with Cole and giving an illustrated artist talk at the 2023 Ausglass Conference to Australian glass practitioners demonstrated the entangled relationship of plasma phenomena within glass. Fitting with the conference theme "Futures Past," I linked historic gas discharge object making with my current practice. The video documentation provided evidence of plasma behaviours and the interactive quality of the medium, and the workshop used hybrid glassmaking techniques, introducing ways to work with the fourth state of matter.[414] This work continued at Pilchuck Glass School (2023), a world-leading glass centre for art education and experimentation, where I led a masterclass with Echols II under a session themed "Transcendental: To a Higher State."

In our masterclass titled "A Glowing Potential," we exposed glass professionals to technical, theoretical and conceptual approaches to plasma illumination, describing how "plasma differs from neon in that we create dynamic and interactive light that responds to your proximity and touch." Guiding students through the tripartite process and witnessing their wonder, understanding, and joy when they first elicit a plasma-illuminated form confirmed the profound impact and relational quality of mentoring,

[413] This documentation will be included in the research exhibition.
Additionally, artists Peachy & Mosig have filmed several installed objects for their own creative performance project.
[414] "Ausglass."

sharing the value of the interpersonal relationships in the diffractive way I experienced this research.[415]

The paper at Cambridge enabled me to present alongside research related to Holocaust memorials, locating common themes of the invisible being made visible. This opportunity to engage with interdisciplinary academic discourse strengthened the theoretical rigour of my research.[416] At the 2024 AAANZ panel "All the Energies," I presented my leaks and tangles process, combining blown glass and electrical potential to transform inert gases into luminous plasma. Conference participants engaged in an informal session, interacting with my work on display in the Classics Museum, allowing me to see how energy transfer between encased plasma and viewer-participants makes visible moments of connection.[417] In contrast, presenting my research at the "Looking at Bodies: Sex and Gender in the Health and Medical Humanities" conference, which focused on medical imagery, allowed me to celebrate the slipperier and fluid inferences I draw between circulation and connection.[418] Visual documentation has strengthened my ability to communicate the subtleties of interconnection to specialist and non-specialist audiences.

Although I have been challenged by the practical and theoretical aspects of this research, from the rigours of contemplating the quantum realm to being implicitly

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[415] *Pretty Plasma AND Kiln Talk! Percy Echols & Harriet Schwarzrock*.
[416] Constellations – 2024 AHRC International Conference 16–18 September 2024, Robinson College, Cambridge. Arts and Humanities Research Council (AHRC) Doctoral Training Partnerships (DTP) across the UK, the Open-Oxford-Cambridge.
[417] "2024 Conference | Past, Present, Possible Futures." AAANZ | The Art Association of Australia and New Zealand, n.d. Accessed December 22, 2025. https://aaanz.info/aaanz-home/conferences/2024-conference-australian-national-university/.
[418] "The Medical Humanities in Australia." Looking at Bodies, Sex and Gender in the Health and Medical Humanities" From the 5th to 6th June 2024, researchers gathered at the Australian National University (ANU) in frosty Canberra for a symposium on the medical and health humanities. The symposium was the second one organised by the ANU Health Humanities Network, led by Katie Sutton, Keren Hammerschlag and Claire Hansen, and funded by the Research School of the Humanities and Arts at the ANU.

reliant upon the expertise of others, there is something comforting in the fact that this medium insists upon the decentring of the viewer-participant, including the artist. Through communication, engagement, teaching and research, a philosophical understanding emerges that sharing methodologies for eliciting plasma illumination through practice-led research models the action of relationality itself.

5.7 Reflections

This chapter has traced my experimentation with installation strategies for proximal audience engagement, exploring how plasma illumination's properties emerge through multiple relationships rather than existing independently. Testing, showcasing, and presenting research outcomes reshaped my understanding of plasma illumination from an inherently responsive medium to a relational one, influenced by the tripartite production of objects, their setting, and their proximity to other objects and viewer-participants.

Resonating with Carlo Rovelli's relational interpretation of quantum mechanics, which builds upon Werner Heisenberg's quantum revelations, I recognised that plasma illumination makes visible that phenomena are contingent and manifest through relations rather than in isolation.[419] This theoretical framework was initially informed my studio investigations, and then enacted it through strategies for exhibiting the work.

As discussed in this chapter, testing and exhibiting across diverse settings evidenced plasma illumination as profoundly relational. Each location posed unique challenges demonstrating plasma's environmental responsiveness. Transformers placed in proximity required careful adjustments, while unseen influences on electrical circuits

[419] Rovelli, "The Relational Interpretation of Quantum Physics." 3. "The solution offered by RQM is that facts are labelled by systems. They are labelled by the systems involved in the interaction where the fact happens."

within suspended vessels both enhanced and impeded responsive possibilities. These experiments demonstrated plasma art practice as one of responsiveness and relationality rather than fixed production. Implementing strategies for interactivity and observer engagement during exhibitions led to the intimate capacitive objects of the ongoing *Symbiotic Object* series.

By embracing plasma illumination within experimental glass vessels, my work remains open to possibilities. These objects invite and make visible invisible relationships between viewers and artworks, responding to proximity and interaction. These installation configurations and settings reiterate that plasma illumination is influenced by multiple dynamics arising and collaborating between objects, observers, and environmental conditions, a finding that repositions responsive plasma art as fundamentally relational. Plasma illumination within creative practice reveals itself as a medium that is continually affected by broader influences, making visible relational dynamics that typically remain imperceptible.

Chapter 6: Conclusion

Through this practice-led research, I have made illuminated glass objects and installations, engaging the physics of light through conceptualising models of the subatomic actions of matter. When I elicit plasma within a glass vessel, this "aurora in a bottle" demonstrates the luminosity of plasma as a radiating phenomenon at an intimate scale.[420] This practice makes visible plasma illumination as constituted through ongoing relationships between glass, gas, and electromagnetic energy, together eliciting a continuously changing state of matter.[421]

In my sculptural blown-glass artworks, I initially considered plasma as responsive, observing its reaction to the touch of a viewer-participant.[422] By changing my focus to conceptualising action at the subatomic scale, I found that proximity is a far more accurate description of the variable influences exerted by our mere presence. Our bodies, which generate electricity and are composed of conductive fluids, can alter plasma's visual behaviour as matter and energetic fields intersect. Here I will discuss the conclusions reached in relation to the development, production, and exhibition of these works. Through installation and engagement, both maker and viewer-participant directly influence the phenomenon within the vessels. My exegesis frames this understanding of plasma illumination as fundamentally relational, demonstrated through the artworks.

6.1 Historical Context

I positioned my investigation by connecting historical gas-discharge illumination with contemporary studio practice. In the 1800s, plasma practices in the

[420] Cole, interview with the author.
[421] Burm, "Plasma." 226.
[422] Barad, "On Touching—the Inhuman That Therefore I Am."

sciences made visible the relationship between electricity and magnetism. A tripartite process for producing gas discharge illumination within glass was innovatively developed for creative plasma practice, comprising vessel formation, atmospheric manipulation, and electromagnetic activation. Historic exemplars allowed for the observation of the glowing behaviours of radiant matter, making visible the interconnectivity of electro-magnetic within a glass vessel.[423] Experimentation with gas-discharge illumination led to revealing the subatomic particulate nature of matter. These practices illuminated the relationship between charges, particles, and radiation (including visible light).

To achieve these effects, blown-glass vessels were meticulously crafted for aesthetic as well as scientific purposes. Geissler tubes became objects of intrigue, delighting salon audiences. This historical confluence of making within science, where the glassmaker's creativity influences discovery, provides a purposeful framework for contemporary plasma practitioners seeking to harness plasma's capacity to invite curiosity and evoke wonder.

The term plasma derives from the ancient Greek "to mould," which I initially understood as physical shaping. Through this research, I have come to understand it relationally, as evidencing the relationship between luminous phenomena and the conditions that elicit them: the glass vessel that encases them and the electromagnetic field that activates them. More importantly, Langmuir's analogy between blood plasma and luminous plasma, both circulating smaller particles within a containing medium, was utilised as a conceptual lever throughout this project. As both subject matter and iconography, it informed my vessel making through abstracted circulatory vessels

[423] Crookes, *On Radiant Matter*. 3.

(*Chambered Vessels* 2024–25) and tangled vascular conduits (*Entangled Vessels, Lightly Tethered* and *Symbiotic Objects* 2024–2026).

6.2 Methodology

Employing a diffractive methodology consolidated my project in two significant ways. First, it allowed me to acknowledge and celebrate my indebtedness to the lineage of glassmakers and plasma practitioners whose historic innovations and experimentation established the tripartite process required for plasma illumination. Through focused mentoring rather than strict apprenticeship, I discovered how waves of influence transformed my approach to making and thinking, emulating physical occurrences of diffraction. My mentors catalysed material investigations, such as working with laboratory glass, enabling me to craft tangled yet robust vascular forms. By encouraging me to investigate minute phenomena at material and subatomic scales, they provided the means and confidence to reimagine my material practice.

Demonstrations piqued my interest in capacitive illumination, where glass components containing very low-pressure gases can glow when brought into the electromagnetic field created by a specialised plasma illumination transformer. These demonstrations led to my own experimentation. I now employ capacitive conduits within installations as symbiotic elements; initially appearing transparent, they glow when viewer-participants approach, demonstrating plasma's relationality as a medium and its capacity to make visible the invisible.

Similarly, by documenting interviews with eleven international plasma practitioners, I extended the documented language and conceptualisation of plasma illumination's responsive and relational characteristics. All practitioners emphasised electromagnetism's centrality in eliciting plasma's luminous behaviours, describing subatomic actions that technical literature could not convey. These discussions

reaffirmed that material interactions and experiential knowledge lead to innovations through sustained engagement with the tripartite process. It leads to a diversity of practice and fosters its development.

Second, this methodology echoes my understanding of creative practice itself, where matter, light, processes, and concepts intersect and influence each other unexpectedly. My less-engineered leaks and tangles tripartite process for plasma illumination, enacted through studio practice, demonstrates how traditional craft methods combined with knowledge of physical properties can inform contemporary creative and material research. Examining this medium and its histories in (at times particulate) detail produced unforeseen effects that inform my artwork, building upon my understanding of this changing state of matter. This re-combinatory approach relates to Ingold's conceptualisation of "flux," where objects are made or animated through the interaction between material, maker and environment, corresponding to the tripartite process for plasma.[424]

Diffraction as methodology demonstrates how concepts, makers, materials, and contexts influence the physical system of these objects. This practice-based research offers a rare convergence: physical diffraction occurs within plasma illumination while diffraction simultaneously operates as the metaphorical framework guiding the research.

6.3 Findings in Relation to the Research Questions

The artworks and this exegesis answer three questions framing plasma as a relational medium capable of making vivid the proximity and presence of the viewer-participant.

[424] Ingold, *Making*. 101.

Question 1: How might novel glassblowing techniques affect plasma's luminosity?

I hybridised techniques from studio glassblowing with neon and scientific glassmaking traditions to affect plasma's luminosity. These were evidenced during the development and production of the *Chambered Vessels* (2022–2024), *Entangled Vessels* (2023–2026), and *Symbiotic Objects* (2024–2026). Variations to colour application techniques during glassblowing, along with phosphor application, influenced the perceived colour of the vessels' discharges in the objects. Moreover, the appearance of the discharges can also be affected by the thickness of the glass vessel. Most directly, it is changes to the interior surfaces of the glass vessel that affect the movement of the plasma and appearance of the encased plasma illumination.

Initially, I considered the interior glass surfaces of a vessel as inert. Yet, as the distinction between gas and plasma states involve subatomic changes, the atomic and electron rich glass surface asserts an influence. Within my practice, I encase non-reactive or noble gases within the vessels. When subjected to increased thermal energy, these non-reactive electrically neutral gases free negatively charged electrons from their atomic orbits, changing the distribution of charge. Within the atoms or molecules that began as electrically neutral gas, electrons become separated from their nuclei. These remaining positively charged ions and freed negatively charged electrons constitute the plasma state, yet the plasma retains overall charge balance. When this gas is excited into its luminous plasma state within a vessel, the plasma is influenced, attracted, or repulsed by subtle charge distribution within the plasma and with the interior glass surfaces. These surface interactions affect gas discharge behaviours, highlighting the glass vessel's role as both container and contributor to luminous effects.

My adaptation of the traditional Italian glassblowing technique *Incalmo* (also informed by Geissler tubes and scientific glassblowing) resulted in the *Intra/twined* (2023–2024) and *Chambered Vessels* (1–8, 2025). These objects make visible plasma excitation within separated and then interconnected glass chambers. The glass surfaces with their transparent structure allowed me to observe the oscillations of plasma as an electric fluid. The constrictions within the interconnected Chambered *Vessels* created volume variations in which evidence of diffractive interference patterns can be clearly seen within the vessels. Streaming plasma, with its particulate and wavelike characteristics, necessarily changes direction as it traverses surfaces, or moves through small apertures, appearing to spill and trickle into larger chambers, revealing intersecting wave-like interference properties.

Question 2: What role does proximity play in influencing plasma illumination's behaviours?

Within my work, proximity between the viewer-participant and the work makes visible fields of influence whose effects span from the subatomic to the human scale. When an object or viewer-participant approaches a plasma-illuminated vessel, the quality of light shifts. In vessels with a soft glow discharge, physical interaction evidences itself through brightening around contact points; sprinkles of light meander towards that site, and arc discharges traverse to make contact. The plasma vessel is powered by a specialised alternating current transformer creating a radiating electromagnetic field. This configuration allows the environment, including observers, to function as conduits drawing more current or providing grounding within this extended physical system. Viewer-participants' proximity alters luminous discharge behaviours, revealing invisible electromagnetic influences extending beyond our own and the vessel's boundaries.

By contrasting plasma illumination equipment (namely, the manifold, with its interconnecting tubes, valves, pumps, and gauges) with my experience of blood plasma donation (plasmapheresis), conventional distinctions between what exists inside and outside a vessel, body, or manifold became blurred. This comparison allowed me to extend ideas of proximity and connection, developing circulatory vascular forms into the subtly interactive *Entangled Vessel* (2024–26) installations.

By harnessing capacitive illumination strategies, I developed the *Entangled Vessels* and *Symbiotic Objects*. I manipulated transparent glass tubes into Möbius-like tangles and vascular circuits. These vessels, filled with low-pressure neon gas, initially appear transparent but glow, flicker, and pulse when brought into electromagnetic fields created by specialised plasma transformers. This capacitive configuration allowed me to suspend wireless components within installations, creating intimate, moveable objects. In the *Entangled Vessels,* one suspended piece is directly powered by a transformer, while a capacitive component glows in proximity without wired connection. Rather than considering this glow parasitic, I developed the ongoing *Symbiotic Objects* series: looping tubes and Möbius forms that glow when placed on specially wired transformer bases. These artworks challenge traditional object-making by demonstrating that outcomes depend on dynamic relationships between materials, environment, and viewer presence.

Question 3: In what ways can plasma be conceptualised as a medium to reveal relational dynamics?

Within my project, relational ontology and studio practice demonstrate how this often-invisible state of matter affords luminous effects, allowing us to visualise and affect complex physical interactions. Plasma illumination within a glass vessel allows us to

intimately and uniquely observe the effects of subatomic interactions of matter influencing the behaviour of visible light radiation, itself a relational dynamic.

During production, the manifold is the site of atmospheric manipulation required for the tripartite process of plasma illumination. The manifold is where conditions for plasma illumination are manipulated, playing key roles in drawing a vacuum and introducing non-reactive gases. Intensive mentoring in adjacent glassmaking traditions and study of historic artefacts demonstrated the manifold's and experimenter's direct contribution to producing plasma illumination. Barad's agential realism, extending Niels Bohr's quantum mechanical insights, positioned these objects as extensions of the manifold, removable components of the apparatus.

By suspending these components alongside plasma-powered objects, I tested how seemingly transparent components could become luminous within the transformer's extended field. The capacitive components of *Lightly Tethered* flicker with viewer proximity as our presence draws more current from the transformer, while simultaneously providing an electrical ground for this leaky circuit, both eliciting changes in luminosity.

During this project, Carlo Rovelli's writing on his relational interpretation of quantum mechanics offered crucial insights. This interpretation reveals that phenomena emerge through co-production; as Rovelli describes, “objects are its nodes.” By employing Rovelli's interpretation, tested through material experimentations, I reframe my understanding of plasma illumination from a responsive medium, which I understood through cause and effect, to a relational medium where phenomena are co-constituted. This practice-based research, including its tripartite process, offers opportunities to provoke, present, and observe the relations underpinning plasma's behaviours.

6.4 Contributions to Knowledge

This research makes original contributions across four key areas. First, leaks and tangles, my adaptation of the tripartite process for plasma illumination, offers a less-engineered, more maker-oriented framework for working at the intersection of glassblowing, vacuum practices, and electrical phenomena. By employing a cross-disciplinary approach that integrates science and traditional craft in the making of contemporary art, I demonstrate how hybridising scientific glassblowing techniques and neon fabrication methods with sculptural glassblowing can produce affective and relational objects and installations. This project argues that artistic practice can become a site for deepening material understanding, showing that making practices can make scientific concepts visible by eliciting changes in states of matter through sustained attention to processes and relationships.

Second, the procedural and technical contribution of electrode attachment hybridises various styles of glass working to warm-weld the glass, requiring a working understanding of temperature ranges to avoid thermal shock when preparing the glass. This method has opened avenues within my blown glass work, enabling me to develop more complex, interconnected Incalmo Chambered Vessels. These make visible plasma behaviours across varied volumes, objects I could not achieve without the warm-welding technique. Working with borosilicate glass, informed by manifold and vascular references, I developed new bodies of work. The material's robustness enabled me to create moveable components.

Third, my interviews with eleven international practitioners revealed insights into plasma illumination's responsive complexity and contributed foundational knowledge to this practice. These interactions uncovered technical innovations and artistic insights, including discussions of conceptual drivers in creative practice, material considerations, methodological approaches, and the roles that wonder and magic play

in both creating and experiencing these works. All practitioners emphasised electromagnetism's centrality while describing subatomic actions that technical literature alone cannot convey. Documenting these interviews provides a vital platform and knowledge resource for future practitioners, preserving experiential knowledge within an emerging field.

Finally, I have demonstrated that plasma illumination is an ideal creative medium for making proximal viewer-participant interactions observable through luminous behaviours. Engaging with Mróz's interactive interpretation and Strattman's kinetic description of plasma illumination challenged my initial understanding of plasma as merely responsive. I employed Barad's concept of intra-action to visualise the nuances of this luminous phenomenon. I was encouraged by Davis, whose interview provided guidance for an artist working without complex mathematical language to conceptualise physical mechanisms within plasma (such as Paschen Curves, Penning mixtures, and metastable states) and how they contribute to plasma’s luminous behaviours. Ultimately, through contemplating Rovelli's relational interpretation of quantum mechanics as a descriptor for researching material interactions, alongside experimental, practice-led research, I argue for plasma illumination as a relational medium within creative practice. Working with plasma illumination reveals a material phenomenon made perceptible through interactive installations that invite viewer participation through direct contact (touch) and indirect contact (electromagnetic proximity). Producing these works has become both method and means for contemplating physical matter while making visible proximal moments of connectivity.

6.5 Impact and Significance

This investigation connects historic scientific methods for eliciting plasma illumination with contemporary specialised glassmaking techniques, demonstrating the vessel's role in luminous discharge effects. Initially aiming to extend a responsive reading, the

research evolved when proximity rather than touch was identified as the required catalyst, challenging traditional object-viewer boundaries.

Tested and disseminated through conferences, exhibitions, masterclasses, and publications, this research contributes to experiences and discussions on making the invisible visible, circulation, materiality, and connection through proximity. This research offers interactive luminous installations with moveable capacitive objects demonstrating that our presence affects plasma behaviours. The artworks explore how proximity, connection, and relationality (at human and subatomic scales) contribute to experiences of materiality and presence.

6.6 Limitations and Future Directions

Technical demands of working with high-voltage systems and low-pressure atmospheres within hand-blown glass limited achievable scale and complexity.

Through this project, I have focused on the part of the tripartite process for plasma illumination that I could most readily influence as an artist and glassblower: the glassmaking. Future collaborations with researchers specialising in electromagnetism or working with quantum field theories could develop projects, objects or installations that visualise the agency of electricity or the ubiquitous connectivity of quantum fields through glass vessels.

While I drew on theoretical connections to quantum physics, through Barad's agential realism and Rovelli's relational interpretation, to conceptualise mechanisms of connection, the scope did not extend to quantitative electromagnetic analysis or formal interdisciplinary collaboration with physicists, which would strengthen claims about plasma's relational properties. Future directions to address these limitations include

collaborations with physicists, engagement with New Materialist literature, Science and Technology Studies, and collaborations within Medical Humanities.

Of particular interest for future research would be the opportunity to work alongside a Baradian scholar, thereby fostering a more rigorous engagement with Karen Barad's theoretical framework and bringing it into dialogue with the material and relational conditions of plasma illumination practice.

The role of wonder, both as a driver of my own inquiry and as an observable response in the viewer-participant, remains a rich area for future investigation, which this research gestures towards but does not fully resolve.

Broader histories of perceptual and luminous installation practice, including fluorescence, perceptual environments, and experiential light art, offer fertile ground for situating plasma illumination within a wider lineage of light-based and immersive practice and remain an area for future research.

The relationship between the material and electromagnetic conditions of plasma illumination and electronic interactive art remains underexplored. How this analogue, sub-atomic practice both aligns with and differs from digital interaction processes and systems-based art is a productive direction for future inquiry.

What began as an investigation into plasma's responsive properties evolved into inquiry about relationality itself: how phenomena exist through dynamic interaction rather than isolated properties. I discovered that the viewer is not an external observer but a collaborator, their proximity influencing plasma's behaviour. Plasma illumination offers more than visual spectacle; it provides a material means to experience the relational conditions of our existence within fields that typically remain invisible, offering pathways toward recognising our fundamental interconnectedness.

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Appendices

Fieldwork Approval Protocol



ANU Research Fieldwork Protocol

All University staff, students and visitors are responsible for maintaining their own health and safety, and that of other individuals across the ANU campus. Staff, students and visitors must understand and comply with the University Guidelines at ANU campuses when participating in ANU activities.

The re-commencement of fieldwork in all Australian states or territories will be approved, provided that:

1. Required Research Fieldwork Protocols are met.
2. A COVID-19 Fieldwork Plan has been approved by your supervisor.
3. A WHS Risk Assessment has been completed and approved by your supervisor.
4. A travel form and all supporting documentation have been approved in the ANU Travel System.

This document will be reviewed quarterly commencing October 2020 by a sub-committee of the University Research Committee to assess the current COVID environment and address any emerging issues.

PROTOCOLS	
☐	The researcher must comply with all ANU, Federal and state government COVID-19 health restrictions and guidelines which apply to all areas of their proposed fieldwork, including travel and transit. This includes restrictions and guidelines applicable to particular locations or sites within a state or territory, such as (but not limited to) indigenous communities or COVID-19 vulnerable populations.
☐	The researcher must develop a COVID-19 Fieldwork Plan (using the template below) for their fieldwork, demonstrating how they will comply with all ANU, federal and state government COVID-19 health restrictions and guidelines which apply to all areas of their proposed fieldwork, including travel and transit.
☐	The researcher must obtain ethics approvals prior to the commencement of their fieldwork if required
☐	A WHS Risk Assessment must be completed and attached for approval
☐	Travel related to fieldwork should be minimised where possible.
☐	Vehicle operation for fieldwork is permitted, subject to the relevant state and territory regulations. If partnership, create and sign partnership agreement.
☐	Overnight stays are permitted, subject to the relevant state and territory regulations.
☐	Fieldwork that requires air travel permitted, subject to relevant state and territory regulations. Information on COVID Safe airline travel can be found here.
☐	Fieldwork should be conducted by staff located within the state of the fieldwork activity. However all instances of out of state fieldwork must comply with this ANU Research Fieldwork Protocol.
☐	The researcher must submit their COVID-19 Fieldwork Plan (using the template below), WHS Risk Assessment and ethics approval notification (where necessary) for approval by the Head of School, who will then forward it to the Research School Director for sign-off.

Australian National University

COVID-19 Fieldwork Plan

FIELDWORK INFORMATION	
Lead Investigator:	Harriet Schwarzrock [Curtis]
Person/s conducting fieldwork:	Harriet Schwarzrock [Curtis]
Location of the Fieldwork:	The 10 artist-practitioner interviews will be carried out in person by researcher. This will be conducted in various studios, in various States in America, including NY, Massachusetts, Connecticut, Washington, California.
Date/s of Fieldwork:	February 18-15th 2023, March 14-28th, July 1-6 th 2023, July 19-26th July 2023

All applications to re-commence fieldwork must include the following information.

The researcher Harriet Schwarzrock, will be up to date with Covid19 Vaccinations and booster shots before undertaking field-work. Travel via aircraft and public transport will involve wearing P2 masks and appropriate Covid19 hygiene measures. The researcher will follow American CDC guidelines. Upon entry into the USA, the researcher will abide by current Covid19 guidelines. Travel into subsequent States will involve following regional and state guidelines.

These semi-structured in-person interviews in the Artist-practitioner's studios, will afford practice-led insights into the working methodologies of artist-practitioners working with Plasma Illumination. This in-person methodology will allow for technical, artistic and conceptual frameworks around the use of plasma illumination to be discussed. In person interviews will enable documentation of specific techniques which are not easily captured over video calls. The researcher will wear masks when interviewing and documenting participants in their studio-workplaces. The fieldwork dates are bracketed by confirmed residency and teaching opportunities in 2023 in The United States of America.

Travel will involve Aircraft, public transport and private vehicles, where the researcher will wear an appropriate mask, and follow any regional guidelines. The researcher will stay in motel accommodation, or with the Artist -Practitioners.

If there is a Lock-down or border closure during the proposed fieldwork period, the researcher will follow regional guidelines. Whilst also consulting Australian travel information for details specific to Australian Citizens. If the researcher or participants suspected COVID-19 exposure during the proposed fieldwork period, the researcher will isolate to minimise risk to self and others. If the researcher suspects COVID-19 infection during the proposed fieldwork period, they will test and quarantine to minimise the risk to others. If confirmed of a COVID-19 infection during the proposed fieldwork period the researcher will isolate for the required period. Following all Public Health guidelines.

Approved Head of School Name	Mitchell Whitelaw	Approved Research School Director Name	
Signature		Signature	Kate Mitchell Digitally signed by Kate Mitchell Date: 2023.01.20 12:10:59 +11'00'
Date	20 / 1 / 2023	Date	

Interview Transcripts

Author's note: I have made minor adjustments to these interview transcripts for readability, removing repeated words, primarily my own (ums, ahs, and likes). The conversational style aided this project, allowing me to understand the nuanced complexity, responsive, and relationality of the constituent methods and interactions that contribute to the phenomena of gas-discharge and plasma illumination.

1 Tate McAluney

[20.11.2024]

Harriet Schwarzrock: HS. Hi. Thank you very much. I wanted to ask a few introductory questions to get started. How would you like to be referred to, and what pronouns would you prefer?

Tate: Okay, you can refer to me as Tate, and I use he/him/his pronouns.

HS: OK. And where is your studio, or where do you work when you're making your plasma illumination?

Tate: So, I work in my bedroom. Because I don't have a space to do that, I have a desk in my bedroom for plasma experiments, and then I have another desk where I just do schoolwork. So, it was just in my room.

HS: ... And what are you studying at the moment, Tate?

... [internet issues]

Tate: Yes, so, I'm currently studying chemistry at the University of Southern California in Los Angeles. Yeah, so chemistry, and I hope to advance the carbon dioxide reduction field and come up with new catalysts to turn carbon dioxide into fuels. And basically, that's because I like having my work and play separate. So, I wanted to have a PhD study in chemistry, more like renewable energy, with a focus, and then my passion is plasma art.

HS: Fantastic. And what is your background that has led you to use plasma illumination or be interested in plasma illumination?

Tate: So, my background would be my bachelor's in chemistry and coming across high voltage devices and high voltage art on YouTube or on and on Internet and I thought it was so cool and I thought I really want to know how to do this so I took it upon myself to learn how to how to make these devices... and because I've always been interested in chemistry and physics and so. Luckily, it lines up and exploring YouTube and seeing plasma art, then being a scientist myself, I just love it! Exploring how do variables in plasma art, for example, I love wrapping my head around a concept, especially if it's beautiful like plasma art. I want to understand what variables affect the plasma. How do they work together to affect it? It is so, they're all so linked together. [And yeah, I answered more than your question.]

HS: Oh no, that's beautiful. Because there is so much all linked together, isn't there? And I guess this next question is a bit of an arty version of asking about those variables, but how would you describe responsiveness within this form of practice?

Tate: So, I would describe it as: how does the plasma behave when you approach it? When something outside the vessel approaches it. Typically, I think it's how we think about how the viewer of the art can affect the art piece. I'd say that's what responsive is to me.

HS: Fantastic. And I know that you've got an amazing project with the plasma toroids. I'm not sure how much you feel comfortable talking about that at the moment, but are there particular techniques that you employ or have devised that expand your application of plasma illumination?

Tate: I'm comfortable, so the plasma toroid artworks are a different kind of plasma discharge than I think the most common type of plasma art, which is the high voltage power supplies. The power supply that makes the toroid creates an inductively coupled plasma, whereas most plasma art uses a power supply that creates a capacitively coupled plasma. I'm pretty sure these are engineering terms that we've adopted as

artists because capacitive and inductive are these electrical engineering terms. But the plasma toroid power supply that creates inductively coupled plasma has really expanded the plasma art space.... I'm definitely going to be focusing on this plasma toroid generator. Because it's a deceptively simple circuit and you can unlock a whole new part of plasma art, which is putting chemical powders inside your volume, and when the chemical powders come into contact with this loop of plasma, which is significantly hotter than normal plasma and plasma art, it will ionise the chemicals. The powdered chemicals that you put in operate in the same way that a fireworks show works, where different chemicals give different light, so I'm super excited by this type of art.

HS: Is the difference between inductive and capacitive due to the circuitry as you're describing it, or in the attachment of the work?

Tate: It's due to the circuitry, so the capacitively coupled plasma typically works because one end of a coil creates a high voltage, and then you bring that near your work, and that will ionise because it's near the high voltage. But for the inductively coupled plasma, what happens is you're focusing on the induced electric field by the circuit, which is circular, so that makes a circular plasma. Whereas, for the capacitively coupled plasma, it looks more like a field; there is no [formed] structure to it. But in the inductively coupled plasma, it comes out [circular] because the circuit makes a circular electric field. And it's not so with the capacitively coupled plasma.

HS: Would you mind describing what you see within the vessels that you make? The plasma that you see within the vessels you make.

Tate: Absolutely, (one quick thing), I've learned over my time experimenting with plasma art is, I'm more of an engineer, I hire an artist in Russia to make the plasma globes because I don't have the materials to. So, I get the globes from him, and then I work on the power supply side. So, I don't make the vessels. That's that. But what I see in the vessels is, well, you have sometimes the capacitively coupled plasma, but then sometimes you need to like kickstart the plasma toroid and you bring a high voltage

source nearby, a little Tesla coil, and then what can happen is you allow that circular plasma loop to form, because you're helping the gas inside the vessel to get conductive enough to form that that plasma ring, and then you see it. The plasma ring starts very thin, and then as soon as it forms, a loop of plasma, then the circuit dumps a bunch of energy into it, and it gets thicker, and it rises as it has some convection currents in there, and then sometimes it can be stable, other times it can disappear as fast as it forms. So, it's very responsive to the experimenter or the artist, and then once you get it working, let's say it's stable. Then you can make it responsive for a viewer of the art piece, because they can move the vessel with their hands and that that moves the toroid inside. Or sometimes you can also change the circuit a little, just turn a knob so that the toroid is more responsive to bringing your hand near it and it'll like wiggle or things like that.

HS: They're very captivating to look at. I enjoy the videos that you've been putting up. [on Instagram @https://www.instagram.com/backmacsci/].

So, when you when you work with getting somebody else to manufacture the componentry for you, do you ask for specific pressures and specific gases for your own sort of experimentation? Or have you already ... worked out what you feel is the best mix [gases and chemicals] and follow through with that?

Tate: Typically, what I've been doing these days is I see the palette that some artists are making and then I say, oh, I really like that. I'd love to experiment with that with my own device, so I could ask, can you make this mix? .... I really like that mix, could I experiment with [it]? And so, they send me one and then I use my power supply to try to get new effects that they haven't gotten. So that's what I like to do, to mess with the power, with existing mixes that other plasma artists have made.

HS: Fantastic... Staying with the toroids... I was very curious to see you referencing the term dusty plasma. You mind expanding upon that?

Tate: I can. I actually don't know too much about it, but I think how I understand it is in your vessel you have gas and you also have some particulates whether they formed

because of a reaction in the vessel or if you added it. And what can happen is these particles could be stirred up because of convection, or because maybe they acquire a charge from the power supply and then they are repelled or attracted around the vessel. It's really cool 'cause you can see the flow of the gas inside the vessel sometimes which is not something that you see in every plasma art piece. There's this really amazing piece in the Museum of Neon Art in in Glendale that I really like seeing, it's a piece by.... Larry Albright, it's basically this huge cylinder with a xenon, I think and some nitrogen or something and it makes this beautiful smoky green discharge. And that reminds me a lot of how I understand dusty plasma, you can really see the gases' voluminous character, and I think the dusty plasma allows that too. So, to see the gas or the particles moving around in your vessel, which is super cool, it's like a mini snow globe, but it's lit. It's plasma, yeah.

HS: Amazing, actually, I've been curious about that xenon and smoky green as well, and sort of wondering what your thoughts are on what you're seeing? Because I've looked at this with a plasma physicist before and there was a bit of a discussion that, rather than just seeing the spectral lines of the matter there that we might be seeing the bremsstrahlung of the electrons bending in space.

Tate: Maybe. Yeah. I don't think I could comment confidently on that, but hey, maybe... OK. I was going to just look up Bremsstrahlung; because I know it happens in like nuclear reactors or something. I say its radiation produced when a charged particle decelerates when deflected by another charged particle. Yeah, that could happen in plasma art, right? Yeah. Yeah, maybe that's part of it too.

HS: Unless it's just impurities in the vessel, it could be that too.

Tate; Yeah, I think it's like more the emission line emission lines... I remember talking to I don't know which plasma physicists you talked to, ... but I know there's a physicist, Carl Willis. He's a nuclear engineer and scientist and knows more about it than I do, that's for sure. So, he posted on YouTube about this... mix and why he thinks it glows green. And I think I really trust his conclusion. It's like a xenon nitrogen short lifetime

molecule that's making this green. (It's chemistry, so I should be able to understand it, but I haven't looked at it enough.)
HS: Yeah. Thank. I'll. I'll look up Carl's work there.
Tate: Sure, I think you have a lot of fun and a lot of learning it's just he has a great YouTube page...
HS: Tate, I was wondering if you could let me know how you envisage the viewer or participant engaging with your work, and if that's important to you?
Tate: Yeah, so I guess I imagined if you were being able to turn a knob on my device and change the behaviour of the plasma. Or moving the vessel and that would change it as well. I imagine they would mess with the vessel because the plasma toroid ...vessel. You can mess with it 'cause it's not connected to any electrodes, so that's nice. Then you have the base with the supply in it you may be turning a knob. And then you get your hand close to. Sometimes it can mess with it and that's how they would interact with it by moving the vessel or the changing the power supply themselves.
HS: Fantastic, and I guess along those lines, what do you [or] how do you experience that kind of interaction with your own work?
Tate: Yeah, it's a great activity. I do the same thing that's 'cause I would want the viewer to do the same thing as me, because I get so much out of it. Like just such a great interaction of seeing something you're doing create something like really beautiful and so I did the same thing. Mess with the power supply. Mess with the vessel and see if I can make anything new. This is just like a time I spend, and can I see anything new today?
HS: That's great. I guess along those lines, with the inductive power supply that you have, is it a similar thing when you come close to the work that you're creating an easier ground as well as drawing more current?
Tate: Yeah, it is... It's also like as you get closer, you can sometimes [influence the] plasma it will move here and there is as you come closer. You know those like those observations that you said, those still hold for the inductive power supply too, because

the coil that creates this inductive current in the vessel, because it's like an inductor and it's operating at a high frequency, then any sort of anything coming close to it will change, like the **parasitic capacitance** of the circuit. And I will say this, though, it's also less influenced by someone approaching it than a capacitive discharge, that's for sure.
HS: Oh, that's interesting. That's interesting. Wow, I do love that term. parasitic in relation to this.
Tate: Yeah. Yeah, parasitic capacitance, yeah.
HS: Well, I guess I'm curious about if there's anything else you'd like to share about working with plasma or if there are things that you'd like to see in your own practice.
Tate: You know, I'd like to see more of these xenon-like mixes and experimenting with, can you use the power supply to generate this [green] in a vessel. There is a piece that I want to make like in the near future, basically it's the smoky green mix and at the bottom is like the inductive power supply, that or a normal like capacitive power supply with just like metal tape with a single electrode just touching the vessel. And then having the glass vessel shaped sort of like an hourglass. Not so like thin in the middle, but a vessel that would allow like the gas, let's say, when I energize the bottom of, like this hourglass-shaped figure with that higher pressure of the smoky green mix, you're able to see these convective effects. So, when you ionize it with like a high enough energy, I think what you'll see if you shape the vessel in the right way. You'll see the gas in the vessel behave like a fountain like liquid. So, I think what you'll see is when you energize it, you have this green smoke form at the bottom of the vessel, and it'll be pushed out of the constriction in the middle of the vessel and into the upper part of the vessel. And it'll be like a glowing green like smoky cloud. I haven't seen any piece like that before, so I want to do that and I think there's some pieces that have done almost that, but not in like just the pure dusty.
HS: They don't mix, yeah.
Tate: Yeah, not in the keeping the cloudy-ness of it, like some pieces have they make a filament, but I'm wondering, can I make a power supply and change it so that it doesn't

make a filament but rather just makes it just makes this glowing green cloud that like goes up like, I'd want to do that.
HS: Well, I guess you'd get beautiful effects with that changing diameter.
And the changing shape it would be very interesting to see how much the shape changes. Even in the Toroid, I guess along those lines, have you experimented with different shapes of the circular inductance field, and do you see changes in that?
Tate: So, I haven't messed with that too much, but I know that if you add like multiple coils around a glass ball for example, like a plasma toroid flask you can call it, then you have the plasma toroid and it jumps between them and it goes crazy. So yeah, changing the coil configuration would change it, but then also some people were curious about the phenomenon, if I make a triangular coil, will it make a triangle? If I make a square one, will it make a square? But I don't think it will I think it'll just stay a circle. Yeah.
HS: Wow. Actually, when you have some of those pieces and you've got the larger tubulation coming out the side. And it's not entirely circular. The whole way round. When you put that vessel on in different orientations, does that affect the shape, in your opinion of what's forming inside?
Tate: So, it doesn't affect the shape, it will always form a circle, but the neck part of it, I've noticed, it does play like a role in it, or at least for the experimenter. So, this is so funny because it's just an accident right, so, my first plasma flask I had made, was made by Wayne, and the way he makes them is he takes these like flasks and basically seals them off with the gas inside. So, you have this sort of neck attached to this sphere, that's just like how he made it... to disconnect [it], like the tip off. He made it just like a round bottom flask with a little bit of a neck, and then it tapers off and so I noticed that it was like helpful in getting the discharge started. Because I could actually grab the neck and rotate like this, otherwise, I'd have to sort of spin the globe by like trying to rotate it in there, but it's just so much easier to rotate that neck. Then also I found that you were saying earlier, about like if I come closer, will I draw more currents from the from the supply, and the answer is yes. So, when put like I this is one of the

tactics for getting the plasma to start is, if you maximize the amount of contact that you make with the neck with your hand, then you can like get the supply to draw the most amount of current. And so that is like a key part in like getting it to form. Cause a lot of people tried to make this circuit that I showed in my video, they're [saying] like I can't get it to light. I was [suggesting] trying to make maximum contact to the glass? That's like a really key part like. So, that vessel shape has been a happy fortunate event, fortunate for us plasma toroid people and it makes it makes manipulating it easier. There's also something going on where, that if you have your hand on that neck, it somehow helps create some like higher voltage that gets it started. I'm not sure if it's creating a higher voltage or creating a bigger load so it draws more current or something. I think it does have to do with like the capacitive effect of my hand.
HS: Yeah, I think I heard Pat Colentine once describe a vessel like that, as a non-self-starter.[425] They need a little bit of a tickle and sometimes in an installation I've some pieces that have required a little touch with a long wooden stick with a little bit of copper foil on. So, the gallery staff could give it a little tickle and buzz to get it going in the morning.
Tate: That's funny.
HS: Pat's "non-self-starter" always makes me chuckle. I guess that changes with the resistive load as well as the different contents of the vessel.
Tate: Yeah, I'd say. So, the different gases have different ionization energies and that makes them easier or harder to get started, and then the pressure is a big thing like. 15 torr is like pretty easy to get started. That's what most of my plasma toroid experiments were at, but then one of the artists that I have make the globes for me his name, is Zerg in Russia. That, in order to get these chemicals to emit their spectrum, he needed to raise the pressure of the gas inside. Because raising the pressure should allow the plasma to reach higher temperatures, and then be able to get these chemicals to, burn

[425] Pat Collentine non-self-starter

brightly. So, he raised it to like 50 torr. Now they're much harder to start and they require more power, so it's [also] the pressure.
HS: That's so interesting, isn't it, that there are all of those variables. So many variables and I mean I don't understand enough about electrical engineering, but I sometimes I've heard Wayne Stratman speak about that the resistance and reactance within the plasma that becomes part of the circuit as well. How it all plays its part.
Tate; Oh yeah, it's definitely part of it. I'm talking to these really smart people on the Discord app. There's an app for communities called Discord app. They're really, I mean, a lot of them are like college or even teenage guys who are interested in testing. So, they teach me, they're like learning electrical engineering on their own. Many resources out nowadays and. Yeah. The plasma is part of the circuit, and if you really want to, mess with the plasma even more, and you consider the plasma as part of the circuit, that'd be another way to affect the plasma is to work that into like your power supply design. So, I know Steve Ward made a power supply that senses how ... much voltage or current or power, and it makes sure that the power supply doesn't generate too high of a voltage. If the plasma streamer like gets too long like he did some great electrical engineering on it, like a power limiting feature, and it was really, it was really cool.
HS: I feel very privileged getting to chat to you in a with your specific knowledge. I think it's really wonderful, I've been so interested in the glass form and how that affects what's happening? And I know that there's an interplay with, the power supply, of course. So, it's fascinating to see your work where the emphasis is the other way round, that, you're forming [different plasma's] with more of a repeatable form. Fascinating.
Tate: Yeah, it's one glass form and then changing the material inside and changing the power supply. But I think I think more than anything, I think the materials inside is super, super interesting and has a big effect on the color and. And also, the brightness, the pressure, I think that has to do [with how] that changes the brightness and then of course the power supply and more power is brighter, and you could never stop learning new things with plasma art. Why I like it.

HS: It is quite extraordinary! I have a cheeky little question that I've been asking people as well. Does wonder play a part in your interest in plasma illumination?
Tate: Yeah, definitely so. I think. I think that's why I do it because. I know that the wonder part is that I don't understand it completely. And it's so incredibly beautiful that I just stare at it in awe. Just like very awesome and yeah, it's, it's amazing. Yeah.
HS: It is quite amazing. Isn't it.
Tate: Yeah, yeah, I'll, I'll, I'll. I have some really cool videos I want to release about, like with the plasma toroid with the work that the artist Zerg is doing and showing off his vessels a bit more for a wider audience. Because he's doing some really good work and playing with materials, so he does mostly like changing gases pressures, because he does mostly plasma toroid stuff too.
Yeah. And I actually want to share with you a conversation I had with Mundy Hepburn once. Like a year or two ago. I remember it was right when I posted the toroid thing and he was like, That's really cool. I've never seen anything like that, you know. And then I was like, yeah, your stuff is amazing as well. I love what he does with the Smokey Plasmas and his huge vessels. And it was so good to talk to him. And I [asked why], don't you just want to make a chart and see how all the variables, so we can actually, get to the bottom of this and see how all the variables and interplay.
His [response], don't do it. Don't do it. You'll go crazy.
It was so funny. He was like, don't even, don't even try to put all these variables on a spreadsheet and try to put the plasma behaviour or even try to draw any sort of qualitative [data]. Because I think that's what I really like about Wayne Strathman's book *The Art of Plasma* is he kind of does that for us scientifically minded people and people who want to systematically experiment, like scientifically experiment with the plasma. So, if I make the vessel thinner, then I'm going to get more plasma current and that kind of [thing]. And so, funny enough, hey, I think maybe one day I'll try to do it, even though Mundy warned me not to, I still really want to have or make a spreadsheet of all these variables.

HS: I'm sure we'd all love [it] if you did that. Yeah, there are so many variables, aren't there? Yes well, thank you so much for your time, Tate, really.
Tate: Yeah. Thank you for facilitating this. Yeah.
HS: Yeah, it's really insightful to hear different approaches and different backgrounds that that come to that same kind of fascination and interest.
Tate: Yeah, that was a blast. About plasma with you?

2 Steven Cole

[02.05.2024]
Harriet Schwarzrock-HS: Hello, Steven. Thanks so much for agreeing to this interview, I just wanted to ask some really basic questions for documentation. What is your name and how would you like to be referred to?
Steven Cole SC: My name is Steven.
HS: OK, cool, and Steven, where is your studio?
SC: My studio is in Bayswater, Melbourne, Vic.
HS: And what is your background that has led you to using plasma illumination?
SC: My background is being a second-generation Neon Bender who fell into it, just went going into assisting my father when his boss was hospitalised and [I] just got hooked from the first time, he put some glass in my hand to actually try and manipulate it.
HS: Excellent. Excellent. Do you do you want to say anything about your father or your father's business?
SC: Yeah, my father, when did this start in? 1940? and he wanted to enlist, but when he turned [of] age and they asked him what he did, he said he's a neon tube processor and they told him he was a required tradesperson is in Australia. As most of the lighting back then was done by Neon in its larger term of cold cathode tubing.

Which was used in most of the munition factories and all that because with blackouts, it would instantly turn off and when the ... sirens come on, the lights would also instantly Illuminate again. So, they refused him to actually [enlist].
HS: Oh, wow. Wow, because it was essential. Fantastic. Wow. And he had a studio in Melbourne.
SC: Yes, he was a commercial artist for a large sign company called Neon Electric. But after many years, he set out on his own and built up his own business in partnership with another bloke. And then I worked there, when I got to the age of 22. I asked my dad if I could have a pay rise and he went to talk to his partner and his partner agreed to give me a $10 pay rise for five hours extra work a week because I was only working for 35 hours.
But I disagreed with him but couldn't influence him anyway. So, I knew that there was a former worker setting up a neon workshop in another sign company in Dandenong and I wrote them a letter inquiring about the possibility of me transferring there. And they welcomed me with open arms.
HS: Wow, so you moved companies?
SC: Yeah.
HS: Just as a as a reference; I know one of the really famous signs in Melbourne is your father's sign, the “skipping girl” or was produced by the company that he was working for?
SC: Yeah, that was produced by Neon Electric Back then. He was their main glass bender. So, he was the one who brought little Audrey to life, in my opinion.
HS: Amazing. Amazing. And then after your time working with the Dandenong factory, you've set up your own studio.
SC: Yeah. Again, it happened by accident.
As with normal signage, Neon goes around in cycles, and after being there for five or six years they were downsizing because other countries where pinching their work from their major clients, they were undercutting them. And my boss at that place at the

Sinner moulding, actually asked me if I'd go on to two- or three-day work. Now, with my father still working in his own business I knew there was a lot of work out there. Not in the field that this large size company was working in. So, I went home, spoke to my wife, I went back the next day, went in to talk to the boss and just said, if you let me rent the room and equipment can I have a go on my own, he said. Yes. He was a great man, so there I started.

HS: Oh wow. That's fantastic.

SC: I spent two weeks virtually doing nothing, rubbing my hands, walking around the factory. First day of being self-employed, I walked into the factory with six layouts in my arms.

HS: Gosh, wow. Now, Steven, I know that you know a hell a lot of a lot about plasma illumination from your history working with neon signage, but also your interest in the Plasma Trade Alliance and in some of the Facebook beginners' groups, you're an excellent [mentor] and taught to so many people. So, I wanted to ask you, or maybe I should just start with what we were talking about before about how you would just [explain]where neon fits within plasma.

SC: Well... Neon is light. Only the argon tubes are doped with mercury and its very small amount of mercury. But a neon tube is pure neon being illuminated by an electrical field. There is no filament running through the tube and the tubes don't actually get above the body temperature of a human in their operation. So, it's more, the illumination is caused by the collision of the excited atoms moving around a tube which creates the colour.

Very early when I started processing tubes, I noticed that neon had its own life had its own.

A feel and in many ways, you could vary it.

It was just an instant, you know. Neon has an Aurora around it as well as inside it to me.

HS: And thank you for reminding me of something I really wanted to capture as well in this interview is how you first described to me what plasma is or what our endeavour is.

SC: As I explained to people who come into my studio **that we capture an Aurora inside glass**. So, we could actually physically make the Aurora Australis, or the Northern Lights within a vessel and put it up as an artist and scientific piece together.
HS: It's magic. Thank you, Steven. I'm very interested in responsiveness within plasma or that aspect or element of it. And I wanted to ask you; how would you describe responsiveness within this form of illuminated practice?
SC: **As we know, the human body is also an electrical field.**
So, when you go near a plasma vessel that is already illuminated it will be enhanced by the electrical field of the person close to it or actually touching the vessel.
HS: I've heard this described in two ways. Sorry, as a subsequent little sneaky question and in one sense, I've heard it described as grounding and in another sense, I've heard it as drawing more current is do you have an opinion or is it just a general kind of change?
SC: No, I have it that it draws more current because the atmosphere outside the vessel is actually the grounding of the field. **So, when you touch it or you place some part of your body near it, it's actually drawing from your presence.**
HS: Fantastic. Are there any particular techniques that you employ or that you've devised that expand the artistic application of responsiveness within plasma illumination?
And that's a bit of a nasty trick question, because a lot of the time you work with double electrodes.
SC: Yes. Yeah, my first plasma units were started as being processed as neon units where I make my quadrants or tridents and I had two electrodes on it. **After processing the tubes, I drew off an electrode, returning it into a single electrode vessel**.
As at the time I did not have an oven or even external temperature [inductor] that I could use to actually clean and sterilise the glass.

HS: Great. So, you were using the technology of the electron bombarder to heat up the glass to clean the glass and then doing that really sneaky thing of nipping off, drawing off that second electrode afterwards.
SC: Yes.
HS: Yes, which is something I've tried hard to copy off you many times. It's quite a tricky little technique that. Steven, I wanted to ask, how do you envisage the viewer engaging with your work?
SC: The people that I showed [it to], were to in the studio, attracted to the organic nature of not only the glass but the plasma that's on display with inside the vessel. It's, you know, a revelation to them that we can actually capture an Aurora illuminated. I still find it astonishing.
HS: Yeah. And how do you experience that idea of responsiveness of the plasma within the objects you make?
SC: **My love is to actually to see the gases after an ageing period, totally separate and you have different light different colours and different and reactions to the magnetic field or the electrical field depending on the shape of the vessel.**
HS: So, are you describing that sort of difference in colour that you'd see within a lower pressure plasma piece?
SC: I like very low pressures. Yeah, where the colour separation sort of stuff [occurs], I am still fascinated by the higher-pressure range and the effects that it can give.
But I feel I'm more organic in nature and the simplicity of just, a vessel sitting there and slowly changing over a period of time it's form or colour output with the different gases as they react to the ambient temperature outside. The gases become “more” … when the area is warm and become more sedate in a cool environment.
HS: Is that sorry, this is me being a luddite now is that how you would describe when you see, say on your try branching forms? The appearance of neon at those at the tips. Or do you feel how? How would you describe that?

SC: That's an occurrence because the heavier gases, xenon, krypton [&] argon actually pushed [by] the lighter gases being helium and neon to the outer reaches.
So, in a neon form if you combine neon with Krypton, it will give you a lilac colour as you have the krypton having to pass through the neon before it comes through the wall of the vessel.
HS: It's very it's been very interesting for me to learn a little bit more about how those levels of excitement and illumination happen. Yeah, and that almost counterintuitive aspect of that, some of the larger, heavier atoms ionise more easily than some of the smaller lighter atoms as well. It's yeah, quite interesting.
Would you mind if I snuck in another sneaky question… I'm in awe of how technically adept you are with the signage and the bending of glass and how intuitive it is for you to work the material and I guess I was wondering, do you see it as a line of light that you're manipulating when you're working in that tubular format?
SC: Yes… I read some other artists I work with described the neon artists as "writing with light" and in a sense, that's very intuitive of what we actually do? **My favourite type of neon artwork is more symbolic using the light as a definitive way of attracting the eye to solve your message.**
HS: Does that move away from text space? More so, is "text" more work for you?
SC: It's more work. Yeah. Whereas when artists come into my studio, because I do facilitate their work. I explain to them the capabilities of working with glass. The 3D aspects of working with glass and the illumination aspects of what working with glass… As it is your work, not mine, I am just your facilitator. I will give you every bit of information you require, but then you tell me what you want produced?
HS: Yes. Yeah, that's very generous. … Yeah, I know you've got a very broad mind and an excellent level of experimentation and eagerness to try things and to help facilitate people. So that's so generous and amazing of you.
SC: In the previous week, on the Facebook group for Beginners, a young beginner displayed a sample of a tube that was quite light [bright]. I commented on that in my

belief that it was due to the pressure, that's drawn back into the tube and a neon tube is only 2% of atmosphere. So, I bent up a series of units exactly the same and filled them with different percentages of neon, with 100% [visible neon] being the 12 Torr that the tube is normally lit at - down to three torr; which is 25% of normal and there is a stark contrast in light being emitted by those tubes.

HS: That's very interesting because ... there's this interplay between energy and pressure as to how it's manifest. So yeah, I'd, I'd love to take a photo of that if that's all right, Steven. That would be amazing. Have you experimented with that with the other gases as well, or just with the neon gas. The neon at this stage, yeah.

SC: Yeah, just with neon for now yeah. I probably will replicate the same in again xenon and krypton, and helium. [Probably] not too much argon because it's a pretty stable and lazy gas.

HS: The lazy one.

SC: It's very, very hard to actually get it to do anything.

That's why there is minute amount of mercury introduced into an argon tube to create the UV light. If you put a mercury inside a neon tube, it will go from red to blue because of the mercury creating the UV.

HS: Hmm. I love that creep that happens in it in one of those tubes. That's yeah. Really beautiful. Steven, are there any other insights that you'd be happy to share about that level of interactivity of plasma illumination?

SC: I guess as an artist we can't exactly design a plasma vessel to illuminate it as we envision. **The actual thrill of illuminating** of illuminating a vessel and seeing how it has reacted to the amount or the percentage of, say, neon or Krypton, argon, whatever you put into the vessel and how it reacts to its driver force it can also a higher energy rated driver will make a vessel completely different to a low subtle driver supply.

HS: I really love the way you've been experimenting and developing work, that's capacitive. Yeah. Would you mind talking about that a little bit?

SC: Yes. Again, being I'd say a quite an organic sort of person. I'm drawn to nature and the Aurora australis... beautiful piece of nature and being able to create that without an actual connecting electrical point, very stimulating.
HS: And you've been doing that, experimenting with various plates or capacitive units where the illumination is elicited by, I guess are covered, large electrode essentially isn't.
SC: Yes. Yeah. I actually did an experiment many years ago with a scientific glass blower who wanted to make a long-illuminated tube, an electrode electroless tube. We set it into my oven and processed it and drew it down and filled it with different pressures then this scientific glassblower who is quite into electronics as well, grabbed some aluminium foil and wrapped it around both ends of this vessel and attached a normal neon transformer and the unit lit up like a neon tube. It was just introducing... a basic electrical field. Wow. How do you do this? So, from there I went to actually building bases for my vessels to sit on. Firstly, it was using replacement neon drivers to go to a metal base underneath a protective film, and they worked spectacularly. And then I saw my Facebook crew, a Russian electronics expert who loves playing with plasma is quite and is evolutionary in his work. He bought out a Tesla coil, a flat pancake Tesla coil base. That you could actually sit more than one unit on and actually have it illuminate and it's just... yeah... I go past my little display and it's very rare that I cannot stop and touch.
HS: Yeah, that's interesting, isn't it, that it's still engaging even though you sort of know what's there? Yeah.
SC: Yeah. Know what's here, but just yeah just a touch and see to get a little bit more excited or you turn it around and it. I like doing natural organic tree forms as plasma vessels and actually to get the branches to like different like by just turning and creating a difference in the electrical field or magnetic field.

HC: Steven, at that sort of more subtle level, do you see a difference in the quality of illumination with the different glasses? Because I know you've done some work with borosilicate, but mostly it's soft glass.
SC: Yeah, it does change because the density of the glass the actual properties of the glass. When it's actually produced that type of glass will react differently to the wave light wavelength that's coming out of the tube or vessel.
HS: Because sometimes you almost see a blue fluorescence off of a soft glass.
SC: Yeah. Yeah, I think that's interesting that there are so many subtleties, especially with the lower pressure... objects. Yeah.
Wow.
HS: Well, thank you very much, Steven. That was, yeah, really wonderful to have the time to, to chat and pick your brain about some of those things. Thank you, unless there's anything else you'd like to say.
SC: When I first met Harry, she'd heard that it was possible to make a single electrode vessel. But never had she come across anyone saying yes, we can do it. I'll help you.
HS: YESSS You've been very helpful, very helpful.
SC: And Harry's engagement into this field is phenomenal.
HS: Oh, thank you. I've I mean I feel so well supported by yourself and by various different mentors. And I think something of what you said before was that you know that you've made something or that you've assisted to make something, **but something else is happening inside something non-human that you're not responsible for is happening and that just keeps such a level of engagement.** And I'm so grateful for all the different levels of expertise and input and insight from areas that I've got absolutely no idea of, that that really clarify things because there's so many different considerations in the practice.
I mean, it's kind of a bit silly, isn't it? How many?
SC: It's really science meet art, so it's.
HS: It's quite stimulating and a bit frustrating at times.

SC: Absolutely. But that's what makes it so exhilarating.
Yeah. When, if you don't mind me, ask sneaking in another little sneaky question when you you're very drawn to the borealis phenomena. Do you think of that as organic or inorganic or spiritual? Or is it because it…?
SC: Totally organic. No, I don't say it's spiritual. It's just a phenomenon a phenomenon that until recently, could never be explained. Yes. Yeah. And even with it being explained, it's still mind blowing.
HS: Yeah, the power of phenomena. Yeah, well, thank you very much.
Thank you.

3 Daniel Davis

[28.02.2025]
Harriet Schwarzrock-Harry: I've [initially] been asking everybody where your studio is.
Daniel Davis- Daniel: Well, my studio, and if you call it that, it is my home. So, we have a workshop in the basement, and I have a milling machine. I have a small lathe. I recently got a Welch vacuum pump from Wayne. It was his first pump and manifold, so I just brought that back from work, and it replaced the pump oil and the diffusion pump oil. So, I'm really excited to get that up and running. So, it would be my home.
Harry: Home Studio has been the most referred-to-place. You are not alone.
Daniel: If you ever get a chance, you should see Mundy's because it is a trip.
Harry: Yes, I've. I've had the great pleasure of staying with Mundy and Judy a few times and visiting or hanging out in the basement…. Yeah, it is pretty wild. It's one of my favourite places to visit actually.
Daniel: He is amazing, and I can't believe that he's made his own glass from beach sand…
Harry: I do love that Mundy is involved in every part of the process, every part.

Daniel: Yes, I think that that's such a credit to him because that provides such a well-rounded perspective, and one of the things that I'm particularly interested in is benefiting from people like Mundy and Wayne and your known expertise. But tying it together, making it more quantitative or mechanistic. I'm fascinated because, if you ask me about different gases and stuff [and Mundy] **ascribes personalities to each of them and I think that's fascinating**. I would be great to connect those personalities, his way of formalising or providing a structure to his intuition… with things like thermal conductivity and ionisation potentials and mean free paths and things like that to just be able to bridge this tremendous intuition and experience with… what other researchers have done. So, I think that's an area… of benefit to be gained in a lot of very interesting things to discover.

Harry: I did want to ask what your background was that led you to be interested in working with plasma illumination?

Daniel: So, I built a Tesla coil when I was in Junior Highschool. My best friend was my chemistry teacher and high school chemistry and physics teacher; he was also my astronomy and geology teacher. In my sophomore year I built a Foucault pendulum and the junior year I built a Tesla coil. Then, my senior year, I built a Van de Graaff generator and particle accelerator, but I will never forget that Tesla coil. My step-grandfather helped me, and he got me a high-voltage capacitor. It's very frustrating because Tesla coils are just like tuning in a radio, they are very selective… so I was getting nothing, nothing and then finally, as we incrementally increased the position of the TAP and got the tuning right… these tendrils started forming …off the discharge sphere and it was just an amazing experience. Since then, I was a finalist in International Science Fair during my junior year. I got a scholarship to New Mexican Institute of Mining and Technology[426], which is my bachelor's alma mater. After a year in Germany as a foreign exchange student, I came back to New Mexico Tech and then started my studies in

[426] https://nmt.edu/

physics and while I was there, I'm very glad that the school is quiet. It's only about 4000 students, and what I particularly liked about it was an exquisite school for was that there were a lot of faculty-student interaction, particularly at the undergraduate level. So, in my freshman year, I repaired a slow antenna which detects changes in electric fields due to lightning. I worked with Marks Brook and Charlie Moore, who are well-known researchers who both passed away. Then, I started working with Paul Krabel in my sophomore year. Then, I drove an interferometer out to Florida. So, this is a radio wave interferometer that can see into the clouds and detect the breakdown in the clouds with an array of radio antennas. Then my junior year, I started working with William Wynn, who is the director of the Langmore Laboratory for Atmospheric Research and started working on artificially triggered lightning. This was first, the theory behind or the proof of concept, if you will again go back to Marx Brooke and he was working with Bernard Vonnegut, who is Kurt Vonnegut's brother, an atmospheric physicist. And together they did an experiment at the Museum of Science, and Museum of Science has the world's largest air insulated Van de Graaff generator. It was built by its namesake, Robert Jameson Van de Graaff, and it went from MIT to the Museum of Science in 1955. But in the late 60s they came up with an experimental test and what prompted this test was the fact that Charlie Moore and Mark Brooke had flown these big balloons in thunderstorms that had kilometres of conductive cable, and they never got struck. Which was very surprising to them but then the Navy was detonating some depth charges in Chesapeake Bay and there was a thunderstorm, and the saltwater plume that was ejected up under the thunderstorm triggered lightning to it. And so, they had these two discrepant events these really long conductors that are just hanging out in the thunderstorm they don't get struck, but then we have this rapidly, ejected conducting saltwater plume that did trigger it and so. What they did with a Van de Graaff was they said, OK, we're going to take a wire and we're going to stretch it back on a rubber band, and we're going to release it and then shoot it at the Van de Graaff, and we're going to vary it speed and see if this has any effect on whether or not it triggers

lightning? Or triggers sparks from the Van de Graaff and low and behold, they found out that if the wire goes too slowly then it doesn't trigger lightning or doesn't trigger sparks. But if it goes faster than about 20 meters per second that it will trigger a spark and so they then hypothesized that you should be able to artificially trigger lightning, and if you wait for a thunderstorm to happen, you can measure electric fields of the ground and you'll see that they slowly build up as the thunderstorm charges, and then they'll be a natural lightning flash and they'll slowly build up again and there'll be a natural lightning flash. And if you launch a rocket right at about the time where the electric fields are still high but before a natural lightning robs you of the field then shooting up this wire, into the sky. A few 100 meters, you'll get sparks off the tip. And it will initiate an upward propagating discharge that then vaporizes the wire. And you have a natural lightning flash that's otherwise identical to a natural one. So, this was first demonstrated off a yacht in the early 1970s and it's since been a wonderful research tool for lightning. Without it, you don't know where lightning is going to happen, and you don't know when it's going to happen. It's really hard to have measurement equipment set up when you don't know those two things. Tall buildings and mountain tops were the biggest targets and research areas. But this allows you to know where it's going to happen if it. The triggering rate, the success rates usually only about like 60% or so. So, in 1994 I started working with John Willett who is an MIT alum on the Rocket Electric field sounding experiment, up until that point, they had done surface field measurements, but they really didn't know what the electric fields were like aloft, and he built instrumented rockets that would measure the electric field with height all the way from the ground up to a kilometre in the up in the thundercloud. And so, in 1996, at Camp Blanding, Florida. It's an Army National Guard base that has reserved airspace so you can do this. He launched the sounding rockets, measured the electric field with height, and then I launched a triggering rocket with one of these wires and did current measurements in the wire and measured electric field changes at the ground. With the subsequent triggering attempts and from those current measurements electric field measurements

we found out that as the wire goes up after a few 100 meters, a spark will be emitted from the tip, but it only goes like a meter or so, and then it stops and then the wire will keep going up and there will be another spark and it will go maybe a little bit longer and then the wire will go up a little bit higher and you'll get a few more sparks and the higher it goes the longer the sparks tend to be until it reaches a breakaway point where the energy that's released by the electric field is greater than the energy required to grow the spark, and so the spark just goes all the way up into the cloud and then you have a wire that is vaporised. So, I inferred the energy of these sparks and the length of the sparks from the rocket trajectory and the John Willet field soundings and then came up with the semi-empirical model that could then be used to predict OK if the ambient electric field is 15 KV per meter then how high of a wire do you need in order to trigger a spark. And what was nice was that it works just as well as a French computational model that was proprietary, and so it gave me some satisfaction that I had some predictive, that was, on par with us. There's also a Russian book called Lightning Physics and Lightning Protection. That's. Eduard M. Bazelyan, Yuri P. Raizer, and they had some analytical formulars in there that I could infer another model from, and it worked just as well as that too. As much as I am interested lightning, it's hard to make a living out of it, my wife was going to Northeastern University at the time, so I found a job at the Museum of Science, and I was like, wow, this is great, I have an opportunity to continue working my interest in high voltage working with Van de Graaff generator. I love working with people, so in 2002, I was an Educational Fellow and then later Educational Associate, so forth. My first my solo project, was up until that time the presenter had to stay in a Faraday cage to operate the Van de Graaff, and there were over 50 switches to operate the Van de Graaff and all the components in the theatre. You had to know not only what every switch did, but you had to know the order to turn them off and on. So, I made an automated computer control with it, and we set up the computer control, with the relays and so forth in parallel and then demonstrated that it worked. Then after it had worked for three months and we knew that everything was fine, that we tore out all

the switches, the manual switches, so that the presenter could then present on the stage, in front of the Van de Graaff and then only go in the cage, when they wanted to be struck and so that was very rewarding. We found, however, that with the Van de Graaff the purpose of what it was being used for is not what was intended to do so. The Van de Graaff was intended to accelerate particles, it's not intended to make sparks, and because the sparks rapidly relaxed the electric field, there is some charge that's stored in the insulating columns that then when the field is relaxed, create small sparks in the column and causes those insulating columns to chip and flake. And so, in abusing the Van de Graaff for lack of a better word, because we're using it for something that wasn't intended to do, we're gradually chipping away at those. I then worked with Chatham Cook at the MIT High Voltage Research Lab, we put some semiconducting bands on the column to relieve the stress in the joints and then push the electrical stress into the healthy regions of the columns, that abated the deterioration of the columns. So, we kind of stopped the clock, but the Van de Graaff hasn't operated quite as well because we don't want to push it any harder than we have to. But in that capacity at the Museum of Science, I was invited by a volunteer at the Museum of Science to go to an annual Tesla-thon, and this is kind of like ... if you can imagine a high voltage geeks get together and they're like, well, look at my Tesla coil, like, well, that's a pretty good spark, but check out this one. This is an annual event that was hosted by Ed Wingate in Rochester, and he did them for 27 years and I started going in about 2005 or so, it was during one of those meetings that I met Steve Ward, who at the time was an electrical engineering student at University of Illinois Urbana Champaign. He showed a solid-state Tesla coil and up until this time the switches had they were either spark gaps which is the same type of switch that Nikola Tesla used, or they were vacuum tubes, and the vacuum tubes had great control, but not very much power output and the sparks the spark gaps had a lot of power output, but not much control. So, Steve, [Steve Ward] really blew the lid off the whole vocation just because he was able to use insulated gate bipolar transistors which have a high current carrying capabilities that a spark gap coil might

have, but it also has the high voltage capabilities that a vacuum tube might have, and so you have control as well. He used that control to make the sparks sing. And the way that that can be done if you can imagine if you're taking a picture book and you flip the picture book if you flip the pages fast enough, then instead of seeing just a sequence of individual images, your eye and brain knit those images together to make continuous motion. And in the same way, if you were to, if you were to hit a drum. If you can imagine that if you hit it slowly enough, you just hear individual percussive events. But as the role gets faster your ear and brain knit those sounds together to perceive a tone equal to the rate that the drumstick is hitting the head. In a similar way whenever you make a spark with a Tesla coil, that heated air expands, pushes on other air that pushes on your ear, that makes a bang, but if you can make a sequence of sparks, and they're rapid enough, then your eye, your ear and brain will hear a tone equal to the rate that you're making sparks. With this exquisite control he was able to change the tones or make tones to tempo or play music with the sparks. This was like seeing pigs fly, and I was like, I've got to learn how to do this, another wonderful thing about Steve is Steve is very generous with his knowledge. He was sharing schematics for drivers and so forth. So, I got some printed circuit boards from him, and I built the first solid-state Tesla coil for the museum in 2010, my boss saw it and he was like, great, let's get that into the shows now.

And it's been doing shows daily since 2010. We had a second spark up coil that failed in 2013, so I built a second musical coil, and Steve has since really run the gamut between really large Tesla. Really small Tesla coils, low frequency ones, high frequency ones, and in particular, it was one of those shows that I met Jeff Feigen and his family (Wayne's protégé) but made that connection. So, it was much, much later, in fact, I want to say this is like 2020 maybe 2021 there have been some videos that had come out by Zerg Labs in Russia and I think the gentleman's name is Anton Zerkowitz, one of them was ball lightning in a bottle or ball lightning in a vodka bottle. So, he pumped out a vodka, and then they had some wires around the vodka bottle, and you can see this

luminous discharge in the vodka bottle. He also made these what he calls, plasma toroid's or he calls them a bagel generator because it's a luminous, ring discharge. And so, Jeff and Wayne emailed me and asked if I would be willing to help try and recreate this effect. I was also in communication with Steve, and Steve was also trying to recreate this effect, Steve recreated it, and then I gave some parts to Jeff, Jeff, quickly succeeded in doing it and stuff. Then, ultimately, I did as well, it was really a wonderful experience and very gratifying because there's also a young man, Tate McAluney, (who is a @backmacksci). So, Zerg was not very generous with sharing his knowledge, but there were some breadcrumbs to go off of, so I asked him was like, what frequency is this that he's like 13.56 megahertz. That's a very specific number. Turns out that it's an ISM frequency for industrial, scientific and medical frequencies, you can have instruments use this. What Tate had found out, well, Tate painstakingly went through a slew of his videos and then to uncovered things like, the power levels that he was using and so forth. But then he also met another YouTube or contacted another YouTuber called the Dooley, who then had done a bunch of academic research and then found out that Zerg hadn't invented these. They are properly known as electroless ring discharges and they go all the way back to a German physicist, Hittorf in 1884 or something, and you might say, how is that even possible? So apparently, they would take like an electrostatic hand crank generator and then charge up Leiden jars, which are old capacitors. And then spark the Leiden jars through a coil and then take an evacuated canister and put it in the coil and they and so they're cranking on these electrostatic generators. Then there's a bang, all that energy built up, and gets discharged through this coil wire and then you make this electrodeless ring discharge. Since then, there's even commercial products that have come out with these electrodeless ring discharges. So, it was very gratifying to just kind of see some of the past history that's come out of that. So, it's a very long-winded answer to say that I've been interested in lightning for a very long time, and one of the challenging things about lightning is that you don't know where or when it's going to happen. I really loved

triggering lightning because, then you could at least bring it down to a point, but that's not something that you can do every day. Requires restricted airspace and so forth and so then meeting Steve and learning about solid state Tesla coils and power electronics. It was like, wow, I can make sparks myself, that's really gratifying. But then seeing how people's work like Wayne's and Jeff's and Mundy's plasma art is, to me, very fascinating because it allows you to see phenomena that are very similar to what you see in lightning, but at much slower timescales. So, to me, it allows you to see things that you would need a high-speed camera to see lightning. I'm fascinated by being able to see what I can learn from, plasma art, like lightning in a bottle, and see how that scales up or what the similarities are in scale and how the scale changes things, how the gas mix changes things, how the pressure changes things. And so that's how I've come to know about and love plasma art.

Harry: Wow, that's amazing. Daniel, where are you working now?

Daniel: I am at Harvard University, so I am director of lecture demonstration, it's a wonderful gig. We are a four-person team, and we support about 30 courses over the year. Most are in physics, the next largest group is chemistry, but also Earth and Planetary Sciences. There're even some biology courses that we support with some neuron models. We support about 2000 undergraduate students every year. And it's really wonderful because from the student evaluations, the demonstrations are some of the most memorable and positive experiences that they have. So, I was at the museum full time until 2015 I have always advocated for raising money for, fixing the Van de Graaff and coming up with a longer-term solution and that I was not sure was ever going to happen. In the meantime, the position at Harvard opened up and in a parallel vein is I never had any demonstrations all the way from bachelor's all the way through PhD. I did labs but no demonstrations with it. And so, when I went to the museum, I was completely blown away I was like, wow, these people really know how to communicate to science and scientific concepts because they would use demonstrations. And what I didn't know at the time, I thought that that was a technique

that the science museums had invented, and **it was only later that I realized that there is a very rich history in demonstrations going back to like Robert Hooke and Michael Faraday and Sir Humphrey Davy and John Tyndall about performing demonstrations.** Robert Hook would do it for the Royal Institution and for the Royal Society, Faraday as well, Tyndall as well and particularly in the time of Faraday, the Royal Institution was in financial straits. It's amazing because the first one-way St. in London was to the Royal Institution because people were clamouring to get to Sir Humphrey Davies lectures and later Michael Faraday's lectures. That's a huge testament to the power of demonstrations to, to be able to attach an experience for the concept. So, what appealed to me particularly about the position at Harvard, which I continue to find very rewarding, is that I've since found this rich history of demonstrations, from academia, but also seeing how effective it is in informal science education, and so trying to, bring those communities together and. Because I think they both can benefit from one another a great deal.

Harry: Wow. When I was last in London, my favourite museum visit was to the Royal Institution and to see that studio down there. I'm sorry there weren't any demonstrations going on. I think that's something that Wayne has always said that it's a shame that there's not an opportunity to make a plasma demonstration-course that goes through some of those fundamental principles. Because I guess for myself, my entry into the field is through glassblowing, my knowledge in electronics and the electromagnetic phenomena is limited. But to see some of those demonstrations and to understand some of those principles really changes the way I think about what's happening in the work.

Daniel: I do hope that Wayne's agreed to talk to you and stuff because I think he's just a fountain of knowledge. And what I particularly appreciate about him and some of the talks that he's given, in Rhode Island and I was very grateful to him because he spoke at Harvard over the summer for a demonstration summit that we did. **He is making the**

point that, plasma art is really the consequence of the sum of three crucial technologies, glass work vacuum technology and electricity. He's given talks and gives talks, outlining the brief history of those three things. **It really is an amazing nexus of disciplines**. And I think it also is particularly demanding of plasma artists because it really does require that you engage all aspects of steam. Science, technology, engineering, art and mathematics. I think that really makes it unique as a medium and I think that can be said for, whether you're an artist or, a scientist that, engaging all those disciplines is valuable. But it seems to be most expressive in plasma arts that it requires that particularly.

Harry: I do like the way you worded that, nexus of disciplines, and that it's demanding. I feel that. I guess I wanted to ask about the thing I guess that's drawn me most to the medium, that idea of the responsiveness. I was wanting to ask you how you describe responsiveness within this form of illumination.

Daniel: So, I would describe responsiveness as a combination of the sensitivity and the scope, or the multifaceted-ness of how a piece responds to an observer, or someone engaged with a piece. I think what makes a piece most compelling is when it is responsive and that means that it somehow changes its shape or form or color or appearance. The palate that one has to do that varies depending on how many of the modalities that you can that you can effectively bring out of the out of piece will it respond to proximity, will it respond to touch, can you get color changes? Is it possible to get sounds out of it? Does it respond to magnets? Does it respond to touch, and are there knobs or dials, you can even engineer something like a theremin into the piece where instead of, instead of knobs and so forth, that you intentionally have an antenna or some sort of coupling device that, that enhances that, that proximal engagement. So, I would say that responsiveness is about understanding what a piece can do and then trying to engage that entire range that the piece is capable of expressing.

Harry: When I've asked this next question, it's been very much in relation to works like objects produced, but I can see that for you that it's probably more about different

apparatus that you've employed in in different scenarios so I am asking are there particular techniques that you employ or devise that expands the artistic application of responsiveness within plasma illumination?

Daniel: I want to be upfront and honest about the fact that, I've never had an installation. Never. I've never produced what I would consider a piece. However, I've been fascinated up until this point exploring with pieces that I've gotten, from, antique lecture demonstrations. So, there's a piece called Vacuum Scala, which is a vacuum scale which is basically, long discharge tubes that have two electrodes on each side mine are 50 centimetres each. There's six of them, and one's at 30 torr ones at, 10 torr ones at 5 torr ones at 3 torr, and then ones at .3 torr and the other ones at point. 03 torr. So, any case that the pressure varies for each tube and then. So, I got those on eBay and then started playing with them and how they, vary when we hook it up to an oil burner transformer or how does it, vary when I excite it with a Tesla coil and then how does the how does the discharge behaviour change. So they were, originally intended as lecture demonstrations to illustrate the change in nature of the appearance of the discharge with pressure. And so, at 30 torr, a discharge doesn't crackle or hiss, like it would at atmospheric pressure. And I think the cessation of the hissing and the crackling is at maybe 2/3 of an atmosphere or so. At 30 torr it's still very silent, but it's comparatively harder to light compared to the other tubes, the lower pressures. **There's a thing called a Paschen curve that talks about how the ignition potential voltage varies with pressure, the electrode separation.** At high pressures and large gap distances, it's hard to ignite the tube because at those high pressures, the mean free path, which is the distance that an electron takes to acquire kinetic energy before it collides with the neutral molecule, is so small that you need a really high electric field to give it enough energy to ionise an atom upon collision, and as you pump down a tube, then that mean free path gets longer and longer, which means that even at lower potentials you can acquire enough kinetic energy to ionise atoms. **And so then, there's a minimum in the Paschen curve where this mean free path is, is the longest.** Then

the voltage starts rising again so, if you pump air out or you pump more gas out past that minimum now, the electrons go, all the way or they don't encounter as many collisions, and so you have to have a higher voltage, to compensate for the fact that there's that there are fewer collisions. So that's why the potential goes back up. I was also in awe at that time because that was the first time that I'd seen striations, people call them beads. But, just seeing these luminous bright and dark bands, in the tube and that they would, migrate along the length of the tube. Then it's fascinating to see how capacitively, you bring your hand near it, can either make them go faster, bring them to a stop or make them reverse direction and so, understanding that these striations are ionisation waves and that the propagation velocity is related to the ambient capacitance and that you can vary that with proximity is really amazing. Although I haven't made original pieces myself, investigating these different phenomena with either pieces that I bought or that Wayne or Jeff have graciously lent or given me. I find it nonetheless fascinating to uncover these different effects. I also think that's where a tremendous amount can yet be done in plasma art. It seems like either the core and coil neon sign Transformers, or Bob Ianinni PVM 400, They're kind of the de facto drivers and Wayne recently had one of Steve Ward's plasma drivers that Bruce had lent him and was just in awe, wow my Tulpa Tubes they look completely different, than they did, with the PVM 400. Or even with Jeff's power supply and so expanding the PVM 400 usually goes between like, I think it's like 30 kilohertz to 70 kilohertz, maybe. I wish we'd had a scope, (oscilloscope) I thought to bring a scope and because I'm reasonably sure that Steve's supply goes higher, Jeff's may go slightly higher than the PVM 400, but not much. With things like the electroless ring discharge that's in the 10s of megahertz inner range and Steve has made a plasma candle that's at about 9 megahertz, and what's interesting is there is that that atmospheric pressure, but the spark no longer looks branched, but it looks like a flame, it's diffuse and it looks really like a flame. And then there's another coil that he's made called a fishhook coil. It's about 6 megahertz, and what's amazing there is that the sparks are all nested and hook-like like so if you

can imagine these nested sorts of fractals, fishhooks, that are coming off of it. Anders [Mikkelsen] has also observed that, with these quasi-continuous wave Tesla coils where you ramp the voltage up over time that, whereas normally you get these very long strait sparks that are not branched, provided that the rise, the ramping rise time is tuned properly with a small change in humidity, they can become very curved and almost loop around in circles. And so, seeing how things like relative humidity change things and the drive frequency change things, how proximity and capacitance changes things and that it doesn't have to be even just with touch, but it can also be with just the tube diameter. And it's interesting that these striations tend to have a separation that is on the order of the tube diameter, if you have a narrow tube, then they're fairly tightly spaced, if they're bigger than the spacing between them is larger. Or observations that Jeff Feigen has had in that if you have a tubulation off of the and you have striations in the tube, where that tubulation comes off, there's always a dark space there and so... Bazelyan and Razier have a book called Gas Discharge Physics, which I highly recommend, it's very technical, but it has a whole chapter on striations and there's other books like. James Dillon Cobain as a gas discharge or gaseous discharges, there's Sanbourne Brown from MIT. It also has one on electrical discharges and gases. JJ. Thompson has a couple of books, I think it's a 2-volume set, Jeff has a copy of them, but there's such a rich history in these things. And so again, back to what do I think would be innovations? I think there's still a lot to be done in expanding the drive frequency, looking at ramping or other modulation of the drive frequencies goes back to the colour changing clocks with the neon and the mercury, and that if you vary the frequency you can preferentially excite the neon, with different frequencies or different modulation, you can preferentially excite the mercury and so I think there's a lot to be done and learned there.

Harry: Hmm, with thinking about the striation. Is there a relationship with diffraction that happens in in the appearance of those baubles of light?

Daniel: Not that I am aware of, and so, but you're absolutely right that the alternating dark and bright bands very much look like a diffraction pattern. In a diffraction pattern you, you have the quintessential historical experiment is Young's double slit experiment, where you have light going through 2 narrow slits, that are very close together, instead of just seeing two bright lines on a far screen, you have these alternating dark and bright lines. And of course, the explanation is that whenever the path length, from both slits whenever it has equal path length or it's equal modular 1 wavelength then the light adds up constructively; you have constructive interference and a bright a bright band. But in the dark sections, the path length differs by 1/2 a wavelength. and so wherever 1 wave is going up the other is a through, they cancel out one another, you have destructive interference and there's a dark a dark band. But in striations, the analogy that I think is most helpful Eduard M. Bazelyan, Yuri P. Raizer point out that you usually get striations at a lower voltage or lower electric field than if you had a continuous glow discharge in the whole tube. And so, **their explanation is that you have the electrons create some ionization and a bunch of space charge, because it's easier for them to acquire enough kinetic energy over a small space then to have to break down the two at once.** And perhaps another mechanical analogy is I don't know if you've ever seen a karate martial arts master break a bunch of boards? What you'll see is that whenever they do that, they always put spacers between the boards and the reason for that is, forces are how fast momentum changes. You can move your hand much faster through the width of one board then through the entire the entire stack altogether, and so by putting spacers in between, you only have to break one board at a time or sequentially rather than the whole one and a lot. **So, in a very loose analogy, I would say that the electrons are acquiring kinetic energy initially and then causing some ionization then with that ionization, there's some space charge there that locally enhances the field that allows them to be further accelerated.** But that acceleration can't happen/or the ionization it's at too low a level for it to happen to light up the entire tube, and as a consequence, you have these

alternating bright bands where they finally have acquired enough kinetic energy to cause ionisation, and then the dark spaces in between where they don't have enough energy but they are being accelerated. ....so, they look very similar, but I think the mechanism is different than in a diffraction pattern.

Harry: Yeah, it's interesting I think I guess I've been thinking about diffraction a lot and I've been thinking about that the Young slit experiment and I've been thinking about how we communicate often 2 dimensionally or in diagrams and wondering how to think about it more dimensionally, because I guess we are seeing diffraction patterns happen in some of the plasma discharges, but it's so hard to describe what's happening because of the volume that it's working in.

Daniel: Then there are other fascinating effects, like photo ionisation, tubes can be easier to start whenever there's ambient light out, than it is in total darkness, so that's pretty interesting. They have sort of antique neon bulbs, I think they're GE-Thirty-fours, GE made them, but they have two electrodes that come up, and they're both hemi circular shaped. And then there's probably maybe a Torr of neon or something in there, they have screw bases, and you screw them in, and then both those faces light up. But the crazy thing is to put them on a Variac and then dial them down you can get them to where there's a threshold where they won't emit light, but then you can take a laser pointer, and if you take a red laser pointer and shine it on there, nothing happens. If you take a green one if the voltages are high enough, then the green one will cause some of the neon to light up. But if you have an ultraviolet laser pointer, that one will definitely cause the neon to light up. So, it's an example of the photoelectric effect is where you're ejecting electrons off of a surface because the energy of the incident light is greater than that required to eject an electron off the surface once it's ejected, then in the electric field within the bulb itself, it acquires enough kinetic energy to ionize the gas within it, so that's an example of photo ionisation, at least in lightning discharges, there's evidence to suggest that photo ionisation at the tip of the lightning flash is active

in perpetuating the breakdown. So, I think it's plausible to think that maybe that's at play in some plasma pieces as well.

Harry: I do love that your background is with lightning. I think it's so interesting to think about the bigger systemic interplay of what's happening within a discharge and how complete (that sort of atmospheric) those atmospheric contributors are into the discharge that happens.

Daniel: It's really very fascinating, but it also can be overwhelming, in that it's so complex I mean, there are papers that are completely devoted to the chemistry in the discharge, you've got nitrogen oxides, and you've got ozone, and the ionisation is happening in the dissociation and so forth. Another really fascinating aspect of it is polarity asymmetry. And so, this was first observed by Lichtenberg, (and I want to say this was quite some time ago, 1777 or so). He was a physicist, and what he observed was that. He charged up a plate and then brought a pointed a pointed electrode near it. Then, that point electrode was connected to a Leiden jar, and then there was a spark initiated from the point to the plate. But there was some dust on the plate. **What he then notices is that he had sort of sulphur dust, and then he had, like, red lead, which is lead oxide, and apparently, the sulphur charges one polarity, and the red lead charges the other polarity, and so he could sprinkle it on the on the, on the surface, and then found there was a dendritic pattern that was left on the insulating sheet.** In fact, that's exactly how Xerox copies work, you charge the surface, and then you can use a shadow pattern to illuminate it and then discharge the areas that are illuminated by the light, and those areas are still charged in the shadow, and then the toner is attracted electrically to those pieces then baked on and that's how you have a printer or Xerox copy. **But what he found was he found that even with alternating current sources, like an induction coil, that he would get negative breakdown in towards the middle, but then positive breakdown out towards the outside**. So even with an alternating current, where ostensibly there's its alternating polarity, he found this asymmetry in the mobility of the different charge carriers.

Coming back to are there any innovative techniques and so on, one thing I've observed that I think is really fascinating is Wayne has an electrodeless cup like a Dewar or a vacuum, but there's a few torr of neon in it, and then, you have these coaster drivers, that you have alternating fields, and you can put the cup on it and excite the neon. Well, there are fingers within the cup, there's no electrodes there. There's alternating current, and you can't have any direct current flow through the glass itself, but nonetheless, if you put a magnet in there, the fingers in the neon cup will turn around they'll rotate, and then if you flip. If you flip the pole of the magnet, then they'll rotate the other way, just like an electric motor. And so yes, they can be explained using the Lorenz force, if you have a positive charge moving in one direction and then a magnetic field that's at right angles to that, then, the force that charges moving or cutting through the magnetic field will be in the direction of your thumb. So, it is consistent with having a positive charge moving up the walls of the glass cup, now, the fields are stronger down below at the bottom of the coaster than they are at the top. And so, just like Lichtenburg observed, the positive charge seems to be able to travel further than the negative charge, and that's consistent with what we see with the positive net positive charge flows up the length of the glass. And so that's an example where you wouldn't think there would be a magnetic effect because it's alternating current, but because of this polarity of symmetry, we observe one.

Harry: It is fascinating, isn't! I do love that in Wayne studio that large, essentially a dewar. Tube with a magnetic spiral that just meanders up that piece. It is, yeah, well I guess it's magnetising.

Daniel: And I'm trying to think of the name but see. So, there was a very similar piece. It was called the electric egg, [Nollet] I one of the things I love about Wayne's work is that he seems to build off of historical examples. But then take them to the next level and I love the spiral tube as well I think it's just fascinating. One thing I'd like to try is using some high voltage Reed relays so that you can toggle the polarity of the discharge, so that first it would spiral this way, and then you could toggle the polarity of the discharge

and then have it, have it change. So that's something to try, again, I think there's huge scope of what can be done in changing the frequency, changing the polarity, how you modulate things, with other ramping or pulse width modulation, there's, there's a lot that can still be played with.

Harry: Daniel, when you were talking about the attraction and the interest in being able to have the lightning in the bottle and seeing it at different speeds. Would you mind talking about what you think you're seeing in regard to different colours or different expressions of discharge?

Daniel: Absolutely so, one of the things that I really find fascinating is like, say for example you have a Krypton iodine tube, and what's great is that by adding a little bit of the iodine, you can really slow the discharge down considerably. One of the things I find absolutely fascinating, I've also seen it a piece of the Museum of Science that Bill Parker made, is that you have these discharges that that propagate very slowly, but they have a fan out in front of them. They have a have diffuse fan glow out in front and then a stem, a serpentine stem behind....

You have this brush discharge out front and then that brush discharge is then feeding this serpentine stem behind, and in lightning parlance that fan out front is called the streamer fan and the serpentine stem is called the leader. Eduard M. Bazelyan, Yuri P. Raizer in their book, *Lightning Physics And Lightning Protection* talk about the different roles of those two parts of the discharge and so the streamer fan is like a glow discharge in a plasma piece, it has relatively high electric fields and the current density is relatively low and the conductivity is fairly low. In comparison, the leader channel, is like a contracted discharge like an arc discharge and in that case, the electric fields are lower, the current density is a lot higher, and the conductivity is a lot higher. **And there is a symbiosis between the two in that the streamer fan provides current to the leader channel to keep it hot and conductive.** And in contrast, that leader stem provides electric field enhancement that sustains the streamer fan. So that's one of the things that I've found really fascinating, because normally in lightening

in order to see those two structures, you would need a high-speed camera that, was at 10s of thousands of frames per second, those are prohibitively expensive [usually on the order of $10,000 for a day.].
Harry: Wow. And you need to have them in just the right place and not get fried.
Daniel: And so, exactly there's some phenomenal work that has been done and continues to be done using those high-speed cameras, but being able to see that in gas discharge, whether it be Krypton iodine or whether it just be a xenon discharge. Again, there's a piece at the at the Museum of Science that Bill Parker called Beaded Lightning and I think that's because originally, he was driving it with a much higher frequency driver, so that instead of having a continuous serpentine discharge, it was had a glow discharge out front and then a striated channel.
Harry: Wow.
DD: And so that's why he called it beaded lightning, I saw one of the Oregon Science Centre that looked like it was very, very similar, it was probably 4 inch or more like a 6 inch or 8-inch tube, that's probably four or five feet long. It has the characteristic white, but then there's a little bit of green in the in the fan, which Wayne says is either due to oxygen or nitrogen.
[Rambling]Harry: I guess that's something that I find fascinating when I'm looking at some of the discharges, even in my work, at one moment you'll consider them to be a continuous stream, but then at other moments you can see those kind of small discontinuities and you can see the kind of sheath around some of the discharges, considering different [atoms] things ionizing, in different ways within that space and what are the effects from the form of the glass as well in propagating what happens where within the space has been interesting for me to see? I guess there's not a lot of ways of really quantifying that but just being fascinated by that from within my own practice.

Daniel: I agree completely and one of the one of the first conversations I had was with Chris Burak [Instagram Barracuda-glass?] I started chatting with him on Facebook and it's just asking, how do different gases behave so forth, and he was explaining that; as you go down the periodic column, for the noble gases that things get harder to light. I was like, harder light, that doesn't make sense, I showed them a graph of the ionization potential, and as you go down the column, the ionization potential goes down. So why would they be harder to light if the ionization potential goes down as you go down the column? It took me a long time to figure out figure out the answer, but the atomic diameter, the effective diameter also goes up as you go down the column, because xenon's a much bigger atom than a helium atom is, and because they have a larger effective diameter, the mean free path at a given pressure also goes down as you go down the column. So that means that the electrons don't acquire as much kinetic energy. In xenon at a given pressure versus neon at a given pressure and so the neon lights more easily than the xenon. I thought that was really, really fascinating. Another thing is that you may have noticed that like Krypton and xenon tend to filament a lot more easily than the gases that are higher up in the column. And if you look at the heat conductivity, the heat conductivity goes down, they become less conductive to heat as you go down the column. And that's consistent with them filamenting more readily because, in order to fulfillment to exist, you have to keep that channel hot, and if it conducts the heat away rapidly, you're more likely to heat or stay with a glow discharge than have a filamentary discharge. It's things like that that I find really fascinating to try and explain or try to just at least get better insight to, by looking at pieces and saying what you observe and then ask yourself why is that? Why does it happen that way? And another thing that I don't understand yet, is **Chris Burak calls them bugs, in Krypton**, you see these little, tiny almost like butterflies, where there's little tiny stems and they have, double ended breakfast and. Yeah, exactly.
Harry: Chicken feet, says Mundy sprinklers. Yeah.

Daniel: you'll see them on the surface of the surface of the piece, they're absolutely beautiful, it's like, why does that happen? And I'd love to know! ... it's beautiful phenomenon. It's just. It's not only is it aesthetically and visually captivating, but then intellectually trying to figure out what the heck's going on there makes them even more alluring.

Harry: Yeah, I guess I was wondering before when you were talking about the different types of discharge within the Lightning, is that something that's happening in those kinds of effects where you're seeing the streamer at the front or the glow at the front rather than the...[arc.]

Daniel: Yes. And so, in high speed in high-speed photography of lightning discharges, they observe that streamer fan out front and then that streamer fan contracts to a leader head and the leader channel. When I was doing my measurements for my dissertation, you can imagine if the wire makes the spark, the spark is going to have a streamer fan and a little leader's section there, and the discharge is going to eject some space charge up in front of the wire. If that spark doesn't only propagate a finite distance, then the wire has to go through all that space charge before it can emit another spark. So, by knowing the rocket velocity and knowing, and with the current measurements, I knew the time between the spark discharges, I could infer lengths of those discharges and then what I also saw in the current records was that there would be a current spike of 10s of amperes and then there would be a delay of about 25 microseconds where it was completely quiet and then there would be another spike. And sometimes there would be only one, one spike, sometimes there would be two, sometimes there'd be three or five, and. As the number of spikes increased, then the amount of distance that the rocket had to travel further before it emitted the next spark would be even longer. And so what that told me was is that the sparks were actually growing in length and I did a regression of the number of sparks versus the length, with scatterplots, and then was able to infer the leader length per step and then the over streamer-fan extent and the streamer fan extent was about 2 meters or so and then, the

leader extension per step was on the order of like .7 meters or so and so, yes, they see that in a high speed lightning photography or imaging. **And I saw evidence of it in the current records. And additionally, back to the sprinklers, these double ended trees, so, we only see the bottom part of the Lightning channel, and it's forked downwards if it starts in the cloud. But you might say well what happens when it's in the upper part of the cloud? Well, you have double ended trees.** So, they see evidence of that and things using things like lightning interferometers, and so having these double-ended discharges is something that you see not only in plasma pieces but also in lightning.

Harry: Hmm. Wow. Wow. Well, I guess we've been talking about viewer participation, in so far as sort of looking at the discharges in the work, but I guess I wanted to ask the sort of sneak my sneaky question. Does wonder play a role in your use or interest in plasma illumination?

Daniel**: Absolutely. So, for me, the wow motivates the why.** I think that's true of most people, and that's one of the reasons why I think demonstrations are so powerful as an educational tool, is because if you can show someone a phenomena or a result that they didn't expect that surprise drives their curiosity and pulls them in to want to find out what's going on, and that certainly is at play whenever I see a piece in plasma art. It's one that I think can be used and capitalized on to draw on as observer or participant, in and it can be with color it can be with structure; it can be with how the, the nature of the discharge responds to the observer or participant. It may be that at a distance that you have a glow discharge that fills up the entire volume of the piece, but then as they come closer bring your hand to it, maybe you start getting some striations. Then as they bring their hand, even, further then maybe there's some bugs that form on the surface of the glass. I was fascinating with some of Aaron Ristau's pieces in that he had electrode down below with a glass sheath over it. But just looking at the at the structure of the of the glow on the electrode itself is fascinating, and recently I took an off the shelf plasma globe, but then put an adjustable driver on it so that I could just dial

down the voltage... You asked about what makes a what makes a piece responsive and well, one of the things that makes a piece responsive is being able to change it, so it doesn't just do one thing, but you see a much greater range of behaviour. And so, as I turned the voltage down on the on the driver then of course the finger is pulling and so forth, but you can get to a point where there's no fingers, all there are just little glowing pads on the central electrode. But the interesting thing is that they're always diametrically opposed, and then so you start out with like 2 and then you increase the voltage a little. Then it goes from 2 to 3, but now instead of being at opposite sides, now they're equilaterally, and then there's 4 and then 5. So that reminds me a lot of Ed Kirshner's work. He has some wonderful pieces where you just have floral effects where you have channels with glow discharge fringes on the edges, but they're all perfectly symmetrically oriented around the piece. And so, you're seeing the effects of space-charge in those discharges repelling each other so that they're always, in a symmetric pattern. And so, yes, absolutely. Wonder plays a tremendous role in my attraction and interest in the work, because again, it draws me in aesthetically, but then it also makes me wonder why it does that. Then I feel compelled the wonder or think about why it's doing what it's doing?

Harry: Yes, I would, I would agree. Could I? Daniel, could I ask you to just speak about that term space charge? I have not heard that used before.

Daniel: So, we talked about Lichtenberg figures, and that typically the positive breakdown can occur more easily and out to a larger distance, than the negative discharge can, and that's not at all obvious or apparent, because electrons are smaller and they're lighter and they have a higher mobility than positive ions do. So why would the positive down go further? **But if you think, about the fact that it takes not only charge moving but also heating to keep a gas hot and conductive. If you have a negative discharge, then all the electrons are being pushed away, and that kind of diffuses the heat outwards. But if you have a positive discharge, all the electrons are getting funnelled in right towards the point and that allows multi-electron**

ionization to happen, so then you can get ionization at a lower level, because if you have two electrons impacting a neutral molecule, that each of themselves didn't have enough kinetic energy to ionize it, but then you have two that 1-2 punch to ionize it. That's going to be much more likely to happen when electrons are converging at a point rather than being pushed away. So that concept discussed by [Jan] Mrázek a Czechoslovakian high-voltage researcher, he was the first one that that I know of, to articulate that. **And so even with an alternating current discharge, you can get charge transport not just out in front of a spark, but also around the around the channel itself. So, you noted that in some of the pieces that you've seen a glow not just in front of the serpentine channel, but also on the sides as well.** And so you do get breakdown not just from the tip, but also from the sides and that charge will propagate out to a certain radius depending on what the pressure is, what the what the drive voltage is and if you have a unipolar discharge, then as the channel extends, you're going to deposit charge on that channel, on its corona sheets, which is on the outside of the channel as well as at the at the tip. So, space charge is just charge that's been injected into the air and it's there and with alternating current discharges, you can charge and discharge the channel each time the polarity changes you're pumping charge onto that channel and then you're pulling it off and reversing the polarity of it. But coming back to Ed Kirshner's work, if you have these finger discharges they're going to, you're driving it with some supply, whether it's electroded or electrode-less, so at anyone given point in time, those stems are all going to be "like charged"- the same polarity. And just like- like charges repel, there's going to be an electric force, that pushes each of those stems away repels each stem away from the other, which is why you see them, typically perfectly symmetrically oriented. I hope that answered the question.

Harry: Hmm. Yeah. No, that, that's very helpful. Yeah, that's interesting to when I've been looking at historical artifacts of gas-discharge or "radiant matter" kind of objects the Geissler tubes there that polarity comes into play so much. And then thinking about

with most of the is transformers that we are using in this practice, they're alternating current and how that effects the type of discharge that's happening, or even various different Transformers affecting things very differently.
Daniel: Yes.
Harry: So yeah, it's yeah, very interesting to hear about that, I guess in doing some looking at some of those, older tubes as, they talk about the warmth pole, at one end of the charge, which I guess is going to be where the electrons are getting attracted to, do the charge.
Daniel: I would imagine so, on the other hand, if memory serves there's a cathode fall, and then there's also an anode fall. And I believe the cathode fall actually, there's a larger voltage drop in the cathode fall than there is in the anode fall, so that's counter to what I just proposed and so. I just want to clarify that, while I am completely fascinated with these mechanisms and discussions, that I quite frequently find discrepancies that I don't completely understand but I think that's where there's an opportunity to learn from and ask myself, OK, well, why? Why, why isn't that the way that I thought it might or that it should have been.
Harry: Hmm.
Daniel: So, yes, under the naive explanation of well if you have more, more mobile electrons they should be pushed away in a negative discharge, and it should be more diffuse. But then also remembering the experimental results that cathode falls are larger than anode falls and that you get more heating there. So, I don't know which polarity the warmth pole is.
Harry: I think that what I quite like about thinking about some of these things and how often it feels a little bit counterintuitive. It reminds me of my yoga practice where you have to go forward to go backwards, like there's always this kind of push and pull between what you expect you see and the reality of what you need to do in order to make some of those things happen. That keeps you on your toes.

Daniel: But remember. **The difference between theory and practice is always greater in practice than it is in theory.**

Harry: There you go.

Daniel: But that's wonderful because that's where you learn and it's how boring would it be if everything was only precisely as you anticipated? So, I would at least hope that I think there's opportunity in those discrepant events or circumstances to learn something new. Even though it can be frustrating, or you get your daily dose of humility.

Harry: This is very true. This is very true. Daniel, I wanted to ask you one other sneaky question about ionization and excitation and the colours that we're seeing. And I had heard one practitioner, 1 neon practitioner, describe that within each atom there's only one event, one event happening within electron at a time, and I was wondering, can that possibly be true or are there do various electrons get excited at different times? How could you even tell that?

Daniel: So, I would, I would not expect that, and I would offer up as evidence, that there can be more than one interaction happening at a time, the evidence, I would argue for that actually comes from Penning mixes. **So Penning mixes, as you know have a gas that's typically at a higher ionization potential and one that is a trace gas that is at lower ionization potential and whenever you have [And we're talking really small amounts of the trace gas at the lower ionization potential, like fractions of a percent].** And so, I think I think neon argon is one. For example, Neon has the higher ionization potential, argon has the lower ionization potential. But if you have just a fraction of percent of argon in neon, then the overall striking voltage is lower than either pure gas … [Penning's has a book] …. But in any case, my understanding the mechanism of a Penning mix and why it why it is that with a slight addition of a lower ionization potential gas that you can drastically lower the striking voltage for that mix is because, with electrons colliding with the higher ionization energy gas, the neon in this case, they impart kinetic energy to those gas molecules, but not enough to ionize them. **They form what are called metastable states, and those metastable states have**

really long lifetimes, we're talking on the order of like seconds, which is really amazing because normally whenever an atom gets excited it immediately de-transitions and then gives off light. So, why these metastable states happen? If you ask someone that knows a lot about quantum mechanics, they're like, oh, well, because the wave functions are symmetric. And that says absolutely nothing to me, even though, but what does say something to me is the following. **Electromagnetic radiation is emitted whenever charges accelerate. Whenever they change their motion. And if you have spherical electron shells, they are spherically symmetric around the atom, and so if you have a transition that's between two spherically symmetric electron orbitals, there's no preferred direction for the charge to accelerate, and so that, that transition is forbidden because, the electron can't make that transition because to do so it would have to be accelerated and it would have to give off energy, it would have to give off light, but which direction is it going to give that that light off in?** And so, for those, those transitions, they don't emit light, but they can stay excited in these metastable states for quite some time. So, you have these electrons that impart kinetic energy to the neon. The neon gets excited and it's in these metastable states, but it's not ion, and now you have impacts of the neon with argon at the lower ionization, that has lower ionization potential and so although the neon itself isn't ionized when it collides with the argon, it's transfers that kinetic energy to the argon and then ionizes the argon**. So that would be a mechanism where you have multiple things happening, and like multi-impact ionization is a is a term ...that's often used in in gas discharge papers, and so it's a mechanism distinct from single impact ionization, whereas you just have one thing hitting the atom at a time.** And in fact, that multi-impact ionization is what Mrazek proposed is why positive breakdown is easier than negative breakdown, because if you have this positive stem and the electrons are being focused in towards the head, or they're all being focused on a point, that multi-electron impact ionization is much more likely than in a negative discharge, where all the electrons are being pushed away. So, based on based on those

examples, I would argue that no you can have multiple step or concurrent processes that do play a significant role in ionization and heating.

Harry: Hmm I read one paper where that and I can't remember. Name now. But he was talking about. The different stages of ionization, or that there's partial ionization within one space at any given time, and I thought oh, that's really fascinating that there's so many different factors at play. And I guess from my perspective where I'm predominantly able to influence the shape of the vessel that the interactions that happen at that liminal edge, where the glass is there are there's an electron interplay that happens at that edge as well that influences what's happening. I think is yeah, really interesting but it's a space that you can't actually access, but it influences the space.

Daniel: **Absolutely, and there's a thing called ambipolar diffusion where the electrons are a lot more mobile than the positive ions are and so imagine that you have a clump of ionized gas and initially has equal amounts of positive and negative charge.** Imagine that it's in a discharge tube so the positive charges are over here, the negative discharges are over here, positive charge to my right negative charge over to the left. And so, the electric field is pointing in that direction, and you have this neutral clump of charge. Then the electrons are going to, they're going to diffuse out in both directions because they're more mobile than the positive charge, but the charge that is diffused out front that adds to the direction of the electric field, whereas the stuff in the back, bucks it and so you get the net effect between the external electric field and the ambient polar diffusion is an enhancement of the field in front, and a decrease in the field behind. **That purportedly one of the mechanisms is at play in striations, that drives the ionization further forward, in that perhaps that these clumps of ionized gas are like the bright spots and that behind because the field is bucked, then that area stays dark, but out front, the field is enhanced and adds to the ambient field, and so there's that accelerates the electrons, even more to produce the next ball of luminosity.**

But that also has an effect on the glass on the glass container, as you point out, because the electrons diffuse out to the walls much more quickly than the positive ions do, and so there is a charge separation in the walls, being typically negatively charged compared to the bulk of the gas.

Harry: Wow, it's a lot, all happening in a small space.

Daniel: **And maybe that's a mechanism at play with these bugs or these surface discharges, that you have charge on that surface that the that the surface discharges are feeding off of**, and I think that's in so Eduard M. Bazelyan, Yuri P. Raizer they've got several books, one is *Gas Discharge Physics* one is *Spark Discharge* and then a third is *Lightning Physics And Lightning Protection* and their background, they were they're both Russian and of course, this is in the cold war, so they're trying to make big lasers, right? And at the time we didn't have solid-state lasers, so to make lasers, you need to have gas discharge lasers, but in order to make a gas discharge laser you want a uniform glow discharge in the whole thing. Well, if you try jacking up the power, then what happens is that uniform glow discharge starts contracting into these into these filaments and you don't get the lazing effect that you're looking for through the for the for the whole volume. And so, their expertise in learning about gas discharges all stems from trying to understand how can we jack up the power but not have filament and so forth. So, I found that fascinating. But as a consequence, they had entire careers and decades of experience, with gas discharges and then in spark discharges. I think it's fascinating, they were talking about having planar discharges where there would be filaments that would dance back and forth, in the plane. It reminds me a lot of, like Wayne's Lumen Glass pieces. So, it's fascinating, I do find their writing very clear and even a lot of the theories fairly accessible in that they a lot of the they paint out the concepts fairly clearly and even with just algebra. So, even the formula I find are helpful because you can get behavioural dependence from looking at a formula that you can't get if someone just says, oh, I have a gas discharge simulation. OK, in order for me to get a sense about what happened to gas discharge simulation, I

have to play around with the simulation a lot to figure out, OK, well, if I change this parameter then how does the whole system evolve? But? Assuming that the model is correct, if I have an equation then all the variables are in the equation. If one variable goes up, if it's in the numerator, I know it's going to be a direct dependence if it's in the denominator, I know it's going to be an inverse relationship. And so, you get a better feel at glace for how thing change and so I think they write well, the math is not ridiculous, you know you can follow it and then. And then they have lots of empirical examples and data, so, I think they're great authors.

Harry: Hmm. I will look them up, that's for sure. Daniel, can I ask you one last sort of baby beginner question? About when you're looking at, say, a neon tube and then there it might be constructed so that there are wider sections. And that section then appears to go into that bluish white, could you describe what you understand is happening there?

Daniel: I will give you what I think is the case, OK. Being honest about the fact that I always reserve the option to be wrong and I'm always delighted to be presented with evidence to refine my understanding. So, say for example you have a standard gas discharge tube that has two electrodes fairly wide diameter, maybe 10mm so-forth and then it truncates down into a much narrower stem for the spectral tube. Then when you fire it up then you get much brighter emission in that that narrower section, and then there's a much more diffuse glow in the wider sections, and as you point out, same gas, but you'll get like a whitish glow of the neon in that in that broader section where you get this beautiful red in the constriction section, all you're doing is you're just changing the cross-sectional area. Why do you get the colors? So, you may be familiar with Ohm's Law: where you have V is equal to IR, where V is the voltage, I is the current and R is the resistance. ....

I'm going to have to table that for a second, but what I will say is this empirically.

If you look at a standard a standard 95% neon 5% xenon. Plasma globe. You'll notice that in the fingers the channels have the white xenon and then the brush discharge has

neon in it. **There are higher fields in the in that glow discharge streamer fan area. There are higher fields and lower conductivity, and lower and lower current density in that diffuse streamer, fan or glow discharge. So, there is higher fields, lower current density and lower conductivity, and those higher fields allow the gas with the higher ionization potential to be excited. Which is why you see the neon preferentially.** In a similar way in lightning in the streamer fan, you see predominantly ultraviolet emission and in the leader in the leader channel, you see predominantly infrared emission.

Harry: Oh really?

Daniel: And. So, there's the similarity or the similitude, that you see a shorter-wavelength, higher-energy-light emitted from the streamer fan than you do from the leader channel. And in gas discharges I would love to see an example where this does not hold true, but what I've seen is that whenever you have a mix, then **you'll preferentially excite the higher ionization potential gas in the streamer fan out front, and then you'll see the emission from the lower ionization potential, lower thermal conductivity gas in the in the leader channe**l.

Harry: So sorry, Daniel does, that means that the higher up the periodic table, those gases are more likely to be ionized in that field of higher potential at the streamer end. Where is xenon and Krypton are more likely to become the streamer, in the leader channel.

Daniel: Yep. Yeah. And I guess that's what we sort of see, isn't it? We see that. But the question is why and so what I wanted to try to come back to was that in that leader channel, you have a higher conductivity, and you have a lower field and a higher current density.

... Let's just go ohms law differential form differential form. There we go... *J is equal to Sigma E*, and so in the leader channel, you have a high conductivity, Sigma is high and so and J is high too, and Sigma the conductivity is a lot higher... so that allows the

electric field to be lower and still have and still have the current density be more concentrated or bigger.

In contrast, in the glow discharge area out front, J is lower and Sigma is much lower, so the electric field is higher, and you get a higher electric field. The electric field can be a lot higher, but the conductivity is so much lower that the that the current density is lower. So, I hope that that works.

Harry: That's kind of amazing, isn't it, that within such a small space, but I guess that's the differential, isn't it, that those fields are so changeable depending on motion?

Daniel: Or depending on motion, but also geometry and so getting back to the sort of how the two, how the two feed one another, that very conductive channel allows charges to be transported, along it, and then they bunch up at the tip, and those bunched up charges enhance the electric field so that it it's higher and it can feed that glow discharge streamer fan out in front of it. In a similar way, the current from the streamer fan, the streamer fan is actually made-up of these little, tiny balls of charge called streamer heads and out in front of the those the streamer heads, there's avalanches of electrons that are that are piling into the streamer heads and then that that current is getting conducted along the streamer filaments within the fan to converge on the leader head. And so, you have a low current density that's all converging into a higher and higher and higher current density, that then converges to the leader head, and so again the leader provides field enhancement to sustain the streamer fan, and the streamer fan provides current to keep the leader hot.

Harry: Wow. I'll have to listen to that again.

Daniel: Well, what I find so fascinating and satisfying about is that there's a lot of papers, a lot of mechanisms that have a good degree, that you see similar things both in the lighting research and in what you observe in the in the plasma discharge and so I hope it helps in terms of like getting a little better mechanistic picture of what's going on, but the point is that in these in that brush type area the conductivity is really low and the current density is low but if you have J is equal to Sigma E then E is equal to J divided

by Sigma where J is the current density and Sigma is the conductivity and. So, if J is low but Sigma is even smaller, then you have a high electric field because the because the conductivity is so much lower than the current density. On the other hand, in the leader channel. J is really big, but the conductivity is even bigger and so you have something that's big divided by something that's even bigger, and that means that the electric field is much lower. Because the electric field in the in the leader channel is lower, then electrons don't acquire as much kinetic energy between collisions. So, you only get the lower ionization potential gas that's excited. Whereas the opposite happens in that in the streamer fan. It took me a while to get there. But.

Harry: That's amazing, isn't it? Yeah, I guess in it makes me think of Mundy's work, and I think about all of his incredible mixes and that, yeah, that there are things happening. That should be able to be modelled, but it's almost impossible to model them because it's so complex.

Daniel: And that's why I think his pneumonic, have sort of like ascribing personalities to each gas is a fascinating and seemingly effective way of him being able to, like, catalogue or intuit all of his experience by, associating these, these personalities with each gas. **And so just like you have, you have different friends and, and because of your familiarity with him, you can predict how they would respond in a given situation. He's done that for these gasses and so has this fantastic intuition built up about OK, if I want this effect, then I need these people at the party.**

Harry: He would love that.

Daniel: So yeah. I would love to pick his brain more. .... Yeah. Just trying to benefit from their tremendous expertise. They just have a lot of knowledge, but just trying to access it and internalise it is sometimes challenging.

Harry: Well, Daniel, thank you so much for your time and. Your patience in explaining so many things and **I'm really taken by your description of lightning in a bottle**, because I guess one of the analogies that often gets used is an Aurora in a bottle. But I love the, especially with your background, I think that that is so fitting and so interesting to think

about those nuanced differences that are obviously so great within such a small space with what's happening in those different charges of the leader and the streamer. That's really been very insightful for me to hear your understanding on those mechanisms. I guess again I have that sort of feeling of considering it becomes such a like almost like a 2-dimensional drawing in my and then it sort of blows my mind sort of thinking about it in in 3 dimensions and thinking about what we're actually seeing and how do you? Like for me? Why would I use? Or why would I rationalize using these amazing phenomena to pursue this idea of connection. ... It's interesting to have all of these different kinds of knowledges about what is being presented or what is being understood, in different ways.

Danieal: Absolutely. And I know it can be overwhelming and dizzying, with all the variables and all the mechanisms and stuff that are going on, but it also is exciting because that's where you get the richness of behaviour, is from that complexity and I find it also interesting that it's like our neurons are electrical, you have action potentials that that build up and then and then fire and these electrical signals are propagated axons and that their propagation velocity depends on the capacities per unit-length along them and if you want if you want the signals to be faster than you change the dielectric properties around the axon and so you have these myelination on the sheath to make the signals propagate faster. That has a direct impact on an animal's reaction time so just thinking about, how we're electrical and, from our heartbeats to our central nervous system. And just the commonalities, in fractal behaviour, that we see, so many places in the in the world. Whether you're looking at alluvial fans from, from rivers and stuff all converging and you see the same dendritic pattern. Or if you look at a tree, and you and you see that branching and so I think there's opportunity to sort of gain a greater understanding of and asking ourselves about why these phenomena are so ubiquitous and what are the common factors that make them all appear so similar. I think that with a tree you're trying to gather sunlight over this big area, or if you have rainfall and stuff that all that water is going from a large area or volume and then being

channelled into the smaller volumes and so it's a very hand WAVY way of talking about it, but you can appreciate how you can have similar mechanisms result in similar appearances and I think that similar to offers an opportunity to look at how are things common? Or what's common between the two things and perhaps gain some more insight there.

Harry: Yeah. No, I think for me not having a background in electronics and electromagnetism really. But then coming to realise how central that is to all of our experiences is revelatory, and it's also that sort of similitude that you're talking about is fascinating to trace some of that those patterns and like when you were talking about was it the Lichtenberg? Yeah. Where you just kind of go well that we're seeing similar patterns and it depends on the charge. Of Those small objects and how that's expressed in form.

Daniel: Absolutely. It's an amazing way to try to peek into seeing... things that you wouldn't normally see, and Lichtenberg used sulphur and lead oxide red lead. I think that's one of the one of the reasons why I find plasma art so compelling is because with these different mixes and forms and so forth, you guys have revealed phenomena that I had only, seen in high-speed videos, or had been abstracted only the high-speed videos only really come to fore in the last, 20 years... People speculated on these in the lighting interferometry, that's only also, since the 90s, and so people speculated that the lightning, lightning trees were double were double ended. But until that actually was verified with lighting interferometry or with high-speed video it was only an abstraction. So being able to see an example of a plasma piece where you have a double ended discharge, you got glow discharge and a glow discharge with a, with stem connecting to and being able to see an example of WOW, there's double ended tree there that. Those are the first physical manifestations that I saw of those exemplars, that were hypothesized in lightning but hadn't yet been verified. So, I it's amazing to be able to just make these, produce these phenomena, that we now know happen at a larger scale,

and presumably also have, some universality, whether it's in crack propagation or rivers or trees. It's. Pretty fascinating.
Harry: It is super fascinating. Super fascinating. I'm going turn off the recording now, Thank you again.

4 Percy Echols II

[02.11.2023]
PE: Call me Percy.
Harriet Schwarzrock HS: OK. And I'd like to ask where your studio is?
PE: I don't technically have a studio, but where do I work out of? I work out of the Pittsburgh Glass Centre and that's in Pittsburgh, PA in the United States. So that's, that's where I work out to make my glass work and that's where I also fill my glass pieces. I do sort of have a home studio in Pittsburgh where I do some more of the electronics and finishing work.
HS: Fantastic. And may I ask you, what is your background that has led you to using plasma illumination?
PE: It's a simple pathway; it comes from working in glass. Now, these other tangential interests allowed me to sort of dig as deep as I have, but it was glassblowing first glassblowing through university. So, Illinois State University and what led me directly to that was my fascination with light and glass, or light in general, and how we can manipulate light or create light? That led me to taking courses, which is called, I think it's still called expanded media, so that's use of various technologies to enhance, you know, certain mechanisms. So that's like can use a LaserJet, laser cutter to cut acrylic and can use that cutting mechanism for the laser cutter to engrave different optics and using LEDs and motors to spin plates and things like that. But then what got me into like the plasma was taking a workshop at Pilchuck Glass School in 2014 where I met Patrick Collentine, who was the person who introduced me to plasma and neon and has been a staple mentor till today.

HS: Fantastic, I guess for this research I'm interested in the idea of what makes plasma illumination different from other forms of illumination, and for me, I consider that to be the responsiveness of the medium. So, I was wanting to ask you how do you describe responsiveness within this form of illuminated practice?

PE: Well, I find it interesting that you're trying to define why it's different but not start to look at where it's the core of all types, all types of illumination, and the difference is how you use plasma in general. Because we have the idea of plasma in the physics realm that is natural phenomenon such as the sun is a type of plasma, lightning is a type of plasma and various gas related lighting mechanisms are also plasma. As well as like, so that's fluorescent bulbs. That's neon signage. That's incandescent bulbs, that's soda lime bulbs. Anything that has a gas and filament is part of plasma. But those gas and filament mechanisms are specified illuminations, so they're not, you know, plasma. It's part of plasma, but that's not plasma. And so, what I think what you're trying to find here is like, hey, this response of the material and how do I look at that? It's very much the same, right? **We are creating these glass sculptures and to specify we are creating plasma light sculptures. We're creating shaped hollow glass objects that may be abstract or may be figurative, that are hollow, and when you're filling those with gases and watching how those gases move and respond with the electricity inside them as it navigates through the interior of that form and due to the properties of which it's been powered, we have responsiveness. We have the ability to interact with our proximity, our nearness and our touch, and where we touch. So, it's a, it's a combination of form, gas mixture, electricity and presentation.**

HS: Excellent, are there in your practice any techniques that you employ or have devised that expand upon the artistic application and inherent responsiveness of plasma illumination?

PE: So, the question is about is there a technique that helps with the plasma effect?

HS: Yeah, [is... how...] how do you navigate the production of your work to make the most of the elements of plasma that you enjoy?
PE: Well, I'm still exploring what plasma can provide for me, but what I what I like about plasma is the ability for it to **fill the space with some kind of motion and we can interpret the motion as a certain feeling or we can create a certain texture or description and that's both an internal and external thing and so from what I understand working with plasma** within a sculpture is to give as much space or interior room for that gas and electricity to move about and it means that like I want to have as much that light throughout the entirety of that object as much as possible. So, technique, is very abstract to me now, even though my skills are not at the level of a master in terms of glass working technique is more so modifier to how you apply it. So, if I want to expand and fill an interior, I need to create more hollow spaces within the silhouette that I see and within the interior of that silhouette to give a wall thickness. So, I like to see how different layers of colors work within glass, so I will layer maybe one to two colors and engrave through one of those to reveal the one underneath. **So, you can see a contrast between those two colors as light comes through.** But to expand the interior space, I start to think. How can I make various objects hollow? and that means blowing different components and then bringing them together and fusing them together hot. In, in ways that may not be seen typical to hot shop work but are borrowed from one who is in scientific glass or one who's working in flamework glass techniques, and the reality is there's no difference in techniques between those two mediums. **Your applications and understandings of how the material work is it is a craft.** The craft is a is an understanding of the materiality, material you're working with and how you manipulate it and how you can progress to develop those skills within the context of whatever meaning you want to present, whether that is an aesthetic or conceptual means and artwork. So, that is how I try to approach plasmas, I want to see how far I can provide an interior a space for the gases, electricity to move through and the more I

can compose that and craft, the more I can start to think about how I can intentionally seek certain behaviours or effects.
HS: Excellent, I was wondering how do you envisage the viewer participant engaging with your work?
PE: How do I envision the viewer to participate with the work?
00:08:40 HS: Oh, I've been using the term viewer 'participant' because I feel like. We sort of end up interacting at some level, but I guess how do you envisage the viewer engaging with your work?
PE: Because of the work being the way it is, one that is possibly fragile and possibly easy to dirty because it is glass and various hands touching it, for the most part, many of the works will not be touched, and if they are they're secured. **So, it I like to try to guide people in sort of the interactive nature to kind be in proximity, but I want, what I want for people to be able to do is to find some sort of level of like interest or curiosity because they see something that is made with the skill that they may be familiar in viewing, such as glassblowing.** But they may be curious about well this person, did they also put the plasma inside there? Did they also light it up? And they did, how they do it? And that these questions would churn up a level of curiosity to, with additional context to, other elements that I want to bring into my artwork which are guiding people in the way, in the way of being able to see the wonders in the mundane. That's sort of my favourite thing to say.
We are so used to seeing things that they are in this world that we never really think about how they work and then when we actually investigate those things to curiosity, we start to see that there's no true separation between the different so-called sciences or knowledge bases that they overlap quite a bit and they help explain each other. **So, I want people to I wanted to incite and curiosity and an investigation into the wonders of what's actually here in life, whether that actually comes to fruition, that's not up to me.**

HS: Excellent, excellent. And I guess this last question is more about your own personal experience of working with the medium. I wanted to ask you; how do you experience responsiveness within your plasma practice?

PE: Yeah. So, like each work informs me a little bit about what can be done in the next form, because you really can't change things. You can, you could take a single object that you've made and start to explore it until you find something that you really like, but you also can find that there are things that you didn't think about in that form and you start to change it up, whether it's orientation or scale or color choices or the use of phosphorescent powders or even changing up how you would decide to make a form based on a new mixture that produces a different color and behaviour. So, like, most recently, I've found myself liking the mixture of nitrogen and argon very affordable and very so-called cheap mixture.

And what happens in that mixture is you have this sort of glowing haze of, of very like deep purple, like a deep purple that floats there with a, with tendrils of orange and peach moving like little, like branching flames. And so that's very exciting because it has an additional property to it. That additional property is that it can also excite with UV, phosphorescent pigments, so that means well for me. I'm like, oh, shoot, I want to see if I can make something that color wise of glass, color wise and layering of glass in a form that meets that mixture itself. And it tries to find the best of, of what it provides. With its UV and its movement, and its coloration, with the color I could put in the glass. So, it's a back-and-forth response. I make something to discover something that's going to be unique to that piece and within that piece I find a new mixture, and it makes me want to make a different piece to meet that new discovery. **It's a back-and-forth, constant back-and-forth, between those two things, making the object, discovering the gases and mixtures.**

HS: Oh, that's excellent. Thank you, Percy. I love how you speak about that as iterative and informing your own learning. And I guess I, I sort of had a specific question to you based on how you answered before, speaking about wonder and that I know that you

describe yourself or describe your practice as alchemy at some, at some points, and I was wondering if you could expand upon that notion or idea?
PE: Sure. And I may even start adapting other sort of terms. **I find myself liking alchemist or alchemy and artifice or artificer, because there are certain things that I do produce that are combining different manufacturing process through the printing and 3D modelling and in certain constructive methods that create objects that also help enhance the way that other things work together.** So, as an alchemist or alchemy it is in one, in one case specific to the art of making plasma light sculpture, acknowledges all the things that comes together. So, my knowledge of the material glass, my knowledge of the gases and their mechanisms, my knowledge of the technology and technical workings that bring it all together at the same time, and it it's also what I do as taming lightning. I bring together people with audio to provide a podcast.
And I bring together their voices, their knowledges with research and books. And I produce blogs or slides or presentations that sort of put things in the context for people that that they may have not seen before. It's not like the information is new. It's putting it in, putting it in in a form that could be understood and followed. And so similarly, if I were to talk about being an Artificer again, it's like I'm producing certain it's almost too similar to like the alchemist, but it it's more like I make art objects and I've not quite hit my stride for, like, the conceptual means that comes through with art.
Which is why I kind of started liking that because I am an artist. But I am an artificer. I make objects that that in the, in the way that you're like lighting this thing up. It is a specialized object, a lighting device, a lamp that it that is made with art in mind, but a mind towards, sort of like making this technology work together, right?
HS: That's very interesting. Very interesting. Percy, I had another question specific to you because partly because of your podcast and also because of all the teaching that you're doing, and wondering, wondering how you communicate about plasma if there

are things that in communicating to other people that you've learned yourself or have been revealed to yourself through that communication.

PE: I'm, I'm kind of confused by that question.

HS: [I was being confusing.] I guess are there, are there points at which in explaining things to other people, during teaching that you realise something about what you understand about plasma?

PE: Oh yeah, it's always coming from. It's almost like the response to the question it's the feedback from the person receiving the information where they start to make sense of it in conversation. That's where I start to understand for myself. Because sometimes even if I state the, present the information to a student...

Sometimes there's moments where it clicks into place, and there's additional mechanism that tells me to say something different to help enhance the presentation. But other times, most likely it comes from feedback from the student or even my co-teachers and teaching assistants, because they will start to click in like oh, I understand what you're saying. So, it's kind of like this, and I'm like “yeah, it is. It's exactly like that.” Or using a different shape to represent a concept versus my previous model. And that comes from the, the feedback from those different, different people receiving the information.

HS: It's a complicated creature.

PE: But I always learn a lot. **I always learn a lot when I'm teaching because for the most part I'm running through a process that works, but I'm not quite explaining why it works when I'm doing the artwork. It comes, sometimes it comes in the moment of observing, but most of the time I'm kind of just focusing on the artwork and so the ‘why’ or ‘what’ doesn't come back until I'm sitting there and I'm observing something that's been recorded.** So, like documenting in some fashion is very important for like even self-feedback.

HS: Yes, it is. Percy, I was wanting to ask a more open-ended question. Are there any other insights [or] about interactivity and responsiveness or proximity that you would be happy to share with me now?

PE: **Yeah, plasma is fire, right?** [It] We can't like, resist the urge to throw something in the fire or poke at the flame that's sitting there. And glass to people is often a barrier. It is something people are taught is dangerous because it, if it's broken, and it gets broken because it's fragile, and when it is broken and fragile, it's sharp and it can cut you so you can't handle it properly without a special tool. Or you might need gloves. You have to be very careful. And even in the space where art is moved into the, the fine art area. It creates that invisible barrier around it and people are like kind of, very cautious around which it makes sense. You don't want to knock over someone's $200,000 like sculpture or whatnot, but it is such a barrier that people have an inherent like fear response to it. That's... But the second you put fire around it like hot glassblowing, it like dissolves some of that for people. And the second you have a finished glass object, no matter how large or fragile it is, the second it has light in it, people forget their caution. In almost, not so great manner, **but it breaks through a barrier in which they're willing to touch something, or if it wasn't lit up, they wouldn't touch it.** And I think that's pretty exciting, but it also poses another question for artists. How will you handle your work knowing that it that it removes a barrier that would have protected it normally? And that's always a question we'll be asking ourselves. But the direction we're going isn't the same direction as an artist normally understands**. It's the direction that goes to a larger institution that to understand how to make things secure and safe, and, and sturdy and that, I think that's really great because it starts to connect us to a greater knowledge that we've sort of never thought we would run into, like talking to museum installers because they have a great knowledge of how to make an object that's interactive, secure and safe and all that stuff.** Once you start getting there, you can really do some great things with your artwork.

That is often a, a barrier, whether regardless of whether it's the material glass, it's just a barrier of like this thing is so beyond you as a human being, you can't touch it. You can't interact with it. It is beyond the means for you to even mentally approach. And I don't like artwork that's like that. I think that artwork doesn't have a true existence if it's not for the people who are viewing it, you start to limit your viewers pretty easily by doing that.

HS: So, you do keep the viewer in mind a lot of the time when you're producing work?

PE: I'm the person that needs to make sure that the artwork is cool by and then everyone else that, like if I like it, people are going to like it, and if someone doesn't like it, they're free to not like it. But, but in terms of answering that question like I don't have to think that hard, my work should never, my work will never go beyond someone's capabilities of being able to approach it. It, it, and that's sort of like if I start to get into some of the conceptual things, I like to think about something that I've termed a somatic symbolism. So, body symbolism in the same way that when I start to talk to people about glass, when I work at the glass centre. I use certain, certain terms that are universal, so the body, people's bodies are universal, so you can start using that as a symbol, right? Everyone kind of has an experience of what the heart feels like when they palpitate too fast or too slow, or like when I'm teaching someone, I use food because food is also super universal. If I can describe a food that that gets you to understand how glass moves or how I'm deciding to add glass color to it, then you have a stronger idea of what's working. When I'm doing the glass work. Like, I'm putting glass frit on there, which is a glass bit of, bits of colored glass and I'm adding it on like I'm adding sprinkles on an ice cream cone. So, you know, so I'm, I'm always trying to look well... So, I guess that that is true. I'm always keep my viewer in mind, but it's so automatic, I didn't think about that at first so yeah, it's so automatic that I serve the people that I want to talk to. It's [obvious], it should be pretty obvious, but not everyone's like that, I guess.

HS: No, I don't think everybody is like that. You're certainly an educator and very inspiring. Yeah. Thank you very much, Percy. That's excellent and interesting for me to hear different responses. So yeah, really excellent.

5 Jeff Feigen

[8.12.2023]

Harriet Schwarzrock HS

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JF: Jeff Feigen: And why? Why do I put so much effort into it? And you know, I guess so many people approach from so many different angles. I think you have more of like a[n] art school background and more of like formal training with glass. I kind of have, I'm in my basement here. I barely have any like real hands-on art education beyond, like, probably elementary school, junior high school. And so, in order for me to, you know, do plasma and fills, there's really not a lot of other good options that I could really do in my house that I'd even know how to approach, how to do. Because you know, I have no background with kilns and just, you know, being able to set that up without knowing or understanding anything, even kilns because I don't have a background in pottery or anything like that, I've never really done any of that kind of stuff? **Gettering just seemed to be some way that I could do plasma at home in my basement.**

HS: Yeah, that's amazing. Well, Jeff, if you wouldn't mind, I'm just gonna start with some background information questions. Firstly, what is your name and how would you like me to refer to you when I'm writing and speaking with you.

OK. And where is your studio?

JF; Well, I'm sitting right now, it's in the basement of my house. And it's like it's actually like a first-floor basement. [Um] and it's a room that also houses the furnace and the hot water heater.

HS: Fantastic Jeff, what is the background that has led you to being, to using plasma illumination and I guess being fascinated by plasma illumination?

JF: **It's such a visceral kind of a thing. It's hard to explain. I just look at plasma, and I just feel very kind of warm, peaceful, interested.** I can just sit and watch forever. Just looking in a glass tube like a neon sign and just seeing that glow, turning it off and on. It's just kind of a feeling I get off, I don't know of air glowing, or I'd say it started when I was, oh it would be long before a kindergarten, even I was just fascinated with neon signs and lightning too. I don't know why? I just AM.

HS: Oh, that's fantastic, Jeff from my perspective. What I'm very interested in with plasma illumination is the responsiveness and I was wondering how you might describe responsiveness within this form of illuminated practice.

JF: Oh well, there's kind of, I would expand there, there's the obvious response of plasma tubes where you touch the tube and you can see the arcs dance around and all that, that that's pretty obvious. But I feel like I have an interaction or people have an interaction with plasma just by, you know, moving around and you see the glass and you see through the glass, and you see the other side, and you see the air glowing inside. And you don't really have to interact with your hands, you just kind of look at it. You turn the piece off and it's completely clear and it disappears and all the effect goes away. You turn the tube on. There's you know and even if it's just like diffuse red neon. It's just such a, such a fascinating thing to watch and just try and figure out what you're looking at.

HS: Yeah, I would agree with you. And I think that insight into the container of the glass as well [um] and that transparency affords the medium inside. Yeah, that's fantastic to hear your interest in it being an object that's off as well as on and that sort of. yeah. Trying to find out what's happening.

JF: You know. **It's something there that literally you can't put your hands on it, it's there, but it isn't there.** It's like your mind is having a hard time just trying to figure out what it is. It's just so fascinating at just such a low primal level.

HS: Jeff, I wanted to ask about particular techniques that you employ or devise that expand your application and of using plasma illumination and I guess I know from conversations with you, how much you know about the electronic and the transformer side, but also particularly about gettering and why you have gone down that path.
JF: So just, at first, it really just seemed like that was the only way I was gonna do this stuff. I was never going to build an oven big enough to do big pieces. You know, even if I wanted to, well, maybe I probably eventually, and that's probably what I would have done if I didn't figure out the possibility of gettering so.
HS: Can I just interrupt for a second? Jeff, would you mind, would you mind explaining what the gettering process is?
JF: OK. So, most metals, almost all metals are super reactive if you get them hot enough. They'll react and destroy anything reactive around them and so that includes even like an aluminium soda can, if you heat it up the aluminium is just going to react with the air. And the only reason it doesn't normally is because the surface has already formed, we call it protective or passivation layer and it can't react any further. But anyway, the chemistry aside, whenever you fill a plasma tube, it has to be really, really pure gas. It's a tiny, tiny amount of contamination. Water moisture, for example, will completely ruin the effect the tube will get very hot, and it won't last. It would be very hard to light it most certainly is not going to be prettier or any kind of color you'd want. So, to get rid of the contamination, there's only really two ways to do it. One is to heat up the whole vessel about let's say about 220 Celsius, which is pretty hot, to drive all the moisture out. That works really, really well and then the and then there there's a method where they do this electrically, they call it bombarding, but it's really just the same thing running a high current. Or put something really reactive inside the tube, like as I'd mentioned a getter, a metal. That will react-out the moisture and the contamination and turn into a stable form. So that all that remains is the pure gas, and you'll get that, you know, beautiful neon effect and all the things you want or plasma

effect and a lasting tube that's going to run at a reasonable temperature and conditions that it can actually operate.

HS: So, you, I mean, understand that the process of what's required within the vessel, but you're developing a technique that means that you're bypassing using a kiln or a bombarder in order to make the conditions right inside of the vessel.

JF: Right, right. To purify the gas. And this doesn't work for all forms of plasma, sometimes you want to use more than just inert gases. You might want to add a little bit of oxygen or a little bit of nitrogen in order to make kind of the plasma globe effects, you know with the fingers and the filaments. And so, this for example would not be compatible with non-inert doping but, it works. It's a really, really good start for me and it's really it takes me a long way. So, some of the reasons why this is even possible is because of just more modern technologies like induction heating and things that are now available very inexpensively that were just not available at a reasonable cost say even 10 or 20 years ago.

HS: And I know that you've shared some videos of the process, which is very generous, and I know other people are experimenting along the way as well, so.

JF: Oh, I'd love to hear about people experimenting, I've heard very little feedback. Except Percy told me he did some experiments, but who else?

HS: A predominantly I've heard Percy having an experiment with it. Yeah.

JF: I'm very, very happy to hear that's the reason I share is really I want other people to do this too and you know, collaborate with on this. I'm really psyched that first who's doing this, and to hear that other people are trying it out, I mean I'm really thrilled when I hear someone say, hey, I just bought a roll of magnesium.

HS: Jeff, I am going to have a go at it, that's for sure and I've been lucky enough to see you getter. Would you mind describing the process?

JF: So, I'm experimenting with a lot of different materials. So, you can buy commercial getters. They're really, really expensive hard to get. The company is extremely, extremely difficult to deal with. If you're not a light bulb manufacturer or something. So,

I like to use ordinary or as ordinary items as I can find, things I can get off Amazon and eBay as my starting point, which makes things a little bit harder because they're not as easy to use or as good as the commercial ones. So, I'll give you some examples of what I used to getter. Here's my box of getter experiments.

HS: Excellent

JF: Let's see what I got. We'll go with chronological order, so this this is barium.

HS: OK.

JF: And it's very reactive. This is what they used to use for vacuum tubes. So, I thought I'd use it here.

JF: And then this is magnesium ribbon and this you can get anywhere Amazon, eBay it's very inexpensive. And so, I started using these two materials and what I would do is. I would pump out the tube.

JF: And then induction heat the electrode. And then I would shake in the getter material, which again is either barium or magnesium. And so, when the tube is on, is that under vacuum I would then induction heat the electrode a second time, and you can see if you look at this, this electrode it's all mirrored and dirty looking. And that was one of the problems with the first techniques I was using is evaporating this metal could make a mess inside the tube. I guess you could keep that under control, but then the other problem is that if there was ever mercury in the tube, it would eat up all the mercury and you would lose you know your mercury effect, which I think is pretty important to a lot of neon, and people who bombard. So it was, it was kind of a partial solution.

HS: So, Jeff, your getter material is contained in a side tubulation that you then drop down into the electrode.

JF: Correct, correct. And so, you could actually just seal up. You could drop your getter material actually in the electrode [um] at the time you're constructing the tube too, it's not really important to have it on the side or go through the tubulation if it's not convenient or, or whatever. And it's really not that important to separately induction

heat the electrode, add the getter and then induction heat again. But it's all really... Whatever you do, it's probably going to work.

JF: So, the next thing I started looking at was a non-evaporable getter. Zirconium, and so I really went on a hunt all over. Where could I get zirconium? And I tried in so many different forms, I got this really, really expensive zirconium wire, which is very difficult to get to work. I'll tell you some of the methods and how I get that to work.

JF: I found this zirconium foil. It's like this really thin foil. And it's actually pretty cheap. I'd say this is probably like $10.00 for this. This is, I don't know what the dimensions are, I don't know, 50 centimetres by a meter roughly. Or half a meter this roll of foil. Yeah, it worked pretty good, but what I've realised is every time. [I was like Googling around for zirconium, I kept getting these annoying hits on these stupid flash bulbs]. And I'm not looking for that. You know, it finally occurred to me that maybe I should be using these flash bulbs for the zirconium I'm looking for, and so I started buying up these single use flash bulbs and they're not hard to find. I have no clue like why people sell them or who would want them anymore, right? But anyway, so if you break them open, there's this very fine zirconium wire inside. And so, in order to activate the getter, you got to heat it up. And so, the thinner, the finer material is, you know, the easier it is to occur. So, this wire is about, I think it's one 1.14 mm versus this fine filament inside of a flash lamp. And so, the other technique I use is I run a very high current through the tube, and so I'm talking in the neighbourhood of about, you know, a hundred, 150 milliamps. And so that current is enough to start heating up the getter material like zirconium. Zirconium is a lot harder to activate. It's kind of unlikely you're going to activate it through conventional like car mechanic induction heating. You know, Bolt Buster, but so this method works for the higher temperature materials like zirconium. And zirconium doesn't evaporate and make a mess inside the tube, which is not that big of a deal if you don't use too much, but it also doesn't eat up the mercury. And it's a better getter material for the impatient, such as myself. I don't have to wait, you know, a day or a week for, you know, the magnesium. I sometimes I'd wait a week to clean up.

HS: Ohh true OK.
JF: And that's a really, really tough thing for me because I'll be getting up at like 2 in the morning to go check on my piece to see how it's cleaning up.
HS: Oh wow.
JF: My feet are loaded with broken glass.
HS: Oh wow. So, so the process of heating up the metal creates a process whereby any extra impurities inside the vessel are attracted to the metal? Or??
JF: Yeah. I mean the metal itself is just viciously hungry and viciously reactive with anything and everything. It's just that the surface of the metal it would normally interact with has already reacted and nothing else can get through it. You call that passivation. Well, most metals are like that, but barium, barium is kind of an exception. Where this would just keep, this is kept in oil, or you'd keep it in Argon because they just keep reacting. And so, once you've scratched off or exposed the underlying material underneath its own self passivation it's going to react with water vapor with the oxygen with nitrogen and some, some of that is, these materials are just going to stick to the surface depending on what the metal is. But then a lot of it is actually chemically reacting to form a metal bond with whatever that material is, oxygen or nitrogen.
HS: And so, it takes time with the magnesium but it's a more instant, but more difficult to instigate, reaction with zirconium.
JF: Right, right. Yeah, yeah, it takes a much higher activation temperature to get zirconium, or titanium is actually another choice. Which is actually kind of a, but the higher temperature thing. Is really kind of an advantage because you control when it starts gettering much better. You know you have a lot more control of ability to turn the absorption process on and off. I guess that's pretty important like the lamp industry or things where they would do certain steps before they would want the getter to work.
HS: Hmm, fascinating. And Jeff, you are you've gone down this path because you don't have a kiln in your studio and...

JF: This is a lot of the reason I don't have a kiln in my studios, because this path has been working.

HS: Yeah. Fantastic.

JF: It distracted me from that.

HS: And that means that you're able to continue producing work and, I guess I wanted to ask you how you envisage the viewer or participant engaging with your work?

JF: Well, one of the things I just realised was I just did a 3 1/2 inch well Wayne made the piece, but I filled it at least, a neon piece. Wayne and I were having this conversation about just how beautiful it is just to look at you know 75 or 100mm neon tube is how beautiful neon looks at that scale and so that's kind of my latest thing, it's actually right here, this this was a piece. I don't know if you can see it lit.

HS: Oh yes, I can.

JF: Probably you can see a little glow. To turn the room lights out.

HS: Yeah, beautiful.

JF: Right. OK. **But just sitting there, looking through it, looking at the glowing gas inside. And you know, part of interacting is here. You're moving around, you're looking through it, you're moving your position and your perspective through the piece. You turn it on and off. And that's all you know, putting your hands on the piece and interacting it is another thing. But I think just it's just the visceral enjoyment just looking at just this *plasma*.**

JF: So, I plan to actually put that piece in my living room. Probably vertically. As kind of a night light and I love when like kids come over and they just, they do the same thing I do, it just doesn't go away I think people like us are just born this way.

HS: Oh wow. Yeah, I guess that gazing at it, and that the shifting, [I guess], quality of the light is something that I enjoy the transparency of that too.

HS: And you know, I guess I wanted to ask you if there are other, I guess techniques, or things you do with your work to make the work more responsive? I know with that low pressure neon piece that there's less responsiveness within the work, or it's a more

even, luminous glow but are you... I know that you have made work that has got more movement or more kinetic activity.

JF: You're taking like filamentary stuff.

HS: Yeah

JF: Well, I really like to watch other people interact with my work too. And I love when someone says especially a little kid can. Can I touch that? Yes! I just love to, I love being able to say yeah, go ahead, just don't touch this part, you'll get shocked. I guess the filamentary aspects and all, that's interesting too. I don't do a lot of that, mostly because I can't dope. I know I still kind of need an oven and eventually I'll get there. I've kind of only just started with gases that it's even possible to fill them out, I really just, I only started with Krypton, you know because of the whole Ukraine situation it was just unaffordable until some appeared on the market for me.

JF: When was this? Probably about June. [Just one second.] So, I'm just kind of getting started with what I would call the more kinetic stuff.

HS: Jeff, I've got a cheeky side question to ask you as well because you've been so helpful to me explaining sort of discharge, and the circuit the more open-ended circuit, and I was wondering if you could describe or explain how you might describe to somebody who is new to plasma what the, what the transformer, or how the transformer acts?

JF: How it acts? Like what? The power supply? Like what is it doing?

HS: Yeah. What is, what is it doing? And I guess it's different from a neon transformer because that's a complete circuit, but maybe to touch on the openness of the of the circuit.

JF: Yeah, that's a really, really tough concept I've actually... A guy with a PhD in electromagnetics, an electrical engineer had a really hard time understanding this. He saw I had a Tesla coil operating and he had a really hard time understanding how? How is this working without a complete path? So, I mean, how would I explain that? **To really just get into... Electricity isn't really what a lot of people think it is, as in electrons**

moving around through a wire. That's probably what a lot of teachers might even teach in a science class. But that's not true. That's just not true. **What electricity really is, is its electrons bumping into each other, influencing each other down a chain.** The electrons themselves aren't actually moving. And the wire is not actually a pipe in any sense for electrons. And so, if you get away from thinking of a wire as some kind of like a water pipe for electrons. Because it isn't. **You can, you can start to understand that when electrons are moving around, they can cause others to move around and influence, kind of like how your voice travels through the air. ... if you start shaking one electron that'll start shaking the next one and the next one and the next one, and that's what's known as radiation.** Not the kind of radiation that, you know, Chernobyl or whatnot. But energy emanating from a point, as in how a radio transmitter works. And so that that that's really the short answer is wire is not a pipe. **And electricity is not electrons moving around, they barely move at all, it's their energy that's moving around.**

HS: So, in that kind of thinking about that influence of the electrons and the energy, the participant or the responsiveness within plasma is... Is becoming... Is the contact with the circuit or with the energy inside of the plasma vessel.

JF: Yeah, yeah, yeah. **You're actually, literally drawing energy, and that energy in the tube, you know, that glowing plasma is influenced by you.** And it's putting your energy in you. I mean, these terms are used so much, you know, in this kind of new wave crystal healing. But in this case, it's completely, totally, you know, the honest truth. That came out wrong... I didn't mean to insult anybody.

HS: No, no, I know you didn't mean to insult anybody. [Laughs] But, yeah, I think that for me, that's so fascinating. **That we're not necessarily even touching it, but it's we're, we're a part of the field.**

JF: But you talked about energy and all that. I mean that really is what this is.

HS: Excellent. Wow. Well. Thank you so much, Jeff... You really have helped me along the way, [to] understand some of that kind of the discharge and the path of the energy,

or much better than I had previously, so I really appreciate that. I do love seeing the work that you're producing from your home studio, it's really inspiring.
JF: Yeah. Did you see the microwave oven stuff?
HS: That is crazy what's going on there, Jeff?
JF: Well, I was just, [um] just kind of thinking of better ways to do gettering, especially in tubes that don't have electrodes. And so, one of the methods is high frequency induction. Another method might be high-powered lasers, which is a little bit too dangerous. I don't really want to go there. And I just had this thought like, why wouldn't it work in the microwave oven? You can put DVDs or CDs in the microwave oven. And so, I just thought it'd be such a cool thing. Just, just such a novel way to make plasma. It's kind of akin to like, microwave oven kiln for fused glass if you could. You know, it's just something that's normally inaccessible, but you can do this in your kitchen. I think it's such a cool idea.
HS: I don't think anybody could do it in their kitchen, Jeff.
JF: I do.
HS: Yes. And so, with that, with that method, you had evacuated the tube and then already had the getter material inside and back filled with your gas and sealed it off. And then the microwave acts as the function to activate the getter.
JF: That's right. And a lot of the reason I can do this at home I think is cause the existence of the oxygen concentrator to do Boro glass. Because I would not have lasted if I had to keep getting bottled oxygen. And so, the getter the process of activating the getter can be pretty abusive. I've done a very little with soft glass and I have been able to be successful with some very gentle gettering but the stuff I get away with Boro, I just couldn't, I don't think it would be possible in soft glass and I almost definitely would not still be doing this, or I'd be really frustrated if I had to keep acquiring oxygen tanks.
HS: That's something I've got to look at investing in is an oxygen concentrator. At this stage I'm working with bottled gas, and bottled oxygen.

JF: Oh, you're working with bottles? Yeah. Yeah, it's, it's... I don't know how the situation is for you with some welding suppliers. I mean, they're nice people and they're easy to deal with and all, but they have bankers' hours. You know and having to drive half hour each way. It was not... But yeah, the oxygen concentrator is a major game changer for me. I guess we have COVID, the only good thing to have come from COVID is the abundance of oxygen concentrators.
HS: Oh, OK, well, that's interesting.
JF: But if I, if I tried this soft glass stuff, put a minute in the microwave oven I'm pretty sure I just cracked the tube, but it wouldn't work.
HS: OK. So, it's that kind of durability and robustness of the borosilicate glass that enables more experimentation with that very I guess, indirect and aggressive heating to activate the getter.
JF: Yeah. So, I think that's a probably a fairly big factor in this, is why I'm able to do this, and also why it affects a lot of my plasma behaviour because I'm really concerned about the future availability of Boro electrodes. I don't believe they're going to be available for much longer. And that that's, you know, so I'm really like aggressively trying to figure out, can I make my own glass seals, how to do it? Pushing people like Wayne to, you know, help me to figure this out because I think it's really critical for the survival of plasma art is the ability to a) use Boro, and b) be able to do the glass to metal seal.
HS: But yeah, that transitional seal..., I was hoping to get my hands on some of the transitional glass to go from the tungsten to the Boro.
JF: OK I have. And you know what? [Haha] Oh, this is awesome. So, I kind of had this conversation on a forum and a guy named Mike Grossman, who professionally made lamps for a long time, contacted me. He gave me some parts and some advice on how to go about this. But, in the notes, actually came from Robert Haus had notes on this subject, traditional glass and they listed three kinds of glass that you could use. Two are Corning product or Schott products, and then one was uranium glass. And they're

almost impossible to get. I mean, you could maybe buy it from Schott. I couldn't get a quote from them. I mean, I sent it from work, a defence contractor, a request, and then they sent me back a credit application. Anyway, there's a guy on the forum I think he lives in Melbourne. His name is Russ, Russ Titchen.

HS: Oh, OK, yes.

JF: You know him?

HS: I know of. Yes, I do. He actually lives quite close to me, but I haven't spent time with him.

JF: All right, all right. Turns out he's got a huge plethora of this stuff. I guess some local shop Rep, or somebody was going to put it in the dumpster.

JF: And then. So, you said you were looking for transitions.

HS: I guess, like yourself, I can see that the borosilicate electrode industry is not going to [um] is potentially not going be around for a long time, considering those really only YanaLux and then people who produce it as individual makers, so having that [um] you know knowledge and access to that transition from the metal to the glass is good information to have.

JF: It is such a dark art. It is so much trickier than you'd imagine. Like I've done probably about seven or eight tubes that all failed. Because I guess part of the thing is the tungsten, it's got to be clean and polished properly and just how to do it, you know, just sanding a little bit a little bit of acetone it's not had the results I'd hope for. I mean, you know, some tubes might last a week, but they start getting contaminated. And, and so, I mean there's methods and then there's like, crazy, crazy methods. But the more functional methods that I think would work, people say you heat up the wire and then you dip it in sodium nitrite, which is kind of a hot dog preservative. Not to be confused with nitrate, and I'm serious about that. It truly is a hot dog preservative. You know that's not something you'd think of. And then another method Wayne is telling me, is that I should take the wire and then put it in a solution of sodium hydroxide, which is a really caustic ingredient in drain cleaner and then run an electric current through the

piece of wire and that will polish it up. I mean, this is really like obscure knowledge. It's not hard to do, but it's just not something I would come up with on my own. And so, I'm starting to, you know, resort to those methods. I got my sodium nitrite and didn't come from a package of hot dogs. And I got my sodium hydroxide and that I'm going to try in the next few days. And then there's more. There're other methods they do like, they bake the wire in a hydrogen atmosphere. I don't know how I would do that but. But yeah, this this is just real, real, like tribal knowledge. There're so few books on this subject. And you just you gotta just hang out with someone like Wayne and just get all this knowledge out of his head.

HS: And in the tubes that you've produced with the attempts that you've made that have failed, is that due to like pinhole leaks at the join? or is that the metal is failing in some sense?

JF: So, So that's a thing. It's kind of hard to diagnose. I mean, this is a tube I did where I was actually able to cannibalize a soft glass electrode. And I don't know how much you can see?

HS: Oh, yeah, yeah, yeah.

JF: I mean it all looks good to me. And I have a really decent stereo microscope in my workshop, so I can look at it under a microscope. And it's really not obvious what the problem is. But yeah, you talk to Wayne or somebody who knows this stuff they tell me it's the wrong color, and I haven't, it's not that mouse brown I'm looking for, and I haven't properly dissolved the oxide layer of the tungsten into the glass. And so, they'll tell me what's happening is you have a few molecules of air sneaking in at a time. Because the tungsten is not wetted to the glass properly. Now I would not figure that out on my own.

HS: Come on, you might. I definitely wouldn't.

JF: I mean, this probably took people like decades and decades of knowledge and experimentation and, you know, just to figure out how to do this. And I mean this can,

this art can really, really just get lost. And I think that's really, really important for our craft is to understand this and be able to keep these skills alive.
HS: Hmm yeah. Yep, that that wetting between the glass and the metal to have that electrode join, yeah.
JF: Yeah, I imagine people bang their heads against the walls and like 1900s with, you know, light bulbs and radio tubes and all that just figuring out how to do this. I think just it must have taken a really, really long time because it's just not obvious.
HS: And I think it's a lot more difficult to achieve with the borosilicate glass than with the studio glass.
JF: Do you think it is?
HS: I imagine that it is more difficult with Boro because of that transitional glass that's required and I guess, I guess Mundy works, has worked for many years, making his own electrodes, wetting that into the dumett wire into the soft glass.
JF: Do you make your own electrodes? or do you...?
HS: I have only experimented and I've like tried the seals.
HS: I've had one that's worked, and I think that that colouring was really crucial, that sort of rusty brown kind of colour, but that was only with the soft glass. I have not tried successfully with the with the tungsten to Boro.
JF: Lot of the problem too is my glass skills are kind of primitive. I don't have a glass lathe. And just having the skills to heat it up all uniformly and all is really another thing I'm learning. It’s because I'm also learning glass along the way here.
HS: Yeah. Oh, well. Thank you so much, Jeff, I really appreciate how broad your knowledge is and your passion for it. It's really, yeah, super fantastic.
JF: Yeah, I enjoy this and I enjoy the whole community.

6 Mundy Hepburn

[23.05.2023]
Harriet Schwarzrock- HS: And where is your studio?

Mundy Hepburn- MH: It’s in my basement. And in my backyard.
HS: Uh huh
MH: And in the spare bedrooms and in the shed behind the house.
HS: It is, I love it. And what is your background that has led you to working with plasma illumination?
MH: Well, when I was eight, I saw Mr Geyer making glass figures at the Gillford fair over a torch, a little crossfire. So, then I started playing around with glass and I was very young. When I was fourteen, we made little pot pipes and when I was older, in my twenties I was making and fixing beer signs then my brother sent me the cover from The Sharper Image catalogue showing the first plasma ball, sculpture, ball. That was in the early eighties... mid-eighties... yeah early eighties now that I think about it, yeah. I'd struggled to figure it out and there's a funny story on my website about how it was taught to me. There was a man at the dump tearing up a TV set and I went over near him and turned around and said I wonder how they make those plasma things, and he said that well you start with a high voltage power supply, you need the guts of a colour TV set. So, he said I know who you are and I know where you live and I'll bring one over and then he without another word he turns around and goes back to filleting the TV set with the exact tools necessary for the job. So that was freaky, a Westbrook dump experience and then the other thing that happened is my drunk neighbour, Bill. He was freaked out 'cause he had the unlucky experience of graduating from high school so now he was no longer the captain of the football team and no longer had access to all the pretty girls and he had to actually figure out his life so he was over hanging out in my garage in 1986 and he said, ‘Mundy what am I gonna do?’ and I said, ‘Bill, you think you got problems? How do they make those plasma things? That, that really bothers me.’ He goes ‘Oh that’s simple, just suck the shit out of it and put more gas in.’ I’m like ‘go home Bill’ and he’s like ‘No just do it’. I said, ‘go home Bill’ and goes ‘just DO it’. So, I go oh ok, so I got out the colour TV power supply and made a little bulb and put in a wire in it, an electrode, and um I said, ‘here you touch it’. I thought it might be able to blast him, you

know, so I just open it and sucked out the air and open the valve to the argon tank and I hear a ‘woah’. I said, ‘did you get a shock?’ He goes ‘no look!’ And in the little end of the wire, right off the end of the wire, little waving thing little, waving arc. I said, ‘my God that's higher pressure than regular neon, you just need more pressure in the right power supply’ And so then I met Kurt and he started building power supplies because back in the eighties the inverter, the drivers for neon’s and fluorescence of the high frequency drivers, were just beginning to be worked on. And now everything is run by inverter, all the power supplies are inverters. So back in the eighties, there was Kurt working for Emerga-light making an emergency exit lamp out of neon and driving it with his own homemade little power supply that would run for, I forget how many hours, off of a battery as an emergency exit sign for ultra-high reliability, that's the technology they used. So, I was all excited and so I was filling gas bulbs and Kurt was making these crude little power supplies that are always arcing out or dying or failing in one way or another, it was a pain in the ass. So, fast forward 40 years and here we are! Now there’s beautiful power supplies that I designed and built and all kinds of cool gas mixtures and electrodes and nice glass composition. Christ, I've been making all my money from plasma since 1990 really, I guess. Well in 88 I put in the neon garage, that was mostly neon that had a few beginning plasmas, but I mean I used to do neon, I did neon a lot of neon art and neon signage back in the 70s and 80s. But now, well who would’ve thought it would come to this? Now it’s so cool I can make a thing that's as big as a human being and you go up to it, and you put your hand there and it makes little sandbars and butterflies and all kinds of colours and patterns inside the light it's really cool.

HS: Well, can I ask you questions along those lines? Starting with, how do you describe responsiveness within this form of illuminated practise?

MH: Oh, it's when the thing changes when you come up to it. if you have sensitive equipment, you can tell when you're near a plasma light from 50 feet away but if you just go up to it, say put your hand 4 inches away from, it'll change the light will maybe go towards you or maybe they do nothing. Some of them don't do anything when you touch

them, other ones they look better when you just put your hand near, and it draws the energy towards you. **See the plasma light is running at high voltage and it's seeking ground because the energy always wants to equalise and mellow out the waves so when there's heavy energy coming out of the light you come near it, you're denser than the surrounding air so you attract the electricity to you, and it goes through you and to ground. That's the circuit. So that's it aesthetically and experientially it's very weird, you turn toward the thing, and the thing turns towards you and you're like wait what? And you put your hand near it, and it lights up the changes, makes wonderful patterns depending on the mixture**

HS: It really does, thank you. And this is a big one for you Mundy, sorry. Are there particular techniques that you employ or have devised that expand upon the artistic application and inherent responsiveness of plasma illumination?

MH: My entire adult life has been devoted to learning how to do all the things that it takes to make beautiful gas discharge lights, high frequency plasma types, cold plasma, wiggling filamentary arcs as well as stable arcs that don't undulate and move but simply glow and everything in between. It's taken me, Christ, what am I 60? I'm almost 68. And I've been trying to make cool stuff since I was 8. So, 60 years right. When I was 8, I started messing with glass and it's just one thing after another and then it was, well it went glass and then pipes and then neon and then signage and art and then plasma. **So, one thing follows on the next. Plasma lights are just neon lights with bigger vessels and higher fill pressures, more complex mixtures, more complex electrodes high frequency drive system but it's basically a gas discharge tube same as any other. Whether it be a fluorescent light or a neon light or plasma light they are all just a bulb of gas and you blast the electricity through it, see what happens.**

HS: There are a lot of aspects to it, and I guess I'd be interested particularly in hearing a little bit about your use of electrodes or production of electrodes because that's something that you're particularly renowned for!

MH: It's really simple all it is you have to have the right glass and the right wire. During the push in World War II, they were trying to make radar tubes and they needed a metal wire to go through the glass and hold the vacuum and so they used Invar 42 which is an alloy of 42% nickel and the balance iron and, (I think it was Westinghouse), developed these wires that were the invar 42 alloy coated with copper and then the copper was dipped in boric acid and heated in a flame until there formed on the surface copper boron oxide, copper borate, on the surface of the dumett wire and these wires had to be kept dry but when welded into the correct glass they would not crack the glass and the glass would seal hermetically tight to the borate glass on the surface of the copper, the dumett wire. So dumett lead in wires are specialty thing but you can get them, you can buy it on eBay for 30 bucks for 10 feet, dip it in boric acid, cook it with your cross, with your little hand torch and then seal it into the neon sign tube. And that's the thing about neon sign tube it's the kind of glass that they use to make the ends of fluorescent lights; they call them funnels or stems. That glass has to be a very uncrackative glass, some glasses are very brittle, and others will tolerate a lot of thermal change without cracking. I mean what comes to mind is Pyrex. Pyrex is traditionally a glass that you can subject to like, put it in the oven. Oven to tableware, that's what they call it, and it's supposed to not blow up, well it blows up sometimes. So, I use neon sign tube now, I used to make my own glass for years and years and now since the lead glass is illegal, they no longer make lead glass, now they make this weird mixed alkali mixed alkaline earth glass and it is a lot like the old glass that I used to make. So that's what I use nowadays.

HS: Fantastic. Can I ask you the next question? How do you envisage the viewer or participant in engaging with your work?

MH: I just watch ‘em. So, you gotta to do, just watch them freak out and enjoy it, all different ways. Some of them just stand in wonder others... all the cool stuff that everybody does when they see the lights. I've seen a little girl jump up and down and clap her hands, that was very cute. I've seen people just stop and the jaw falls on the

floor, and they just stand there and look at it. One woman, years ago, Judy caught her on videotape she's on the internet, she's staring at this light, and she looks like she's about 1,000,000 miles away she's just like ahhh. **Cause the little bugs inside, certain arcs are very nice to space out on**.

HS: They are.

MH: They are like the light dappling on a brook in the summer in the country, on the bottom. **It just shimmers and dances, it's a natural thing that's what's cool about it. In fact, that's what I like about plasma is that it's a totally natural phenomenon, it's just that nobody's ever seen it before 'cause people hadn't done it before.** [Mundy's partner Judy has just walked past] Pudalli! You've been immortalised. I'll now be at the Australian National University archives saying Pudalli!

HS: Excellent. Well, I think maybe you answered this next question a little bit in what you were talking about before but how do you experience this sort of responsiveness within your plasma practise or work?

MH: I grew up on the beach. I was lonely. There was one kid, his name was Echo, he wasn't always around so I liked to play with materials, with *things*. We would like fires, break things, dig holes, try to destroy whatever we can get our hands on. And make whatever so we ended up melting glass cos there was a little torch, and I had seen it done and experimented we tried making little torches. I made a little torch out of glass to melt glass to make other little torches out of glass and an object that squirts over in a candle flame underneath it you can melt you know little 3-millimetre rods and pull little crude things. I used to make little earrings like a drip, I mean I've just been playing around all my life. Same town, it's a little creepy. So, it's a line of inquiry, a natural line of inquiry that I've been fortunate to pursue for literally, physically 60 years. And I look at what I make and go 'who would've thought it comes to this? Oh my God I can't believe what I'm doing!' **And if you add little xenon and you add a little argon and put some neon in there and zap it and it makes these little spinning stars of blue and pink and you're looking at 'em going 'oh that's real isn't it I'm not just…that's real!'**

Yeah, who would've thought it. So, it seems like it's from a different universe but it's just an expression of our own reality and that, I was thinking about what you said the other day and I thought, well art is for us to experience ourselves that's what I make art for it helps me experience me reminds me that I exist shows me that I have an action in this environment and most importantly, it's fun. So I just go along and try to have fun and wonder what the hell I'm doing and then someone comes along and says I'd like that one I'll pay $2500 and I'm like oh okay that's what I'm doing right, right okay, let's go have some more fun and it's really interesting, if I truly can be totally Zen open childlike receptive just gentle and open and receptive and I do my playing with swift glass and I make something pretty, other people read it accurately. Some people don't care about art, but others will read it and go ‘oh that thing makes me feel so good’ and I think Oh my God it communicated! I was just doing something and enjoying my day just having a fun time going oh I like the way that curve goes with this and I think I'll do it pink with blue phosphor yeah and it comes out pretty and people will put down their hard earned money for something that's pretty and I think, I say ‘don't waste your money on this, don't you have bills to pay?’ And they're like ‘yeah but if I look at this every day, I'll enjoy it every day but if I pay my bill, the next one is due next month so I want a piece of your work because it makes me happy every time, I see it'. That's pretty cool. I remember 40 years ago I was at a craft fair, and I had my little crossfire, my little gas air crossfire, in the sun, in the wind getting blown out, cracking just trying to make stuff like an idiot out in the out in the in the backyard of some house it was cool. So, this young man comes along he says, ‘how much for this one?’ I said $2. He goes “how much for the whole table?”. I said uh um uh and he counts em up and said, “there’s 25 here” and he whips a $50 bill and hands it to me and goes “I'll take these”. But you're buying little bits of glass for $50 he looks to the left, he looks to the right, he goes “I could buy cocaine for $50, and I'd feel great once but look I buy these things for $50 and every single time I look at them I get pleasure and I don't have to come down, it's real pleasure.” I was like, I was in my 20s, I was like wow man that's convincing.

HS: That is convincing.
MH: Like jeez you could buy cocaine sure, or you could buy glass, your choice. He could buy hot dogs, I mean you can pay your electric bill what are you going to do with your life? Your money? How are you going to experience your life with your money? And to my absolute astonishment and glee, every once in a while, someone comes along crazy enough to give me money for my artwork and when they walk away there chuckling and one guy turned around and goes “I got the better deal that money is going to be spent you're going to need more but I got your light” and I said cool but I make them. If I need a light, I'll make another. He's like hmm.
HS: Well, I have another question I'd like to ask and that is, does wonder play a role in your use of plasma illumination?
MH: Wonder is what started it, are you kidding? You look at this stuff; you go Oh my God! Wonder is... is it. **That that's what plasma is for; to evoke a sense of absolute wonderment so yeah wonderment is the currency in which I deal.** You wanna have your mind blown? Buy a Mundy light, hang it up in your bedroom, you’ll have eight kids before you know. It’s true though, it’s true. I did the neon garage back in the 80s, this young couple they got one they liked it about maybe six months later ‘We're mad at you! Well, we're gonna have another kid and we hadn't planned on it. Oh, I guess it’s alright.’ ‘Oh shit. Sorry man.’ He said, ‘Yeah, we brought it home hung up in the bedroom like you said and next thing you know we have no idea how it happened of course, I said it was the radiation from the lighting it affects your brain cells.
HS: Oh wow. Well, I have very open-ended question to end on and that is, I was wondering if you have anything else or any other insights that you might perceive as relevant to this interactive or affective dimension of plasma illumination?
MH: It’s just really cool to go from the totally physical, totally scientific, totally practical and create something that no humans have ever seen before and watch the response of what happens when you put in nitrogen and argon and krypton and mostly neon, and you have undulating orange fire that never stops moving inside a land. it's the kind of

thing you want to stare into and perhaps you'll see the future or something. So, it's an exploration between the physical and what we are, the energy things that we are. Cos yes, I have this body, but I am not my body, I feel my body, but my body is not me. But me, I, freak out when I see plasma lights because they're so different and beautiful, they are so different from anything I've ever seen before in my life, that's the constant comment. Oh my God, I've never seen anything like this in my life, that was my response when I first started playing around with electricity and gases and making this kind of light. it's just been this discovery journey and as Wayne says, we're too dumb to know it can't be done so we just learn how to do it and that's really it. I mean everything that I know I've developed, I mean Anders built the power supply but as far as electrodes and gas mixtures and glass compositions and all that, foster methods. My friends at Volt-Arc, you know I go down there and hang out and learn stuff and then come home and try stuff. I mean I've been going to Volt-Arc since I was, I'd have been about 22 I guess 22 years old so since 1977 and what is it 2023?

HS: Amazing

MH: So, the guys at Volt-Arc, I mean I was driving by there all heartbroken 'cause my girlfriend just left me, I thought oh I got nothing to lose. So, I went in the office and said, I want a tour of the plant. The guy looks at me and goes 'are you from EGL?' I said what's EGL?' he goes never mind he goes can you prove I said, I'm a glassblower, I want to learn neon. He goes can you prove it? So, I went outside and dug through my little Morris minor 1000 on the debris of the back floor there behind my chair and by God there was a little purple vase. I brought in gave it to him he flipped out I'm like just a little purple vase because your glassworker yeah in other words on lamp worker and so I was given a tour of the plant and at the end I saw this this neon sign in a in a bin sort of pushed off to one side and it looked messy. I said, what do you do with that stuff? I see the open garage door coming up it's the end of the tour and I had seen the wonders of my life, fire squirting out and doing all this stuff there manufacturing each HID lamps out of quartz, they were making specialty fluorescence, they were coating and baking

neon tube, they had the tart machine spinning around making electrodes it was wonderful. Kid in the candy store. So, as I go to leave, I'm like what about that glass he kind of scowls and I thought oops shut up, I come up to the door he goes put out your hands. I thought I got nothing, he goes no, no like this so like to cup and the guy comes up and starts loading me, gives me 50 pounds of glass and goes is this going to be enough? I could hardly carry it and I'm like 'yeah'. So, I went home with my 50 pounds of scrap and ruined all of it trying to learn how to make neon. So, then I started, I went over to Paul Geyer's place cause he's the one that I saw when I was eight and he directed me to Joey Buetele, his friend, he says Joey got a bum leg in the war so I taught him neon so he can feed his family so Joey was over there and Jo ran neon, now his son does it. Now his son does it. Now his son's retired for God's sake. I was the young kid then now I'm the old fart it's weird it's only been six decades. In a flash, in a flash it seems like I was just over there watching Joey doing a double back. Yeah here's how you do a U bend, you gotta watch for the don't blow too hard right there with heated up with the O when you're making an O on the ribbon burner the trick is you warm that glass and you let God do it, you just stand there and let it fall into shape and then right when you got a good U you just bend over the top to make your own and then check it against the pattern but don't leave it on the pattern or it will crack it just hover above the pattern shape it, then let it cool. And don't be waving it around or it'll crack. That was lead glass. Glass now, they got this wonderful lead free stuff which is so similar to the glass that I used to make in the 80s and 90s and 2000s but now God I just get this crap clean it out cool it off you got nice glass and it's compatible with Dumett so I can pull my own tubes or use scrap tube and get the Dumet wire an just seal it in carefully and then kind of flaming anneal it and whatever you crimp on to the end of that Dumett wire that's your electrode, it could be anything. I made a little guy out of tinfoil, and he had lightning coming off his head or I made a, well those flowers with the colour aluminium inside and then for other things that sheet aluminium, or I also use sometimes nickel. Nickel or aluminium but the thing is when you have a low-pressure lamp it's going to sputter away if your electrode is too

small that's why the neon sign electrodes are pretty chunky ‘cause they, they have enough mass to run cool and carry the current that the neon column, gas column, is about 30 milliamps they're good for. If you run too much current through them, they’ll heat up, that's the thing. I used to make all kinds of electrodes and some of them sputter away, or they just turned black and burn up inside the vacuum 'cause they're too small and I have too much current going through them. So, you have to have the electrodes have enough surface, but you can make it a decorative electric, that's what I do. I just paint them, I use aluminium cook it, burn off all the stuff and get the oxide going on there cook it a little bit, paint it with phosphor, with boric acid and water, distilled water mind you, and you don't want to leave phosphor in water so I mix up a teaspoon at a time and then let it dry out afterwards. Then if you want to use it again you dump more water in but if you leave phosphor in water for more than a day or two it loses brightness. I had forgotten that it's in the literature in the 1980s back, way back. General Electric or somebody was doing experiments measured the output of some phosphor solution that they had left for five days versus the fresh stuff, that's the same thing happened to me I had some old stuff in jars I left the water in it and the output it just looked half dead. I just didn’t remember from 40 years ago being told phosphor does not like water.

HS: Well, thank you very much Mundy. It was very insightful.

MH: Okay now let’s go take a nap.

7 Ed Kirshner

[17.12.2023]

Ed Kirshner EK:

HS: OK. And the next question I've been asking is where is your studio?

EK: My studio is in the city of Alameda, which is right next to Oakland.

HS: Oh, fantastic. And I guess as a leading question I was wanting to ask what your background is that has led you to using plasma illumination?
Ed K: My background is way back both in art and science and then architecture. I've been involved with aesthetics for as long as I can remember, since both my parents were artists or designers. Early on, it was decided I'd go to architecture school because I wanted to be a physicist and they wanted me to be an artist, so it was a compromise. So, I went to architecture school and at the same time took a lot of sculpture. So that is sort of the start, but I also as a kid played around with electronics and radio and shortwave radio and things like that. Including high voltage which I shouldn't have, but I did. [Um] So that's how they got me started on that and I guess I was always intrigued with the Aurora borealis and into play of light and glass. It's just something that was something I was really interested in and liked. And then **I started getting involved with the science and the things called chaos, chaos theory and the related aspects of the thing in science called emergence.** And in that regard, I played with, I discovered, but I discovered something other people already discovered I didn't know they had, a thing called video feedback. Which is actually a good representation of a chaotic system that produces, from what seems to be random, produces forms. And shapes and patterns. So, I was playing quite a bit with video feedback. And then I started researching it and found that there was a whole institute that worked with chaos, one of the physicists they had specialty was video feedback. So, I got in touch with him and since I wasn't a physicist, he didn't give me the time-of-day and. In my childish way I said, well, I'm going to do it in three dimensions and hung up. And from there I said, now how the hell am I going to do this? So, I had the idea of the Aurora in a bottle. Started the from there, but also because the electronics end of it and I was studying Tesla. Basically, I read most everything I get my hands on from Tesla, including most of his patents. So that was a good start also. So that's kind of what led me, led me into it. In addition, I had the, this all that time I had sculpture, I was always doing sculpture, but

as an aside. My work was, I quickly went out of architecture into urban design and then urban planning, but I always had you know a thing with art?
Not too much, mostly for 30 years. I guess it was mostly the photography as the art representation. And went into development of affordable housing. Multifamily affordable housing mostly. And then the bug got me when I was about 50-55 the art bug. So, I decided to go, you know, back to school to learn it. You know, study it again which is what I did at, you know… Oh because I wanted to do the Aurora in the bottle. I knew I had to learn about bottles. So that means going to glass school. Which I did because the CCA, the California [College of the Arts][427]… down the block from where I live.… It used to be CCAC when I went there but they thought they would drop crafts.
… It's actually, this is the hard thing, crafts were a big thing in the arts in this area, back at the turn of the century and then time after it, you know, with Julia Morgan and the other architects and artists, craft the idea of craft, was not the way we think of craft, but it was an art, it was like art deco, but it didn't have the same meaning. So, they decided to drop craft…
HS: I have been doing a little bit of reading about early electricity and I don't have as strong a background obviously in electronics and tinkering as many in the Plasma Art Alliance, but I have been fascinated to see how a lot of trades and crafts really informed electrical, or learning about electronics and electrical circuits and systems and how that material knowledge was so important.
EK: Yeah. So, in any case I sort of jumped into it and in the glass end of it and I took all of the studio classes at CCA for about 3-year period or so and, you know, went to Pilchuck a few times and went to Corning and went to Northlands. Mostly for glass, but they occasionally like would have a neon plasma class. There was a little bit of that being done. I mean, plasma was around before I jumped into it and there are some folks working in it, so I figured, yeah, that's what I'll do. And I guess that's what got me into it.

427
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Previously, as I said previously, way, way, way, way back. I also studied sculpture directly, I went to Oscar Kokoschka's School of Art, in Salzburg, Austria and studied sculpture there with a really, really fine, [I didn't catch the name] ... Viennese Austrian expressionist sculptors. Modernist sculptor. Really was fine and I studied with him. Oh, I can't show, behind me are some of his sculptures but. But yeah, and all the time you know following science. I mean, I always say I've you know, I've read every monthly issue of Scientific American for the last 65 years. I try to keep up with it. So, it's a combination.

HS: I do love how it is so, so broad and so defined within the vessel and all of the elements that contribute to what's happening inside in that auroral space.

...

Ed: Since I was really looking for patterns, I wanted three-dimensional patterns in the gas, very few other people were actually doing that, if any. So, I started developing, and I realised that it was the geometry in the glass that would do it. So, I was playing with the geometry and some of it was pure accident. I mean, its alchemy, mostly alchemy, not science. It's science some, but a lot of its alchemy, trial and error and luck. And from that, that developed some of the different forms that I used in terms of the glass which then produces different geometric patterns etcetera. And most of the geometric patterns are actually related to chaos, at the, I believe at the molecular level in the that there are feedback loops within the electromagnetic field that caused the patterns. And if you tune it and with chaos, you don't get patterns unless it's fine-tuned. So, you'll have what looks like you know, normally random, the normal idea of chaos, but at a certain point, that's just what differentiates it from random or your Brownian motion, it will click into a geometric form. And it just fascinating that it does that and going back, that's what happened with the video feedback.

ED: I mean, it was just amazing. What's the word? the Mandalas, and that you get that kind of pattern very easily with it, I mean I don't know why you would? Why should you? But it just does. It's this feedback caught somehow clicks into a geometry and that

happens in some of my plasma work. And that's intentional to do that, like the one over my shoulder.

HS: I can see that it's beautiful. They're some of my favourite pieces, yeah.

Ed: So, and there are other things you can do with it. And it's, I mean it's endless and I'm so happy that there are so many people now getting into it. I mean, basically there were six people when I got into it. Or, you know, maybe six people taking it seriously. And now? Now there are, you know, probably 100. So that, and that was, you know, pretty intentional the pushing it. I mean, that was the idea, you know, but Wayne and I talked about that for a long time. Being how do you, how do you expand and field? And I think we've done it, you know, with the help of a lot of other people, but that's the whole idea, you get it, parlaying and the new generation. Strangely, even though my relatively Johnny come lately in the field I'm the oldest one in the field it is true, I started so late. Ouch, shocks me every time I think of it, I'm 83.

HS: Oh wow, Ed. Wow.

Ed: Yeah. And I'm a great grandpa.

HS: Ah, that's wonderful. Ed, you've been such a fantastic mentor and inspiration to so many of us starting out. It's really evident that your passion and knowledge are so well grounded.

Ed: I really like that, by the way of orientation I had my other fields too. I always felt that like, you know, I learned from others, so it's, I want to have others learn from me. And also, I like working in fields that I, how do I say I like working in fields I like. Which means I want to expand. So, the way I expand is to have other people develop the ideas and work with them. And I've seen that happen, you know in like affordable housing and a whole lot of, you know, I mentored a lot of people there too. And helped develop the field of that affordable housing in California and the country. ...

HS: Well Ed, Ed I guess when I experienced plasma, I've been very interested in the idea of responsiveness, and I look at your work with the chaos patterns, and it's not a still

diffraction that we're seeing, it's, it's moving and so I wanted to ask how do you, how would you describe responsiveness within this form of illuminated practice?
EK: Responsive... **There's definitely a feed that's part of the feedback, and it also indicates why I think I'm pretty sure that the patterns we're getting are really at the at the molecular level at the electromagnetic level, because when the interaction is coming from affecting the electromagnetic field.** And by affecting the field it changes the pattern. So, the patterns develop because of feedback. If you tune it, once you tune it to get the patterns. **Then you have, that's you, you've tuned the feedback so that the chaos and effect clicks into pattern, but then that's basically, a tuned electromagnetic field.** With feedback loops and interplay with the surface and with the geometry and the power level and the gases and the, the frequency somewhat. But you can interface with it. If you since in effect most of them are single electrode it's always looking for the second electrode.
So, and the fact you're acting as sort of the return and you're changing the electromagnetic field, which it effects and changes the pattern you're getting. I saw that like was very intentional with that I wanted to see that and see that happen. Some of the newer things that I do, I don't have that happen for other practical reasons, you do that and the piece can be... you can have a problem, for example with it transmitting because it is radio waves and it can transmit, and it could affect your cell phone and that kind of stuff. Can get a burn, you know, that kind of thing. But some of the new ones I've been doing intentionally, using a grounding plate, sort of a semi-Faraday case. And that's used to help develop patterns, but those patterns cannot be affected from the outside. So those ones you've seen that using those little flat pieces where you have? Of the dancing pillars of plasma that cannot be affected from the outside on the top because that top plate. It is grounded and so you're not. The ground is already there, so you can't affect it, and that's a good one and effect because it can be used like table, it can be used. It can be table-top, it can be on the wall. It doesn't affect anything. It internalises you know, like the electric, the electromagnetic.

HS: So is that that is then a more closed system or circuit. When you're employing A grounding plate.

Ed: Yes, it is. Yeah. No, there's another thing. This is just technical one for exhibiting. And you know, sometimes we've had problems with the pieces being too powerful and affecting other things around it. Well, you can always make a what's called a Faraday case out of transparent conductive class. Which is my grounding plate being conductive, it acts like a metal. And then that that you can use that around the whole piece.

...

HS: And sorry, and when you're referring to that conductive glass, is that around the transformer or around the piece ...?

ED: If you want to, in that case it's so that the electric the radio waves don't get out and you still want to see the piece, so your display cases can actually be made so that you can have a case around the piece and it [contains the electromagnetic radiation], but then it's not interactive. You know, it's a trade off, but when I'm using it in the piece, that's a different story. That's true, but I'm actually using it as part of getting an effect, but the effect is being tuned with the grounding plate. And by doing that, it eliminates the interactive-ness from the outside. You get different patterns. But the patterns I've been playing with are from tuning with the grounding plate. And that seems to be, I like some of the stuff from getting.

HS: Or they're mesmerising, literally. Well, I know with this next question, it's up to you obviously how much you want to answer, but I'm wondering about the techniques that you employ that expand the application of for plasma illumination. I know that you've got very specific methods of filling and tuning your work. Are you happy to share some of that?

Ed: I share everything my proprietary with anything. That's another thing I like about if you, if I want to, I find if you want to expand the field, you don't be proprietary.

HS: Oh wow.

Ed: That my goal is not that, oh, I have something I, you know, I want to be the only one selling it, trying to find. No. That's if I find it, other people can have it and that expands it. Some of it is so difficult though not too many other people take it. So, I think the thing is that I like I would say, one of the things I've developed, the major thing so. The idea of the glass geometry, emphasising glass geometry wasn't done particularly before, and I use it at with very, very explicitly to get certain patterns. And that's that. That's something I think I've had. Some of it was, you know, learned, some of it was spark, some of it was simply an accident. And to come up with some things and some of it had to do with not accepting the rules of glass, I mean. There are several patterns like that shouldn't, according to glass people should/can't happen because you can't make glass that way.

It was easy. Soft glass studio glass you know, people always be saying it happened and it wasn't. So bad, but you don't pinch it. The glass because it will have a tendency to, you know, to break. So, I assumed that at the beginning you just getting very close and you can get the pattern because you don't pinch. It and then I was working with someone in Corning

And they made a mistake in one of my pieces, it pinched and he was going to throw it out. And I said no. Don't throw it out. Let's see what happens! It didn't crack and we got beautiful, beautiful pattern.

And from that point on, then when I worked with Jaime Guerrero. We used the technique of pinching to get the very fine pattern, so you could pinch the glass as long as it gets annealed it was, it worked fine that. I have never had a pinched pieces with soft glass. Break everybody thought it would break. Now the big, big, big change was with borosilicate. That was an absolute no. And I was working with Berndt Weinmeyer in Austria you know probably one of the top or scientific flame workers in the world and he would not even consider trying to pinch the glass, he just wouldn’t though. That's not going to work, so I couldn't get him to do it after 10 years later I decided hey, well, I work mostly with soft glass, so it doesn't matter, but I'm now doing stuff in borosilicate, so

with it. I'm working with Adams and Chittenden and the glass scientific glass people in Berkeley here. And I said do it. OK, I'm paying. Don't work. Just do it. But do it in a certain way. Don't do it the way you usually do it.
What you need to do is see normally with Boro they'll let it cool a bit before they put it in the kiln. Keep it hot. Keep it hot if you can do it. Do not let it cool and get it immediately into.
HS: Ohh so like a glassblowing technique for the studio glass, OK.
Ed: Just use the glass by the soft glassblowing technique, which is to get it in the kiln as soon as possible, so it doesn't crack and see what happens and it works.
HS: Wow. Wow.
Ed: So, [we'd] do that and you know, then you get a different, you know get a different, more fine powder using glass, even though like the one behind me is very tight. If man made them very tight and he wouldn't hit you and we give a good pattern, but if it's pinched, you get even a finer pattern. Anyway, that was one kind of thing the other.
The other one is just playing with gas mixtures you know, I developed a few things with gas, that hadn't been used. Just by playing with it. But there is one that is a hard 1 to get, but I you know I have.
One where it's Kelly Green with an orange spine. I mean it's beautiful. Beautiful. And **it was trial and error trial and there and one of the tricks ... there alchemy is when you play, if you see something starting, that's what you focus on, you play with it more and more and more.** And you know that was one that really worked.
One more recently that I came up with some it's really nice one because we can't get the expense of, I mean the neon and the Krypton, the xenon, it's all so expensive. What do we get we have cheap argon cheap. So, I said, what the hell? Can I do with these and Lo and behold, you just use argon and a little bit of nitrogen, and you get this absolutely beautiful. Colour combination of a lavender outside and lavender feathers with orange spine. Bright orange spine Why knows it just.

Worked out and you can do some beautiful things with it. It's that kind of claim. The other is, you know, finding out that you can do the xenon spider you can get the xenon pattern with if you're high enough pressure. You go up to 600, you go up to 4 to 600 with argon pure argon. You're going to get this xenon snake. Yeah, try it. Uh, let's see how they did. I think of those things beforehand well.

After all these years I have a little inkling but not really. You know it's you got to just play with it. So that was that was another that's another, and the approach is the other. That gets them out approach. Just playing with it and back and forth and back and forth. And if you see something developing you work on.

... I had one more thing to add.

Obviously, the Glass solder

HS: Yes, obviously yes.

Ed: And the reason I [developed this method with] glass was because I wasn't a good enough glass blower and... it was expensive to buy stuff

I mean to do things I just couldn't do it, or I'd have to hire somebody to do it. So, I thought to myself, well, what the heck? Isn't there a way I could put these things together? Besides it's like repeating patterns. It's just thinking. My father had used enamels in copper. He [used] enamels, I thought, ohh, but how that turns to glass? And it sticks and its stuck glass marbles to hey, who knows? Maybe I could stick glass to glass.

And lo and behold it worked after I found the right base for glass solder; I found out later that it's some that's existed for a long time for scientific use and for television tools. For that reason, we're very that's how they put the front of the television screens on. But it was expensive as hell, so I think. How do I? How do I do this and make it cheap? So, I thought I saw my father did, enamel it! OK, I'm going to look and see if they're enamels. Before I checked a bunch of enamels and found that these this Rauche. An enamel flux, we have with a relatively low temp, have a low melting, relatively low melting point which stuck to the studio glass. OK, I'll try it and it worked. And I actually found the

better solder than the scientific stuff. And it crossed the, you know, 100th as much. Now they've increased the price. But it was $15 a pound when I got it and the scientific was $100.00 an ounce. And it worked and you? It could solder all sorts of stuff together, as long as the two pieces of glass are compatible. That was that was the trick. The solder can work as a wide range of [...glass] that's about the same expansion ratio and within the range the solder can take.

And you know you've seen pieces of bad things. I even do 12 pieces like 6 feet pieces of stacking and have it kiln my work with David Ruth, who does a very large scientific work. That we developed, we, he made a kiln of the octagons that they stack. He pulls them up to the ceiling, then drops them down. And you have a great big kiln in each section is controlled and you're able to put together tall pieces using the solder. That's another one also, I didn't. It wasn't necessary mostly but for borosilicate is so easy to use out in the atmosphere, solder is. There are things you can do that you can't you know you can't take two pieces of glass outside and saw soft glass and flame work soft. Very difficult if not impossible. But you can also can with borosilicate. Occasionally something we've come along, or we wanted to do a very large piece of more borosilicate. With their putting 2 negative lenses together and you have a space on the inside and I kind of think how do you do that that that's to be able it's impossible to hand that something was so heavy and so thick. Couldn't have done it without slumping. So, I said I'll check it, I'll check around and see if I get it. Maybe there's a borosilicate solder so we could solve it. Lo and behold, I found the borosilicate solder. And it worked, it worked but nowadays you can't get it because the company that makes it worth only sells at an 80 LB lot. Right. Back in the day, they sold 5 LB watts, which I've had for 25 years. I still have most of it you don't use much of it, 50 bucks for like 5 lbs and. Lasts forever, but anyway, that was another thing. So, I did a lot of playing with it and now I use it for other things. There are certain things I just did, a piece where there are some things you want to put together and you want their shape to be sharp, or whatever and you can't do that. It's very difficult if you, you know? Well, maybe Berndt

would be, but very few other people would ever be able to, but you could then use the borosilicate solder, so it's in certain cases. So, and an extension of that I've been working on trying to do that with ceramics. Which would be, yeah, I have, it works like the solder, but the solder that works for ceramics that I'm trying to do, and this is a real tough one is getting a sort of a glass of matches and ceramics solder. That that's still a work in progress.

HS: And that's about the coefficient of expansion. I would imagine. OK yeah.

Ed: Yes. And that's because, you know, porcelain and thin, fine porcelain or bone-china is translucent. So, you can do plasma pieces inside the inside porcelain piece, it could be quite interesting because I've done it with the sort of being acid etched or sandblasted and you know it you can get the form just you know. It really worked; it really worked well. So that's another one using the using the solder. The next trick, if I ever get back, I don't know if I've got long enough years, I don't think. Is to get it so that we can mix porcelain with glass. That that would be something. Right now, it's just getting the solder to work for tubulation blowing. I mean, for evacuating it.

HS: Of course. Oh, maybe the borosilicate glass is closer mixed to like coefficient of expansion with the porcelain. Maybe that Boro-solder is going to come back in handy for you.

Ed: It turns out that the porcelain generally runs halfway between the soft glass and the borosilicate. So, they have to, well, I can make a solder. Of it works for that, that's easy but getting a glass for it [is tricky] there is a borosilicate that has a higher expansion. The people who work with doing these are proprietary and I've had a problem with that. The people who work with borosilicate, so like, you know, what do they call it the phase jointing. They they're not helpful, some of our friends are not. So, and I know they could do it for me, like sort of they put all sorts of weird things together and they work... Unfortunately, right now, the main priority is fixing old pieces. It's nice that some of the pieces you know, last for 15 and 20 years with no problem, but there are an awful lot of this stuff. And I have to be redone. The stuff is playing with transformers too.

...
HS: Ed would, would you mind talking to me about or talking me through how you fill your pieces because you're not filling in the kiln, I understand.
Ed: No, I think that's that is just wrong, because the kiln can affect the pattern no! I do a very easy way, OK I heat you know, I heat clean it, [the glass] depends on the glass. I'll heat clean it at least 600° if it's Boro or I'll go to [Fahrenheit] and I'll do it overnight and just and it's absolutely clean now. It's well clean and I don't wanna go play in the kiln. So, what I do is I back fill with argon. Argon's cheap, so I fill it with argon to atmosphere. Cork it. Oh, remember, people who still use a torch to put [things together in the kiln] that is cuckoo. I use this silicon tubing as long as it's not in the kiln.
You got to have a long enough piece [of glass tubulation] come out and then make the connection with the silicon tubing. This idea of having to make ...this [tubing] has to be changed, and I've never had a problem with it no problem. It just has to be its good quality. You don't use rubbish tubing you use. You know, if you want to be really touchy, you use the hot, the, the platinum annealed/ the platinum made medical tubing and it's absolutely pure. And for the time it's there, it doesn't out gas for anything. ...it wouldn't be good for a permanent piece but just for filling. Mm-hmm. And the other is you could match the different glasses. You know I'm doing a soft glass piece, but my manifold is borosilicate. Well, I do tubing, it doesn't care. And then I backfill it to atmosphere, take the tubing off and put a cork in, I put on the shelf for three weeks. And then when I'm ready to fill it, I can take it over to the manifold. Take the cork out, put it on the manifold.
HS: Oh wow.
Ed: And then and then evacuated all the way down, it acts as a wash. You know, while it's on the manifold, just take it all the way down as far as you can [with the vacuum, achieving a low Torr reading] And then you start playing with it, and if that's it and it's still, it's on it too. I mean, you didn't have to do this and blow into it the other if you do that, you have to blow into it, you get your breath and spit it into the piece. That's no you

don't need to do all of that. It's so much simpler. So, yeah, that's another thing that the...

HS: Sorry. Excuse me. Can I just ask when you have the work in the kiln and you're and annealing it you are you evacuating after annealing temperature?

ED: I put it in the kiln. I turned the kiln on, and I turned the pump on, and I just let it go, OK, OK. I will not be evacuating it. No, I will not be vacuuming at annealing [temperature]. You don't want to do that. OK. I only vacuum it down for cleaning. OK. But you're saying I would not put the? No, I would not put the vacuum on it, [or] you'll have a piece and you'll have a piece with stress.

HS: So, it's below annealing point.

Ed: If you're doing it in a one-step thing, which is you're putting it into to anneal, yeah, I would not turn the vacuum on.

HS: Yeah, I tend to turn the vacuum on the way down.

Ed: That would be fine. You can turn you turn the vacuum down on the way. Yeah, yeah and it still should be on the temperatures going down. Don't turn the vacuum on until you're down around 700. [700 Fahrenheit] yeah at like at the most, if its borosilicate, maybe 750, but you know 600 is good enough too. But then then you just let it go and then wait until it's all cooled off. Then you're back filling and you don't backfill until it's cooled off. You backfill with the argon or if you want to do it, or they make a clean air. They make a dehumidified like air, a dry air, you can also just dry air. But I don't think it's much different cost than argon and right now, a lot of my pieces are using argon so having some residual argon is fine. But again, you know, it's filled with argon. Corked that's at atmosphere. And then when you want it, put it on. Pump down. And then play with it. So, and it's so much easier. And it's so much better to be working with your piece at the manifold.

It’s so much easier you know than what are you doing inside the kiln and then and then how that you're checking? You, you know and so much better ... you're in the kiln and you're trying to check the joints and with the Tesla coil, and you're in a shape that has

metal around it. It's affecting the plasma. It's just, no, that's... I see people doing that. They have that many times, but everybody seems to like this idea of suffering I could say that I absolutely consider the joining of the tubulations as torture, it's almost a pun, torture using the torch.

HS: That's beautiful.

ED: So yeah, you might try it.

HS: I would like to try your method, it sounds very sensible and I think that that opportunity then to come back to a piece and to work at temperature/ at room temperature is, well, yeah, makes a lot of sense

ED: In an area where you can get around the piece makes a lot of sense. Whatever. And especially where there are certain things you want to play with in terms of how patterns work and so on.

HS: Do you fill on a like on a trolley that has a non-conductive surface?

... do you fill on like a on an acrylic surface or.

ED: ... I don't know the name of it, but it's fireproof material. It's like a ceramic material, that stuff they use for building. So, because I'm torching there and they won't want to [heat it]

So, you know it's on a sheet, but I always cushion it anyway.

HS: That. Yeah, that's fantastic. Wow. I will try this rather than kiln yoga. I will try your method.

Ed: The other one is you don't have a problem of the tubulation breaking, since sometimes when you're doing the fusing and you have a long one. I mean, you've got to be very careful not to move anything or it's going to break. No problem because it's a tube. It has flexibility. So, you, you know, they can move a little bit and then you know it aint gonna break.

HS; Yes, fantastic.

Ed: Some of these things I did just because I wanted them to look simple. How do I get this done simple.

HS: Oh, well Ed, I wanted to ask you how you envisage the viewer or participant engaging with your work. Is that important to you?
Ed: Yeah, particular pieces are interactive. I like the idea that people can make the piece change of it tends to attract to them... and the idea of motion. That's why I like plasma so much more than neon. **It's mesmerising because of the motion.** And I like this one. It's universal. I have a show in Innsbruck with a whole lot of pieces with, I don't know. I might have told you that story. And during the show in Innsbruck these two Tyrolean hunter ladies come in and the whole garb, you know, it was, you know, out of central casting. With their hunting dogs into the gallery, and after we're showing them around and then I look over and one of the dogs is sitting in front of the cherry, it was that dog, this was mesmerised by the plasma cherry. Ohh, there's something to this, yeah.
Wow. And also, **I think that there is a connection wired connection between some of the patterns we develop and how they develop. And the way the neural networks work within our heads.** So, there is actually some sort of connection there, you know, not so defined, but a really, it's just something making a connection with the plasma. The way the plasma acts in motion, light movement, it's... The mesmerising goes deep. That's yeah. And some of the patterns too we like them because, in my view is that they tie into patterns that are natural neural patterns in our brains. And you know, I play. I play with that my eyes closed. I can make patterns and I see some of the patterns are similar. There's a there's a geometry to it. So, I think we're really attracted to them that way.
HS: Oh, that's very interesting.
Ed: It's at least, maybe I have a brain of a dog that's.
HS: Well, I guess that's the sort of expression of the electron, isn't it with the material or expressed? In a quantum sense, that is echoed throughout our experience.
Ed: Yeah, I'm not sure about quantum aspect of actually. Since it's electromagnetic waves, there are quantum [actions] going on there and I don't know enough of the

physics, but that but really, for example there is a very special, electromagnetic process, which is a pretty short quantum related that could produces the green from the xenon. I**t's yeah, you can that Kelly Green comes from the xenon with little something, but it's not, it's not created the same way the other colours are created. The other colours are it's a is a quantum thing, in that the colours are the electron drop and gives off a problem this. Is a different effect. It's not from the electron drop; it's from some [...] interplay with the electrons.** That's, and I don't know what it is, but that could cause green.

HS: Wow. Wow. [I believe this may be bremsstrahlung, after doing more research] And I keep looking at that piece over your back shoulder in the in the image and I guess I wanted to ask you how do you describe what's happening in the pattern from? Because I guess in one sense, I sort of understand that maybe the neon has an expression further away from the electromagnetic source, but that that delicate kind of pattern that is expressed right to the edge of the work

Ed: The orange it's an interesting thing, there is the electron and that's why, you know, you think of neon as being the orange, but you notice in the piece, there's the blue grey in the middle. That's the same neon. It's not different..., I found that out in terms of the, that's what the geometry because different. **The electrons act differently in relation to the surface, and one of the physicists referred to it as the mean free path, and depending on that depends then affects the electrons somehow if it's tight, it's interfacing with the with the surface more, it's going to for whatever reason, it emphasises the orange if it's a volumetric and it doesn't.** To that, it's going to be the grey/ the blue grey. The pattern is feedback in the in the electromagnetic field, I'm fairly sure. And there's just it's tuned to that, it's. **Things are doing all sorts of things with back and forth and back and forth, but if you tune it to a certain point those. Back and forth, they click into a geometric pattern within the electromagnetic field, and that's an interplay with the surface.** It's an interplay with the gases interplay with the power level, and it's very sensitive because it is sensitive to outside vibration, sensitive

to outside humidity. Sensitive to the building materials and the building you are in. Sensitive to how many people are in the room, I found this. Yeah, the part you know. The way it moves does change from day-to-day, somewhat so some and it will have to do with the humidity, for example, but if you think of it. You know that's the return power and the humidity does change the electromagnetic field, I guess. Is that what you were thinking?

HS: Yeah. Yeah..., I mean it's such a, visually stunning effect in those chalice pieces of yours with the double wall and in in my mind. Sometimes I think that we're seeing the different inert gases doing their thing within the space, but they've essentially become their own mix in there. And from what you're saying, it's more about the geometry of the structure.

ED: **It's how the geometry of the structure impinges on the electromagnetic field and how it impinges, causing feedback within the electromagnetic field that caused the ...[pattern] and for whatever reason, who knows why it's a chaotic system... that self-organises at a certain point, when tuned to a certain way it self-organises. It's- I shouldn't use it, it's magical, but it's scientific, but no one has been able to figure it out yet.** There's an entire institute with top physicists who've been working on this for decades called the. What is it called ... the Santa Fe Institute? And their whole thing is now they don't even talk about chaos because they thought they could develop a mathematics of chaos and they failed. They know it's there, but they can't do they because ... it can be repeated. And it happens, which, you know, something could be repeated and it happens. There should be mathematics behind it. They can't get the math on it, oddly current math won't work, won't do it.

HS: I from my naive perspective, I'm looking at it and I see that we're viewing it. It's a two-dimensional thing, but it's a 3-dimensional thing in that space and like when you when I think about that and I'll have to revisit this again, looking at the Young slit experiment and how they you see waves rather than bands of light and I guess. That the dynamics are so complicated within that chaos pattern because we're viewing it as

something 2 dimensional, but there's so much activity happening on a three-dimensional spatial.
ED: I'm not sure it would be related to the two slit factor that I don't know I that that that. You know, I wanted to be a physicist, but I didn't become one. So, I don't know.
HS: I love that you wanted to become a physicist almost as like defiance. Set yourself apart from your artistic parents. That's fantastic. Ed, I wanted to ask you, how do you experience the responsiveness within your plasma pieces?
ED: I mean other than like the little holes in me? [chuckles] all the tiny little like you knows that stink when they smell. That's a lot of the responsiveness. To me it's it. It really is, you know, it's just fun. What can I say? And I'm intrigued by doing things that haven't been done before, I just always admit that. But I just like doing something different. And something that's systematically pleasing to my eye and, based on my background, I have an eye that can pick up aesthetically pleasing things so. And it's you know it's pretty well ingrained into me. So that's the way I see it. Like a lot of the things that are being done in plasma really bother me, because there's no aesthetic to them. So, even though we need to experiment... for other people it can be whatever they want. ... that it's never just plasma. It has to be the aesthetics of plasma. The aesthetics of this shape, the aesthetics of its placement. All of that is, is interwoven with the work I do. The pieces just looks like you know it has a nice look. It has a nice plasma that you know, it's in the shape that looks like shit. I'll give a damn. No.
HS: So, it's the form and the medium inside that.
ED: Yeah. And how they, you know, and how they support each other. You'll find also that a lot of the geometrics will reflect the shapes, some people pick up on that. You'll find that the points that are up there often reflect the shape of the big vessel that are in this, and I don't know why but it's one of those things that I picked up on that I like because that's an aesthetic, repetition both repetition within scale. Is a very nice aesthetic.

HS: Well, well, thank you very much, Ed, but very insightful and really wonderful for me to hear such a grounded and so much depth to your practise and your investigation. And yeah, that although for me, I'm coming from (like) messing around with the glass shape that...

ED: Oh, that's important.

HS: That it the interactivity and that sort of effective dimension of plasma illumination is really wonderful for me.

Ed: Yes. Ohh another important difference is, and this is a hard one, but to me, the part, even though it's the aesthetic that it's in, it's the plasma, the important form is the plasma. So, glass is secondary and most of the people in the field are glasses primary. With the plasma, with plasma, glass with plasma, with me it's plasma. With the glass and you'll see that I very rarely have very involved shapes in glass. The glasses they have to; present the plasma, not the plasma to augment the glass. I mean, I'm not saying anything wrong with that, but you know the generally the sculptural form where the plasma is, is you'll be focusing on the plasma. You're not going to be looking focusing on the glass with the plasma augmenting it’s quite a difference there. And as I say, most people in the field are doing the glass augmented by the plasma.

HS: Yes, I think I would fall into that category, a lot of the time when I think about it into that category I would say.

...

ED: Either way, it depends how you do it can be limiting, so, yeah, sometimes you play with the forms and at some point, you hit a form that just gives you a really fantastic plasma. And you're working with that... You're with the majority. I think, I mean, who else, who actually, who else just does is just into the plasma. And has an aesthetic to it? That's a that's an interesting one. The closest, but then there's not much aesthetic to it, when people do the columns that have the patterns, because that is plasma.

HS: Hmm, it's the envelope of glass. Isn't that it...

ED: Yeah, that has to be both. But then it needs to be both, but it has to. But the primary is the plasma. But you can't lose the idea of the sculptural aesthetic...this balance, you know, it's the sculpture and aesthetic the glass is for me is not primary. That would be kind of the difference. I mean you can see it in the sculptural part, but definitely the glass is primary for the vase, but for the top part it's a beautiful vase shape. I mean, the proportions of it, the way band did that. I mean, it's beautiful piece of glass by itself, but look at the plasma, which is more in that place, which is more important? Clearly, it's the plasma effect on the inside, not the form of the glass. You can look at others of this work, a lot of his [Berndt] work, most of it you'll see the glass stands on its own. You know, and then the plasma, you know, those augments, it gives it more of the wow effect.

HS: That's really interesting because I guess I think that when I when I think about making work, I think of it in daylight and in darkness, with the plasma and I sort of feel like, and maybe that's my training, that I'm thinking that I've got to make an object that is both. And that it's not just about the plasma at the end, yeah.

Ed: It's interesting. I'd see very rarely do I think of it in terms of the form like the glass form. When I'm thinking about, I'm thinking about the plasma. But then sometimes I mean like our favourite piece is has been the cherry. You know and that was a dream. And seriously, I dreamt that piece. Maraschino cherry with plasma in it. The story was that I couldn't make at all... and it was one that I couldn't put together with solder. And lo and behold, ... I might have told you that story, I was in a show up in the Napa County and next to me, the first time I ever met him was Mitch Laplante. Who does these large vegetables and fruits and he had these, you know Queen Anne cherry things, and I looked at him and I said Hey, Mitch, could you do a maraschino cherry? And he laughed. And he said, come to my studio. He had the transparent Maraschino cherries. No kidding. Oh my God. There they are. And all I do is I have to work out a little of the geometry of how to make them work for plasma. And that was it, serendipity, I must say, that's happened more than once, but yeah. Right.

HS: Well, oh, Ed, thank you so much. Yeah, it really gives me a fantastic opportunity to think differently about the practise. To step back a little bit and think more about the medium within rather than the skin that holds it... and your deep knowledge of yours about systems and patterns is very interesting, and to hear that the video feedback informed [your work].

8 Amy Lemaire

[25.01.2024]

Harriet Schwarzrock: [H.S.] Thank you again so much for participating in this. I wanted to ask some really basic questions first, just so I get things right during the transcript, script, but I want to ask what your name is or how you'd prefer to be referred to in the writing.

Amy Lemaire: [A.L] Sure. OK. My name is Amy Lemaire, and you can just refer to me as Amy.

HS: OK, fantastic. And whereabouts is your studio?

AL: My studio is in Brooklyn, NY, USA.

HS: Fantastic. And what is your background that led you to working and using plasma illumination?

AL: I work at a school that specializes in scientific glassblowing and when I first started working at that school in 2013, a colleague of mine and I started experimenting with plasma, Dennis Briening**,** who was the current department head at the time for scientific. So, he and I worked together on plasma, and we thought it would be an interesting way to combine science and art and possibly build into the program. And then he and I took that show on the road and we developed curriculum at Urban Glass over a course of five or six years working together there teaching. And eventually, now I'm back at Salem. Yeah, designing programming for that program that I originally learned in scientific glass technologies program.

HS: Oh wow.

AL: It's come full circle.

HS: Well, ... I'm so appreciative of your time and participating in this interview because I'm really drawn to your amazing work and I think that because of your background, as well, you have such an intriguing and powerful way of communicating. And what I'm interested in particularly is capturing some of that language that I'll use in my writing and also your insights into the responsiveness of the material, which I guess from an artistic perspective, is what I'm most interested in, in it. So, the first question I wanted to ask was how would you describe responsiveness within this form of illuminated practice?

AL: I would describe responsiveness as a recognition of the viewer or a way for a viewer to have an effect on a piece. Most Simply put yes.

HS: That's fantastic.

AL: Yeah. And I would say also responsiveness is different from the piece being active.

HS: OK.

AL: Yeah, I think that the, the viewer is a is an important ingredient for responsiveness.

HS: That's brilliant. Yeah. It's not just about the kinetic movement. It's about that interaction.

AL: No, not at all, not at all. Because if the plasma piece was active with no person around, would that be responsive? You know, I mean, if there's no viewer to view it, it's sort of a philosophical question at that point. I think that responsiveness is contingent on the viewer experiencing, to elicit a response.

HS: Fantastic. Are there any particular techniques that you employ or have devised that expand upon the artistic application and responsiveness of plasma illumination? And that's loaded, because I know that there are, through your work at Salem, so.

AL: Several and I, I would say like there's two, two major things. **One is the current, my current mode of investigation, for you know, exploring responsiveness and that is through using sensors and microcontrollers.** Recently, I've decided I don't want

viewers to actually touch the pieces, that I'm interested in more hands free or like, what are some ways that I could, I could achieve this responsiveness? The satisfaction of responsiveness from a viewer without having them actually touch the piece? And that's in response to changes in technology where we have a lot of like our, our finances have become smart now and are anticipating kind of some of our movements in the world. And so, I feel like my sculptures also need to become smarter. So yeah, I've been. I've been using sensors, particularly a proximity sensor that the viewer is instructed to interact with directly, and then that initiates a cycle that you know flashes, or you know presents some sort of a changeable display in the vessel, the glass vessel that the viewer can experience. And those cycles are different from piece to piece.

AL: So sometimes it's a 'hello world', just a very simple acknowledgement of the viewers presence, and then other times it's, it's a more complex message.

HS: Is that, does that difference that you program into that, is that a planned kind of program or is it in response to the fill that you've got in there or the piece once you have it?

AL: I determined what the piece is going to do as far as how it's going to visually present after it's been filled. Usually, I have an idea going into a piece, but as with any art piece, some decisions need to be sort of fluid. As you know, you're responding to constraints for fabricating the piece. So, I take all of that into consideration. Yeah. Yeah. And there's also one other thing I would like to add to this section, which is before I got into using sensors and microcontrollers, I was thinking about responsiveness in a different type of way. I was using plasma in performances and really thinking a lot about responsiveness and what the viewer's expectations might be in a situation where they might be confronted with an RP setting includes technology.

AL: So I had set up these performances that where, as the artist I was an active participant and my role was similar to like a, a you know, a salesperson at an Apple store, for example, that's sort of how or like a service person at like, an Apple store, sort of how I pictured myself, where they would just be all this technology spread out and

inviting the viewer to come and experience it. And then my goal there, the responsiveness was actually conversation. That was what I was looking for was, was to initiate and then participate in communication and to try to get the viewers to narrate their experience and their responsiveness. So that's sort of like some older work that kind of closed when meeting in person became hard with the pandemic.

HS: Oh, that's so interesting, I guess from my perspective, speaking with you is so, is potentially so broad and insightful because I know that you participate and work in collaboration with people or as a fabricator for, for making other artists work as well. So, I know that you've got a really broad depth of knowledge in, different approaches, which is really incredible. And so yeah, along the lines of sort of the conversation you were just relaying then, I guess I was wondering how do you envisage the view or participant engaging with your work?

AL: **I'm always really curious about the viewer's expectations, and I would consider a plasma vessel to be a type of technology. Meaning there's something happening in this kind of black box, right? So, I'm not expecting the viewer to understand what's going on, and I would I want them to engage with my work and be able to have it like sort of a magical mysterious experience, if that's what they want.** That's not what everybody wants, but I want to leave that as an option and not give them too much information or too much exposed. So, I think that's a big consideration is what is the viewer's experience going to be like and then, how does responsiveness fit into that? Basically how, how are the viewers interacting with the piece? Is it through the mediation of technology? Is it touching directly? Is it with a facilitator? With an artist facilitator? With a third-party facilitator? So those are the questions that I asked myself, but it really has to do with what is the viewer's experience and how much space do I want to leave for the viewer to wonder?

HS: ...brilliant. I love that you acknowledge wonder and magic in that because it's such a slippery kind of area of yes uncertainty in a way. But I appreciate that you're building

an experience that has potentially multiple layers of engagement. So, I wanted to ask you, how do you experience responsiveness within your plasma practice?
AL: Well, in the past I have experienced responsiveness as a facilitator. Facilitating the viewer is responding to my work so that that's been a kind of an interesting role for me to take as an artist, a challenging role. Now my role has shifted, and I would say now my role as an artist is to... **I'm actually trying not to educate; I'm trying to create as much mystery as possible. Try to make kind of a very high-tech feeling futuristic situation for my viewers, where there's maybe some aspects of the piece that are familiar, but a lot that's unfamiliar and I'm not giving them a lot of clues. It's the ultimate black box, and so that's what I'm exploring.** Currently, with my most current piece that's on view now.
HS: Fantastic. Oh, that's so that's so exciting. And I guess that so beautifully balances out you as an artist and you as an educator, you know, that is really.
AL: Well, you know, I made those decisions because I've been spending so much time as an educator thinking about responsiveness specifically and, and being in conversation with my students and most of the time I wear my fabricator hat down at school, how are things made? How can we do this better? You know, like how can we honour the original design? Right. And so, as an artist, I asked myself all those questions because I also fabricate my own work. But there are extra questions that I get to ask as an artist that I don't always get to answer as a fabricator, or as a teacher, which is an extension of fabrication. So, I appreciate that there's, I have enough attention on this subject that it's kind of split into two. And that's given me the confidence, to not feel like I have to put everything that I think I know into one piece. So that's giving me, I guess, almost a little more permission to leave a little more mystery or leave a little more space for wonder and for the viewers to have their own experience and not try, not try to curate that experience, but to try to anticipate what the viewers reaction might be at this time and place in our technological journey as humans and try

to have my piece sort of, not match up, but simulate that type or draw attention to how we respond to any given piece of technology, not necessarily a plasma piece.
HS: Wow, that's... brilliant. Wow. Thank you. I guess that that was sort of the last of my specific questions, but I guess I wanted to ask if there are any other insights that you might perceive as relevant to interactivity or the effective dimension of plasma illumination?
AL: Yeah, if it's OK, I'd like to share a couple of insights that I've gleaned through teaching and these are conversations that I've had with students, and it's prompted by student led investigations. So, we're getting a little bit away from my work here. **Last semester, I had a student who was very interested in capacitive fields and likening the capacitive fields that we experience in plasma to social energy. Or what it might be like to interact with a group of people and how people can affect other people's mood or other people's quality of being, by the level of energy that they bring to the engagement.** And thinking about how the capacitive pieces in particular that don't have a, a hard-wired power source really kind of can behave in a way as stand-ins for these bodies in a social situation. So, I thought that was pretty interesting insight. And then the second thing that I've been thinking about is, recently it's come up, we exhibit plasma at school, and we have all kinds of signage and safety and stuff like that. **We talk a lot about presentation, and the question of consent has come up recently, consent being like: How do we let, or do we need to let the viewers know it's OK to touch the piece? Because depending on where in what situation the piece might be presented in, there may be sort of an unwritten rule that you don't touch the art, like in a museum.** Or, like sort of an assumption that you do touch piece like in these performances that I've been doing that are more in public spaces. **So, it's interesting when you change the venue the, the permissions, or the assumed permissions, can change, and that affects whether people have an experience of responsiveness.** So, I think at this point it's more of a question of what kind of

directions do you need to give or permissions do you need to give the viewer in order to direct them to interacting with the piece or do you need to?
HS: Yeah. Or I guess what sort of consent do you give over as well? So, it's, yeah, that's really interesting discussion.
AL: Right, yeah. Yeah. And especially in the form of instructions. So that's another thing that's come out of dialogue with my students that I think is interesting it also very much mirrors conversation that's happening in the, that's being had in the social sphere, you know, obviously like consent around bodies is it is a topic that our, you know students are talking about a lot and I love that they're finding ways to talk about these important social issues through the medium of plasma and especially it's this responsivity that seems to really be a catalyst for these types of, this way of thinking, I think.
HS: Wow, thank you. I wish you were my teacher. That's brilliant. And these are things that I've been thinking about. So, I really that really resonates with me. So, thank you. Thank you for your insights.
AL: Yeah. Thank you. Thanks for asking. And I feel like there could be a lot, bonus content, I feel like there could be a lot more of this using plasma, in a more sensitive kind of way, right? And I think one of the challenges is access. It's not very common that the designer, the artist and the fabricator are the same person. **And I think when the artist and the fabricator are the same person, they have all these experiences through fabrication, which include the responsiveness of the vessel that inspire how it gets installed, or that, that inspire, that can inspire whatever the viewers experience will go on to be.** And so, I wonder, it would, that would be an interesting thing to study. The evolution of the development of an idea of a plasma piece, where the designer and the fabricator are one in the same and where they're different, and those thoughts, maybe that's what you're doing. But yeah, I think that there is definitely a difference.
HS: Yeah, that's very interesting. I guess I can't really extricate myself from that very well having not been in a position where I fabricate for other people and I, you're in an

incredible position to really navigate both of those positions and, and see those conversations that happen with another artist to bring an idea into light, and then you must be feeding in your own experiences as artist-fabricator to, to realise their ideas as well.

AL: Yeah, it's, it's, as a fabricator it's really all about communication, communicating with the client to make sure you understand what the task is, what, what the message of the piece is. **So that, you know the, the artist is essentially (or the designer) is essentially trusting me and me using my body and my hands to fabricate this piece in their absence.** So, it's important that I understand what the goal of the piece is, what the goals of the piece are. So that way when it's time, there are always decisions that need to be made along the way. And I think that's what separates a good fabricator from maybe somebody who can just get the job done but not give the peace any life, you know. You can, you can follow drawing, you can make the form OK. But if you understand also what the concept is, and you understand that the vessel is in the service of the concept and all decisions get made to support that and elevate that concept that you arrive at a different place as a fabricator than if you were just following a drawing. It gives its soul.

HS: Amy, thank you so much, I was hoping that I might just be able to sneak in a little part of the conversation that I overheard you say in a Plasma Art Alliance meeting once, which is something that I have used and attributed to you in between about talking about and aurora, as plasma in the wild and I think that that that's been a really helpful way to, to start a conversation sometimes about what's happening inside of the vessel.

AL: Oh yes. You know that whole idea of “aurora in the wild” was it was a way to demystify ... not demystify but start with an idea that everybody knew what it was, right. Everybody is familiar. Maybe you haven't seen it, but you know what the auroras are, right? So, it's a great baseline and that's actually how I started my plasma course. It is ‘what's this?’ ‘Oh, it's plasma in the wild’, you know like. Alright, so we all can experience this or know of it. Right. So now let's talk about how to make plasma in the

lab, which is a different thing. And then we can trace the development of why and how, you know, people are doing that. And those are questions we should be asking, you know.

AL: But yeah, that's a fascinating wormhole and sidebar, I'm, I just planned a trip for January, next January, I was going to try to do it this year, but I pushed it, to go, I'm going to go to see the auroras up in northern Canada, so I've just set aside time for that and planned it all out.

HS: That's certainly on my bucket list.

AL: Well, you can see the Aurora Australis.

HS: Sometimes you can see that from mainland Australia, but mostly you have to travel to Tasmania or further South on a vessel. So yeah.

AL: Yeah. Well, for me it will be Northern Canada. There's a two-day train trip with a like a viewing like a glass dome, viewing car. So, I'm mostly interested in viewing the Aurora from the train if possible because I love trains.

HS: That's beautiful. Wow.

AL: There's something about a slow, a slow, reflective journey that I, I just want to be, experience the Aurora firsthand because I've been spending so much time thinking about plasma and I feel like it's, it's sort of blasphemous to, to not have made an effort to experience it, so it's on my list. I'm going for it.

HS: Well-done. Wow. Wow. Well, thanks again so much, Amy. Yeah, it's, yeah, been fun and insightful and reveals a lot of deep thought about your various practices. And I am very grateful for your time.

AL: Thank you. Thank you so much. Thanks for your time and thanks for the invitation to participate in your research. I really appreciate it.

HS: Oh, thanks Amy. Well, I look forward to hearing about your train trip, and I hope to catch you in the future, yeah.

9 Aaron Ristau

[04.12.2023]

...AR: I'm pretty easy. Just by my full name. Aaron Ristau.

HS: OK, Aaron Ristau. OK. Fantastic, and so is there any other, do you have any other things that you'd like to be referred to like previous work or just as an individual?

AR: Yeah, yeah.

HS: OK. And so, my one of my background questions is where is your studio?

AR: I am in, like smack dab, in the middle of North America, Northern Colorado, USA, so I'm you know, Loveland Colorado is a little bit north of Denver and the whole state of Colorado has like, we call it the continental divide. So, there's a very central, massive mountain range, has multiple 14,000-foot peaks in it and then it like goes out onto the plains of America. And that abrupt change from mountains to plain, I literally live like right along that fold.

HS: How beautiful.

AR: And yeah, it's a, it's a great area.

HS: Would you mind telling me what your atmospheric pressure on your transducer reads at again?

AR: Yes, but I can see it from here it looks like it's 616 Torr.

HS: I love that I feel much relieved about my 710 now, yeah.

AR: To that end, though, we were talking about that. So, I did not do a good job of grounding my metal manifold portions that my sensors were attached to. And then I was tinkering around and either when I had a moment where it crashed it back to atmosphere or when I was doing an excessive amount of leak testing. Basically, lighting up the air because it was pretty and playing with it. I seem to have, not completely, but knocked one of those sensors way out of Cal[calibration] cause now my low-pressure number is like 10 to the -2 and I can just swap out the sensor and go right back to where I know I am below 1 Micron, 10 to the -4. And the atmospheric pressure though, looks pretty close to normal, so here's what I got to looking into and here's what you may

come to find out is that you're still off, apparently, and we need Mr. Jeff Feigin to walk us through how to do this. You can basically run a script on these sensors. And there's a script to reset atmosphere and there's a script to reset your low pressure.
HS: Oh, OK.
AR: Here's the tricky, and here's the trick on the low one though, you have to be able to, you know, basically have redundancy in your sensing as well as get a system where you can get to 10 to the -5.
HS: Oh, that's not happening here.
AR: And that's, that doesn't happen here yet. I have plans. I got equipment. I have the know-how, but it doesn't happen here often, or it hasn't happened here yet. There we go. So, that's disappointing for me, so I, a) I've got a figure out, like through Jeff what... and this is where I don't have the knowledge, but somehow there's some kind of computer application that I can run on a Windows machine and plug into that sensor and run scripts into it. And I don't know exactly what that means or how to do that so, I was getting super excited and comfortable by having one of those sensors on the pump end and one of the sensors on the gas end because I've been doing a lot of big, long tubes, so I'm doing them like Wayne where I have the gas at one end of the work and the pump at the other end of the work. So, by putting the by putting both, you know having the exact same sensor and one of them on the pump side, one of them on the gas side, I'm able to see all that conductance and they all respond quickly enough that it's great real time information and whenever I want to do one of these fills where I'm trying to dose either 10s or even hundreds of a millitorr of a gas amount. And then with these big lamps, you kind of have to like, let that equalize if you will, because it pulls into that big old volume, but with the sensor near the outlet of the gas side. I know the instant I'm starting to dispense gas, and that's a big deal to help me not overshoot those micro fill amounts. So having two of these sensors has been super cool and I was like I've loved it. I've done dozens of fills with it and then I shocked the crap out of one and it's down. Though I've stuck this other, it's one of my older capacitive manometers, in place but,

just having two of them meant I had that redundancy where I immediately knew when things were off and when I wanted to test it. It was as simple as swapping them out and that told me frankly there that there was a problem. It was, it like worked on multiple levels having two of them in within the system.
HS: At the moment I don't have a backup because I also fried one of my capacitance manometers, so I've got to make a decision whether to try and get another of the MKS units. I think that would be helpful to have.
AR: Well, out of desperation and panic, I've read through that owner's manual hard and there's a couple of deeper than just the reset buttons that we can try.
HS: Oh well, maybe we can have a little tutorial with Jeff one day.
AR: If it is off but like you know, powering up. You know, if you have one that's powering up, it's just your numbers are off. Maybe we can all, because we're going to need to know how to maintain them.
HS: Well, well, I wanted to ask, what is your background that led you to using plasma illumination?
AR: Yeah, I grew up in a very artistic household. And I mean like what my first maker skill set was holding boards above my head while my dad was working off the table saw or the radial arm saw or whatever he was doing woods related, cause just out of his arts passion he did a lot of he did a lot of things, but one of the things he did was build most of the furniture in the house. And so, I was a super into all things maker. And as I got into my like high school years, I started working for an estate and commercial auction company and that was freaking awesome in that area of North Central Texas I had like, maybe an 800 mile radius territory that went up into Oklahoma and through most of Central Texas, where every weekend it was different, it was either... a Dust Bowl era farm, or a, you know, an entire town's civic municipalities will get together, you know, you'll get the sheriff, the school department, the Police Department, the fire Department and everybody will get their crap and once a year, they auction it off. I was just running around and learning a lot about like all these and seeing all of the

agricultural Dust Bowl era. You know that area of North Texas is where you may have heard stories about the Dust Bowl in America, right? And how we clearly overran everything with our farming technologies. But the culture that was behind that led to these incredible individuals, the people who stuck it out. And I'm basically at the South edge of that entire swath of American land is where I'm growing up. But those individuals and that lifestyle and that like rugged Marlboro man attitude kind of came out of these Dust Bowl personalities. And I got to go sell some of their estates and you'd go in a barn, and then go into the guy's shop where it was clearly his little hangout spot, his man cave, and you'd see 40 years' worth of maker detritus and handmade tools and MacGyvering we call it, you know, when you when you don't have anything and you're on the farm and you got to do what you got to do with what you got. My boss, you know, we love these things. We would go and we would just not touch anything for about an hour and stand around and try and learn about what was going on and think about what this person was into. And of course, families were involved. There were all kinds of different circumstances, but there were multiple times that we were like, we, you know, there was a guy who repaired cash registers for a living on the side, there was a guy who, of course, did ham radio. Part of our auction contracts was, you know, the reason we would get these one of the reasons we would get the business was everything goes the family needs to sell the farm. Something transpired where we are cleaning up an estate. So, everything does go, and if we can't sell it, it's got to go home. So, I start winding up with machines, and I'm you know, not like my parents weren't like traditional artisans, but I'm seeing, like, we're going to museums when we travel. My aunt ran the International Folk Art Museum in Santa Fe for like a decade. And we travelled all the time, and we would always do arts related things. So, I see this traditional art on the walls, that is, it is wonderful art, but to me as a naive male, I don't appreciate it because I want art that's like somehow compels the viewer to interact, art that compels you to interact. And I found that I could do that by some kind of like kinetic aspect of the work. So, things like motion and light, but I also like utility. So, I was like how can I make,

basically decided by 20 years old that I was going to continue to take shit apart and have this hilarious pile of crap? And re-assemble it into these simple lighting assemblages that were intended to be quick, satisfactory projects for me. That, and I was pretty sure I could take this body of work and basically take it to the flea market. Not like full white walled gallery fine art, but that's also the kind of mood I was in. I wanted to be the outsider at the flea market trying to sell things people didn't need just to meet other artisans and to put a smile on people's faces. But I wanted to make that art that compels the viewer to interact, and lighting was definitely where it was at. So, I made a lot of incandescent stuff, but from those auction days I had gotten really, like my niche became science and medicine antiques. That was the stuff that I gravitated to and would buy every time I could, is science and medicine, antiques. And I, along the way, came across what turned out to be like 4 broken and one almost spoiled and one working set of 6, Geissler tubes. So, amongst all my stuff like you know, I'm starting to already make lights for a couple of years, and I had children really young, so I many times was financially motivated and would buy things for next to nothing if anything and try and intentionally work off of like, you know, donations, go to recycle yards a lot. I was very, very cheap because I had to be. So, as I got a little further along and started selling things, so maybe I can afford this time to incorporate this fluorescent light bulb. To me, that was going to be expensive I was using a lot of like super cheap Christmas-light level, little incandescent bulbs, but I build sculptures that were serviceable. You could open these little weird drawers and, and doors and compartments and unscrew things and service the work, but I was getting that like creative moment where I was like, how do I make the luminary aspect of my sculpture *The Sculpture*, you know, how do I how do I progress from having illuminated objects, which is great, it works, but... And I had those Geissler tubes, and I needed to resell them, and I go nosing around online. And so, this is about 1998. By 1998, I'm looking on eBay at Geissler Tubes, and I figured out what I have and lo and behold, and I can see at that time on eBay in Lubbock, TX, there's some guy named Tornado Alley, that makes these modern interpretations of

Geissler tubes. And still to this day, I'm dying to find a couple of these borosilicate glass artisans and I've not shown anybody yet, but basically his architecture of what Tony made as basically a modern stand-alone Geissler tube, novelty Geissler tube, that he was selling on eBay for like 3-$400 was absolutely brilliant and he made them all out of neon soft glass and they were very segmented. They'd have, you know, 50 pieces to them. But the whole thing would stand on a desk maybe 20 inches tall. They were three legged. And it had an electrode up the centre bud, and then a kind of a tall Spire up the centre. So, the three glass legs allowed it to sit on the table, and then you just connect the electrode up the bottom of the centre and the whole piece would light single ended with one of the T2 Neon power supplies. And so, he was one of the people early on that showed me how to work with that stinker of a power supply. You know, some people just can't seem to handle it, but anyway... So, there's Tony, right? And I'm like, oh, my God, these are amazing. 300 bucks. That's such a great price. Like, I couldn't afford to buy one, but I had to meet this guy. And I was driving from that area of West, TX to my parents, whom they were building their house up here from ‘98 to 2000 and relocating from the North Texas area up to here. So, I was I was doing like two to three trips a year about a 14-hour drive. Because I wasn't about to put my kids through the schools down there in the Texas border lands. I knew I had to leave. There were no jobs for weirdo like me. I worked for a gunsmith, a ceramicist, but there was no technology. And I had already done the auction business, the auction business in my high school days is what I did on the weekend and in the week my dad ran a robotics business. So, we sold an educational robotics package to over 100 public school districts in Texas. That in that was basically a product that, became Lego Mindstorm. I don't know if you know of Lego, the toy manufacturer. They have a whole product called Mindstorm. It's like these little microprocessor units and you can plug your motors and switches into it. All of that is stuff they walked away from after seeing what we were doing, but we only had enough investment money to kind of prove it and grow it in Texas. And our investment or my father's investment partner, when they knew they needed to take it to countrywide if we

were going to get anywhere with it, basically, sat on his toes and Lego took off with it. But I was I was doing robotics as a teenager, I was doing robotics, and I had all this, all this electronics background with that, and that's where that started. But then as I went off to West Texas and was making all these little lights and stuff because I had my young family, I got an arts degree. I didn't focus on any electronics or engineering because in my mind, I literally didn't have the mental capacity. But these art teachers at this little bitty college out in the middle of nowhere. They loved me because I did my work. I already knew what I wanted to do. I was a good student... this was this was a 5,000-person town, so when everybody was around, it you never said goodbye, you just said: see you soon, because at the grocery store or the bank within hours you were just going to see each other again, and it was just always 'see you soon'. You never said bye. So, it was a great little community to finish an education. You know, I knew I wanted to get a college education, but so it, it became a hobby, Harry. You know, I was doing these light sculptures to fill in the financial gaps with the young family. And then I met Tony and it turned out that Tony had a big heart, had never had kids, and I just somehow hit it off with him and was super respectful and kind of had known through all of the other art professors through my parents and the college that they taught at and all these wonderful people that I've met, I had the humility to understand what it means to mentor. And to like outright talk to Tony about that and say, Tony, I think I'm interested in enough of this to come by and say hi, work for you, and scrub floors if I need to, just to learn it. And maybe someday I'll get my shit together and get my own, but for now, can I just ask a few questions a couple of times a year? And he loved it. And he did, and we became buddies and that gave me that like base process knowledge. And then you know, so that was all turn of the century, in 2013 I got a commission for a restaurant and the same week I got an opportunity to buy a guy's pile in his garage that had been a local neon shop for like 23 or 25 years and it was literally put in one pile for one money. So, I told that guy selling that and the folks talking to me about this restaurant project, I said I will do whatever it takes to make this work, you know, help out. It wound up being

the magic number was $4,500. So, I did this big restaurant commission, and I got my entire neon store. And to me, that was like the coolest thing I've done in life yet. I got this pile of glass I got all the little shit that I knew was going to take me eons to stack up. And you know, right down to the little weird hand tools that you don't even know what you have in the beginning until you watch Michael Flechtner or somebody else and you're like I've got one of those, that's what that is. Oh, my gosh. Now I know what that is! You know, so, yeah, by about 2015 I was functioning on my own and not having to shuttle projects out to West Texas to get them filled. And that was a good timing for me because I could still buy 50 litres of xenon for $1,100. That helped. Yeah, that's, that's kind of how I guess how I got into it, I hope that wasn't too long winded.

HS: Oh, no, no, that's fantastic. That's fantastic. Well, Aaron, I know that we're both interested in that sort of the movement and the draw of plasma illumination. And so, my initial question is. How would you describe responsiveness within this form of illuminated practice?

AR: Well, to me it was like one of those massive 'aha' moments. You know, where it came from, especially was Tony Greer because he was making those little desktop single ended, so touch sensitive to touch little xenon pieces, so they had that, wonderful little tight wind wiggle, and I was already trying to figure out how to you know, compel the viewer to interact, and here it was, times 10. And I just had to figure out how to bring these processes under my, under my studio. And you know what I've come to find out now 47 years old is if it were easy, I wouldn't have gotten into it. I'm that weirdo. **So, the complicated process had some bizarre appeal, but I couldn't get over it.** You know, one of the others and, and this is important, right, because there's those like formative, I guess that's the right word, experiences that really like lock in your 'Oh my gosh, I want to be a part of this' like we've all bit the bug. Well, my bite the bug was that very first time that I got to see Tony Greer, in his studio. He had this like; it was like on this roll around cart but the coil for this Tesla coil was like 6 feet tall in the air and maybe like 3 feet in diameter. Out of like big old aluminium round air conditioner duct.

So, it's pretty big and it sat in the middle of his neon studio for good reason. I had no idea, I'm like, literally holding my less than a year-old son in my arms at his studio, meeting him as we're just getting through town. Thought I might get to talk to him for 15 minutes knew better than to interrupt his workday, you know. And it's evening, and he's like 'you wanna see something cool?' Of-course I said yes, and he has me back up to the edge of the door of this little studio room and literally stand outside in the doorway, with my baby, for good reason, and he lights that Tesla coil up and it's a spark gap Tesla coil which probably as you've figured out by now are screamers. They are, this, it sounds like they're unzipping the air. It really does. They're so loud and he turns that on, and for a 30 year-long neon shop, there's hundreds of gassed pieces of whatever in that room and that room is flickering and alive. **And I, I like had one of those spiritual moments and I was hooked.** That was it so, it would just become like, there's a lot here. I'm poor. I'm, you know, humble and modest and let's just bite this off in pieces. And 23 years later, I'm here. **Yeah, the responsiveness is like to me is like amazingly spiritual and emotional.** And when you can make something that... I don't, I don't, see anybody that like comes up to plasma and gets creeped out. Says, 'ooh, is that like Satan in a bottle?' like even on the deepest red. No, no. There's, like, positive and fun and amazement and joy, and people want to touch and kids, kids walk away, you know, considering science. It's weird that it's even important to me enough now to get emotional about it, but, yeah, it's really cool. And these volumes of gas, right? So Tony was doing the single ended things and that's really weird. You know, there's an expression that I forget who told it to me, but it's perfect. **You know, everything Neon has the path through the secondary where you go through a lamp and you come back. It's a loop. Here we are in single end... well the fun begins when you break the path of the secondary**. And when I say the fun begins, the complexity begins. And you know I really missed, missed the boat on the right kind of education that would have given me the electronical knowledge. You know, at the beginning, if I'd have been passionate and listened that I might have been able to learn enough to design circuits

on my own. But through especially starting with a, you know just an interest in the electronics and all, that stuff I built, starting in my dad's business. And then just winding up maintaining weird systems for employers, I figured out I was good at fixing things. I just took all that together and was like trying to self-teach my way through understanding the greater systems here. Not hoping to be an expert in glass, not hoping to be an expert in electronics just saying no one does the gas, at least when I started it really was so few of us. And I mean, it was like me, Carl Willis, Wayne Strattman and Mundy and Ed Kirshner. That I could find from my naive chair out in the middle of no-where, in West Texas. There were others that Percy has... It's been beautiful, hasn't it? To see the history and how much is actually going on. As Wayne will show us all the way back into the, you know, 100, more than 100 years ago. It definitely felt like an island. And I was like, well, you know, once you get these larger gas volumes, the dynamics of the movement is all amazing. And as I looked at the electronics, I was like, wow, this is all, like kind of like, I mean, everybody always talked about Flybacks back then, and I was like, wow, this is kind of antiquated. I wonder what, like what my dad's company, I was like, what would happen if they put a microprocessor on these. And that simple core kernel of 'what if... but I don't know how', has led me to the last like I don't know, 15 years of trying to listen and collaborate and find others who can, who want to make something that no one needs. That reality has definitely come and but it's weird, I don't feel right saying that I'm like working in that facet of the medium because I wasn't able to innovate any of that, I was like a catalyst to that. I said to people, this doesn't exist yet and I know it's possible, but I don't know how. But here's a bottle. Here's one to light up. So, I'm at this weird like crux with it all where you know, they got these great relationships with these other people. But I almost feel like none of its possible, the way I've chosen to do it from tip to stern all on my own, because I've collaborated so much. You know, being where I'm being. Where I could if I wanted to, I could holler out and wind up slapping 25 different borosilicate workers in an hour's distance from me. I've got multiple scientific glass shops that would love to have my business and other shop

now that I've, you know, can just say ‘hey, hey, Mike. What do you think of this chicken scratch, you know, napkin drawing? Can you make me a half a dozen of these in a couple of months?’ ‘Sure, Aaron,’ you know. I didn't have to learn glass. By way of just, you know, being gainfully employed and trying to create scenarios where everybody gets to make the money if we get the job, have been able to, you know, pay to have glass made or trade to have glass made. And is, isn't it amazing that my spoiled little butt has been able to get where I'm at with my plasma on the backs of others you know. I'll go to them with my designs and everything, but I can't do any of this on my own. I'm OK, with that, but it's weird when you're going out there with one person and one name like, we've seen this pop up on the forums of the other page about, you know, projects that have a really big artist name that took a fistful of artisans to do. And at the end of the day, there's one person’s name on it. Some people don't like to work like that, will not work like that. And I've done it all to that end, and all the craftsman I work with, I try and have those conversations in advance and make sure I'm trying to do my part, you know, and if it takes three of us, I'll say. Well, guess what, everybody gets 30%. It takes two of us 50 and I try and get the maximum I can. And so, to that end for Steve, I think that's how I won over a lot of Steve, trust with Steve is, it just you know supported his interest in casual development to the point that he was flattered enough to give it a serious go. And then what few sales we had...

HS: Excuse me, Aaron. Is this Steve Ward?

[https://www.wardpowerelectronics.com/]

AR: Yes, yes. Yeah. Sorry. Yeah.

HS: No, that's fine.

AR: And then we had we made some good money last summer. That always helps.

HS: That does help.

AR: When you when you're like when you tell somebody. Man, I can tell you, I can, people are going to love this’ but then you do throw down some cash that always helps because it's never free to develop these things, yeah.

HS: Now Aaron, just back to your point about speaking about the interrupted or open-ended circuit, how would you describe that to somebody who's not in the field?
AR: Right. You know, a lot of times in all the traditional line work of all the other noble gas lighting, you're just trying to light a, you're trying to glow a tube and conduct through a tube like a wire. And [um] you know, we're trying to, we're trying to support a column of gas. Especially if you're trying to begin your mission at the bottom, you know what I mean? And light something from the bottom up. And what's been really interesting to hear from somebody like Steve, who is you know very professional on their development side and can look at the electronics and tell you yes, these are like very dynamic capacitive loads. There's a there is electrically something going on here. It's not as simple as an incandescent bulb or as simple as a neon, traditional neon lamp. Rein me in here. I'm, I feel like I'm about to slip off and.
HS: I mean, I'm. I'm thrilled that you're about to slip off.
AR: No, it's OK. We were talking about how... Right**. Breaking the path, right? So, when you when you break the path, you also have, just a completely different electrical situation** and like Steve, was just describing it to me yesterday, giving me the numbers behind it that, that this makes a lot of sense. So, you have like a traditional Tesla coil that has that large diameter primary coil at the bottom the big pancake. And then it'll have the long secondary coil that comes up the centre and that primary and secondary magnetically coupled to each other around like 10%. Whereas a traditional fly-back circuit, something more not unlike what Mundy's doing, is going to couple closer to like 85 to 90%. Very different. And then like, what Steve has made recently is 98%. So, he gets these efficiencies by way of his architecture that allow him to run with lower input power, cleaner power, you don't have like all this noise inherent in some of these systems. It's really cool it makes it nice to touch. You don't wind up with any spiciness or really spiciness. And then all that wonderful microprocessor stuff that we're doing so now. OK so you talked earlier about the responsiveness right, and you and I have seen about when you when you break that path and you make these pieces that are sensitive

to touch. You have the animation of touch, but the work also is very animated when it's just off running by itself, agreed. You know, just turn these on they're great. Well, I've been able to tell for a while from losing a lot of power supplies that, yeah, you know you can have things look great down low or you can turn it all the way up and it looks neat too, but different. And those continued thoughts, 'wouldn't it be cool to microprocessor animate automate that?' So last summer, Steve's rendition of that concept. You know our lamps would turn on and then dim down and turn on and then dim down. But now we have the second mode, where it'll go up and drop off. Up and drop off; sawtooth. So that's that, that's what you no one understood that I didn't really want to take the time to explain. Because it means like questions, questions, questions. But the other day, when I was doing my red smoke in my lamp when it would cut off and boof. [during a PAA meeting] That was none of my magic that was Steve's magic. That's the sawtooth mode on that power supply where we're just trying to further animate these lamps when you're not necessarily interacting with them, and we're also this entire system of ramping things up and ramping things down has been selfishly designed, also just to manage heat. So, you can, as you know, you take one of your great single ended projects and turn that dial up to 11 and walk away, might not come back to it anymore lamp. Or it's just going to get damn hot. We can manage that heat by not running it at 11 all the time, but we'll have to get up there. You know the program will shine it. So now we have, there's four potentiometers inside the unit that give a value to the microprocessor to set this loop. And you have one that sets the maximum output, one that sets the minimum and one that sets what's called the slew, which is how fast you know, if you're, if you're going up or going down, you can do that very directly, linearly. Where you can have it kind of come up. And then the fourth potentiometer is the duration of that section of the Sawtooth, if you will. So, you can see real quick with those four potentiometer adjustments on these power supplies, they're meant to be very carefully, slowly tweaked and tuned to a lamp. And you know how on the PVM series supplies and everything they will give you a little volume knob, or Mundy's too,

there's a little potentiometer... Nice potentiometers are really expensive, especially the ones in the ranges to do kind of like what we need to do where they're very electrically isolated. So if we were to make one of these power supplies, like Steve and I are doing that had like bench, desktop friendly adjusted all the time for each lamp that you do, you know like a desktop play model, it'll probably double the cost and we'll have to build it up and build it different electrically to withstand all that right now we have these little, bitty plastic potentiometers, because those are five cents a-piece. And they work great, but those little bitty guys will only handle they won't handle a lifetime of adjustments. But these supplies were also $500 at that level. So yeah, you know, you pop off the top and you do all this very specific tuning. There are these little bitty dip switches that decide if you're in, I forget what he calls it, but the sawtooth mode or the peak to peak. Or, if all that's all, you can turn all of that animation off and just run it at a constant as well. But yeah, and we have a lot more to go in the direction where we're headed with all this this has been kind of some preliminary stuff. There'll be some safety systems. Right now, the system wouldn't entirely know if the load were removed, it might continue to run. So, we'd like, we'd like to take care of that we can hit like, right now if it... it knows if there's a short to ground and it shuts off immediately, but that is not how everything breaks, especially as you know. When the fun begins and you just connect the secondary, it's like a little radio station sitting there broadcasting. And if it doesn't know that the load has changed, it will just keep trying until something gives or the fire starts. That's another thing that's fun, too about all these high voltage transformers and all the worry about fire. I am chuckling about it because they're all made with the wire and the secondaries is like hairs and when hairs get hot and melt, it's usually not very dramatic. It's just a little bitty hair, just like a fuse. Every one of these, when they fail well, it's not dramatic. That's very encouraging... There's a document, just reading Steve's owner’s manual for this should be paid admission. It's an educational gold mine. I'm going to be talking to all y'all through it. Steve too. He's got some great graphical information and text. Everybody's going to have questions, but

there's a touch off for everybody in the way of, you know, explaining just how this simplicity of it works, but also the electrical details of the overall circuits that all of us are making.

He has some information that's going to be really helpful. I think you know I'm still wrapping my head around it. Like yesterday when I went over there, we had lunch. I basically walked into an accidental... edit of that document. And I was like 'OK, let's talk because this is amazing' like it was a crush of information for me, so in person we had to have that edit talk in person and I wound up basically getting a college education in a couple of hours as he broke it down for me and I feel like after yesterday after all these years beginning to get an even better handle on. On what I'm even trying to do.

HS: I look forward to reading that or seeing that.

AR: Yeah, it's been very rewarding, very rewarding to just have you know, a really cool, brilliant guy who has been willing to bite the bug with all of us. And made something that worked that like I had envisioned and I'd seen all the information, unlimited stuff. And one of the reasons why I never bring myself to spend a lot of money there is because I envisioned the next generation. And this is already the... And, and... OK, so there's Steve. I know of two people that know Steve personally that in no sense of like competition or trying to make a product but are totally doing power supply development on their own. I've got one customer in mind that is doing all this stuff for stage shows. There's this programming language for all those lights and the insanity that is any kind of stage show called DMX, and it's kind of like MIDI. So, his power supply is all about tying music to the plasma, and I've made him two different kinds of lamps now trying to cater to that idea. And [uh] you know, it's just, it's gonna be great. I'm very excited about what will be going on a decade from now. Because there's a lot of this, these microprocessor guys. And then a few more people like you know Jeff Feigin or Steve Ward that decide to kind of open source like the core of how they're going about it, that just hands the baton to all these other makers to hear somebody that they value their opinion say, well, this is the architecture I chose because there are options as you can see what Mundy

makes works. I do not fault it. You know, people get really competitive about all this, and I've always been one of those ones it's like there are multiple ways. It's just I happen to be interested in this way.

But yeah, seeing what these gases do, finding those ways to essentially microprocessor program animation. Because I've always been interested in the convective heat, convective aspect, and when I say volumes, I'm thinking like anything that's like one litre or bigger things that are like 50mm in diameter or bigger, you know. That get more of a bottle shape than a tube shape, even if they are a big-long tube, and will only have usually one illumination point. It's just really amazing to see what the gas that does, that's different in how, you know, we've got all our processes that will take us in a different color direction and that's definitely something that I've got going on here with my halogen work, you know. So, at the end of the day each of some of our chemistry slash color directions that we can take have different electrical needs, ideals, possibilities. What Steve and I are finding is that we've got some of his modern Tesla coil type circuitry that operates in these certain frequency ranges and can push power in certain ways, and then we've got some of his other stuff like I was talking about earlier that we've made that has much more traditional frequency kind of ranges for all the plasma products that you've seen. Things that are in the like 20 kHz to 50 kHz kind of territory. There're different possibilities, right? So, he's like. Well, can I build a transformer that... there's this other device called an inductor, inside these plasma power supply systems. We're trying to figure out basically a way where we can do, can we take one transformer, one lamp, a microprocessor and pattern and broadcast very different signals, not simultaneously but timed, you know, if we could do it 20 kHz of 20 milliamps and a ramp with our animation and then the next cycle is at 100 kHz. You know, some of these plasmas have very well have a very different look. If you can convince that transformer to be able to do that and then sequence it, so then we got to talking about the sequencing and that's all taking me back to a lot of what my father was doing way back in the 90's where all of our robotic stuff was about teaching kids.

So, we had the hardware, software and curriculum. The software was the brilliant part that my dad brought to the table where he is a, you know, masters level graphic design person, and there were all these tiles that were either a decision or a performance that you had in the, in the menu and this was all Apple based back in the day, like Apple 2. You'd choose what you were going to do, and you'd bring it out onto this map, and you'd basically create this road network where people could visualize a circuit or a process by way of these little performance tiles that they brought down like a choice. And then that's how they'd assemble the robotics, and our hardware would actually take that graphical software map and quote-unquote run it for you out of this black box that connected to the computer. That then connect it to your little motors and everything so that 'graphical application' is where, my, you know I can't do it myself but my end vision is, is that not unlike the other guy with the DMX controller, but that we would have these microprocessors that you could get into and set up a very complicated or very simple arrangement for your plasma piece. Where you literally can play music through it, you could set up your own different changes of frequency and power and ramping and all these attributes. [And you know] the Little Loop Command and hit go, unplug it, throw the lid on top. Just have a power button left for your end user. Yeah, to me, that's the kind of frontier stuff of where we'd like to go. That's years of continuing to mess around, oh yeah, layers of software. And Steve too, you know, his goal is of course, different from that he'd like to do one of those little toroid drivers. He has his own, like all of the Tesla coils have this type of driver board and he's he has a circuit for that. He's got induction heating circuits. So, he's kind of doing some of the thinking about, you know that this is another circuit in his 'stable of circuits'. He is kind of an information unlimited type person. It's just there is no web storefront for it yet, and he doesn't really know if he wants to go there because he's, like many of us, he's way more excited about the R&D than customer interaction

[.... casual conversation removed...]

HS: I think you've almost answered the next question I had; are there particular techniques that you employ or had devices that expand the artistic application and responsiveness of plasma illumination?
AR: I just I like I've tried to find some shapes that I feel like do enhance, movement or interaction, or playful in-and-of-themselves. But have also fell down this rabbit hole of these really simple tubes and just focusing on what is possible to get that gas by itself to do. You know, not only, how can I reduce the form of the lamp? And just make you think about what that gas can do. Now as a light sculptor, I feel like I've got your focus. As well as that interaction, right? I feel like these lamps feel very much alive to me. And when you get them at scale, that gets powerful quick. That's what I'm really finding about these ones that are life-size what? I'm calling the X-size.
HS: Well, I guess to that end, how do you envisage the viewer or participant engaging with your work?
AR: When I've completed a system that I feel is safe enough that anyone can interact with and that has been a really tough balance for me because there's times where I do like to make and present things that are very fragile and I think that's just part of working in class but that end user experience has always been very upfront and centred to me because, you know, starting to make are in my own name at a young age, you don't really want to, be in the service industry of your work over the course of a lifetime, you know, like we all understand if you things do happen. There's this quality, fine art, supposedly is to last forever. There's some I feel like there's some kind of inherent opinion out there that when somebody buys fine art, so, what we make is very complicated and very hard to. Say this is good, to go throw thousands of hours on it, it’s going to last. You're going to love it. It will never, never everlasting gobstopper like the Willy Wonka movie, The Everlasting Gobstopper of a lamp. So, I'm very careful what I call done [....] If that lamp isn't perfect, I'll just give it away for giggles [...] And really revelling in the process, I don't need to make any money from my work. I don't need to do any of it. So, I'm trying to follow my whim, focus on these differences in, you know,

making better equipment and processes, and I'm doing a lot of my continued halogen experimentation, and I try and do that in private because it's something I want to try and figure out. [As well as it's hard to talk about because most of it's not the safest thing and just leads to questions. And you know, sadly, guys like Percy may always struggle to ever bring it into their education environment because no institutions want to hear what you're doing in their public space. Not super unsafe, but on paper it doesn't look good.]
[...]
HS: Aaron by halogens are you referring to dopants within the fill?
AR: Well, I mean, yeah, I guess there's all kinds of dopants... Yeah, I'm trying to find safe, tame ways to introduce as you know with the iodine, it is disappointing that bromine and chlorine move into controlled substances territory [...] I want to do stuff right as well as make something that lasts, so even the times I've done some really cool lamps and made some neat things, I'm hesitant to let them go anywhere just so I can ... get tens or hundreds of hours out of something before it spoils. I still say that's awesome. That's still making plasma, but some of it may not be the everlasting gobstoppers that are fine art clients want to purchase.
HS: Wow. Well, I wanted to ask you, and you've probably touched on this a little bit as well, but how do you experience that aspect of what I'm describing as responsiveness within your practice? Interactivity.
AR: Yeah, absolutely. And some of my favourite moments are when I'll wind up doing a fill. Especially early in the morning, and of course, if it goes well and just spending time with it.... It's a very satisfying step in the process for us, and I find myself a lot getting that very quality time and artistic practice where I'm so pleased that I pause and don't have to tell myself, 'enjoy this moment', I just do. You know that that work life balance that we all struggle with when I see a new lamp, I just life slows down and just enjoy it and look at it. Think about it, make my little notes. I've tried to keep a lot of notes as I've gone over these years, and that's helped, I think a lot in my practice and I've tried to advocate a lot of those ... you know, so little help in finding consistency in what they're

doing. You know, because like, I think you've mentioned it too, repeatability can be so tricky. So, trying to be regimented in your process is one of the only ways, and if you keep notes that can help you keep yourself in line. I know I like many others. We all have that 'Shiny Syndrome', right? Just. Oh, shiny, when we're supposed to be focused somewhere else, you know. [...] I've been really appreciated seeing your work too in recent times. What you've been up to, those pieces have great interactivity with the. Branching and like ... with no defined path. Through the work and those side bars and stuff, and how they're still lighting and that the fact that you're getting that like that uniform light, I was just really excited..., I was like, wow, it did all light up?
HS: They do favour at times, which is something that I am interested in as well. But then as somebody moves around the work that different areas get. Certain paths or regions, the light gets drawn into those spaces. So, I have been enjoying that. But I guess it's it makes me think of what you were saying before with the saw tooth curve, and the that sort of red smoke that you had appear in that one lamp. That I guess that the difference powering of the space. Within that envelope of glass creates different visual I guess experience and phenomena of what's happening inside and that we are seeing potentially my understanding with that saw tooth curve and the red smoke that appears that we're seeing the change in the electromagnetic field within the space based on the power and the.
AR: Talk about it being like a dynamic load. There's a capacitive and inductive I'm going to say value, but it's not something that's easy to measure because it it's constantly changing, but that capacitive and inductive load that is that sack of gas. The capacitive side of it, right, so they're receiving voltage and amperage. It takes on some of it. It fills up and then it can keep running where it can be asked to just momentarily discharge. But the point is that capacitor bucket can fill up that buffer. So, you see in that sawtooth when all of a sudden, the power, that there's that turbulence leftover. There's that microsecond in space, where there was still charge, but it's dissipating through everything and it winds up being that that smoke and these turbulence and all this

movement and animation, that's just wholly different than the discharge that was just happening a moment ago, and you can only witness it when you're alone in a dark space with that lamp, and that becomes another one of those like very tangible, visceral. I'm here with something alive, kind of spiritual experiences too. They feel alive when they get animated, like these this I feel like. That's been really rewarding and really fun, because before you know. We're all just over. There, yanking the plug out of the wall. And going oh cool I hope I didn't just mess it up.

HS: Yeah, I really, I really appreciate hearing your passion and your insights and also because I know how much depth you have on that side of developing the transformers and understanding the developments in the transformers that that really affects the way you work, and I think that that is It is really fantastic and I can hear your generosity and generative-ness in that as well.

AR: Also, to just you know as a side note being that, like young intent artist. And then with a weird measure of, like humility and guilt of having a young family said, you know, OK, I'll finish my Bachelor of Fine Arts. I'll finish my college degree because in that generation in that area of the country, I grew up in, you, you really weren't a full adult until you at least went successfully fully to college. So, I did finish I finished as easy as I could. I greased out the door with that art degree. I maintained a day job, I said. Aaron, buddy. The realism it would be so selfish of you to think that you would put your poor little family through you, being a starving artist because that's what you want to do? These kids deserve for you to at least give them some decent go in life. And through my father, my parents I've had a great work ethic my whole life. I had good parents, but I also have a borderline unhealthy work ethic, so I carried these other careers and then I started realizing during those few years where I did try and supplement my income, slash needed to supplement my income with artistic efforts. And then when I didn't have the creative liberty there, I was like oh, that's nice. Nobody gets to decide how I play and I always had that concept too of focused, serious play. I was I wanted to be a big kid. To me that's like a way of practicing your art to keep yourself mentally ‘on’ [fit]

into your old years, focus on being able to play, so now I get to continue to play in my work and I try and take on the stuff. That keeps me with that Ethos, so.
HS: So, is that something that that you would say is something that you're trying to elicit in your work or experience through your work in this play?
AR: Yeah, yeah. When people say this is cool, like how does it work? I want to touch It, I want to play with it, I'm; like there's a win for me. That was what I was trying to do. Because I want, you know that that old idea of art being so important and so lofty on the wall that oh, heaven forbid you, you know us little active boys we're not allowed to touch in the museum. Well, I wanted my art to be much more interactive and approachable as well as functional.
HS: Well, that's very rewarding having this conversation with you and seeing that another way of looking at responsiveness is that perhaps play is interaction as a form of play.
AR: I think also the, you know, the overgrown night light, the unnecessary side of what we do. Also, like from the get-go, well, we must be playing. You know, no one needs no one needs this. This is about fun.
HS: Yeah, that's excellent. Thank you, Aaron.

10 Kamila Mróz

[25.02.2025]
Kamila responded via email, and then we had a further discussion.
HS: What is your background that has led you to using plasma illumination?

1. KM: After graduating, I was looking for my own way and in 2014 I moved to Łódź, where I received funding from European Union to open my own glass studio. But finding a space where I could work freely with open fire was a big challenge. Finally, I came to the FabLab, a space dedicated to designers, engineers and

artists, where I ran my own studio in the shared space and focused my activities on creating glass jewellery and running flameworking workshops. At the same time, I wanted to expand my knowledge of neon creation, which led me to a job at Kapilar, a company that produced light advertising - mainly neon. There I gained valuable experience in the entire production process. Despite my busy schedule and commitment to my own business, I found working at Kapilar to be a very effective educational method that would help me in my "looking for light" journey. An additional advantage was (sometimes limited) the access to professional neon equipment.

2. It was during this period that the work "KNOT - to remember! and "Devourer" was created - the first neon sculpture that went beyond the shape of a tube; it is currently in the collection of the City Museum in Wroclaw.

3. After a year in Kapilar, in May 2016, with the help of an investor, my partner and I started building NEONOFF, a specialized neon and scientific glass workshop. We renovated a 400m2 space, imported and refurbished equipment, including glass lathes and a vacuum processing station, and expanded our capabilities. With a team of six, we undertook neon projects and produced special discharge lamps.

4. For me, the most important project we completed was a series of exhibits for the EC1 Science and Technology Centre in Lodz, including a stunning display simulating the 'Aurora Borealis'. It consisted of 6 glass tubes with a diameter of 100 mm and a length of 100 cm, filled with air under reduced pressure, with electrodes embedded at the ends.

5. Another exhibit was a tube 150 mm in diameter and 150 cm long, inside which it was possible to observe the influence of the magnetic field on the flux of moving electrons.

6. We also made a Crooks tube with electrodes and an enclosed internal moving wheel with blades covered with a coating that phosphoresced during the experiment.
7. One of the exhibits was also a plasma globe with a diameter of 76 cm, made by Wayne Strattman in the United States. Unfortunately, it was damaged during assembly. Due to the high cost of transporting, it back to the US, we took on the challenge of repairing it and we succeeded. Throughout the whole project, the practical knowledge gained was priceless and served as inspiration for my research on plasma discharges.

8. This is my first single-electrode plasma sculpture, entitled 'Christ of Nations?', consisting of a glass crown of thorns against the background of the outline of the borders of Poland. It was created in 2017 and presented at the Ireland Glass Biennale in Dublin in 2019 and at the Glass is BIOTiful II exhibition in Biot in France in 2020. The crown is filled with neon, which illuminates its interior with a riot of orange-pink plasma discharges, and the work is equipped with a motion sensor that turns the crown on when someone stands underneath.

HS: How do you describe Responsiveness within this form of illuminated practice?

KM: In my work, I begin by marking out the glass boundary, where I enclose reactive plasma. But I don’t see the glass as a limitation—rather, it’s a surface of contact between two worlds. It’s like a skin that lets stimuli pass both ways. One of the key

properties of glass in art is its translucency. Often, we're allowed to see through it, but usually, we aren't invited to interact with what's inside.
What I aim to do is treat the glass like a living organism, where its interior can be interacted with, even though it's sealed off. In my pieces, the glass surface is an impassable barrier, behind which a world of molecules and atoms in constant reaction is contained. Plasma sculpture may appear fixed in its form, but inside, it responds to its environment, changing in subtle ways. Even though the glass and its shape stay the same, our own electrical potential interacts with the piece, giving the impression that the light within is reaching out to us—like it's alive inside its glass shell.
My goal is to invite the viewer into a relationship with the energy of the work, to want to reach out and touch the light. I want people to forget about the boundaries and let themselves get lost in the magic of combining noble gases and electricity.

HS: Are there particular techniques that you employ [or have devised] that expand upon the artistic application and inherent responsiveness of plasma illumination?
KM: The inductive electrode is made from a very thin copper sheet, attached to the glass using epoxy resin mixed with graphite powder. This allows me to use oxygen, which glows pink. As I'm a huge fan of all shades of pink in plasma discharges, I love this effect.

HS: How do you envisage the viewer-participant engaging with your work?
KM: "I feel there's no need to invite the viewer to interact with the works, as the natural human urge to touch is enough in this case. But the real challenge is how to create a safe space for the artwork to interact with the viewer. In my experience, it's almost impossible. If you allow the viewer to touch the work, you can't guarantee its safety.
At the Jewish Contemporary Museum in San Francisco, a staff member demonstrated how plasma discharges react to touch. To me, it felt like trying to lick ice cream through a window—it's better than nothing but still far from the full experience. So far, I've

found that the most complete experience for viewers happens when I stand next to my work and allow them to touch and interact with it directly.
I imagine the perfect environment for the full experience is when someone buys the piece and spends evenings staring at it and playing with it."

HS: How do you experience Responsiveness within your plasma practice?
KM: As a kind of magic. Although I see myself as a very rational person who strongly believes in science and understands the laws of physics that control plasma discharges, the responsiveness of plasma discharges is still hypnotizing and magical. So maybe I'm not so rational after all!

11 Wayne Strattman

[08.02.2023]
Wayne Strattman
Harriet Schwarzrock- HS: So first I'd like to ask you, what is your name?
Wayne Strattman -WS: Wayne Strattman
HS: And how would you prefer to be referred to?
WS: Wayne would be fine.
HS: Wayne fantastic. And where is your studio?
WS: The suburb Alston of Boston, Massachusetts in the US.
HS: Fantastic. And what is your background that led you to working with plasma illumination?
WS: Growing up, I was a maker from an early age. I grew up in a culture of makers in a blue-collar type of environment. My father had a workshop, and he died while I was young and I inherited all his tools in the workshop and all my friends, we, we built things. We'd ...we grew up basically in, in an era post Sputnik, where there was a big emphasis on this on making things and developing technical skills and we loved it and I

went to school for engineering, but after doing a full degree in liberal arts, where I discovered a love of the arts as well arts and philosophy and psychology, and I wasn't mature enough to do the engineering the first time, so after that degree was out in the working world about four years and went back to engineering and minor in physics.
WS: So those two together, I found the perfect thing to focus on, that was neon art, originally. Which was hands on, which is what I'd love to do in **a very difficult field of glassblowing within the combined technologies of vacuum and gas discharges with electrical discharges** were perfect for me, and within that context, it wasn't too many years after start graduating from engineering school and working engineering jobs, that I started doing neon art on the side. And eventually sort of took a flyer to start my own little studio company because people were asking me for lots of things and I was teaching and sort of never looked back. I really didn't even know what I didn't know back then. I was tremendously ignorant. I had no mentors, no, no formal training. But a lot of enthusiasm and I was always the type that could learn on my own. I've been stumbling my way through it ever since. Literally and, literally and figuratively, I quickly started writing an international column called Neon Techniques and looking back on it I had a lot of misunderstandings of things that which I published under my own name. I think I got mostly right because I researched things, but every month I published a technical column, and that technical column led to being hired as a consultant for Corning Advanced Lighting Products division. And gave me the confidence to start going well beyond neon, and to working plate glass, neon and developing products. And going bigger and bigger and learning scientific glassblowing, eventually teaching scientific glassblowing at MIT.
A couple of semesters, just everything kept expanding. And I developed lots and lots of products and new techniques and have always maintained an interest in looking deeper and deeper into the subject.
HS: Amazing, I would like to ask you how you describe responsiveness within this form of illuminated practice?

WS: As I understand the word responsiveness. I'll redefine it and tell me if this is correct. **Why do I use light and kinetic light to make sculpture? That's a very complex question.** The use of light has so many inherent mediums, I've written about this a bit and like to plan to do more writing on this and there's been some fantastic books that I have read that throughout history the metaphor of light is philosophically and religiously significant, important to intellectual development this is seen as you know, seeing the light and the light of inspiration.

It, it taps into a, I guess the learning from my first degree, in sensation and perception in psychology, that we are like moths, attracted to light. We're attracted even more strongly to movement. It's something we don't have a choice about. It's a built-in thing with us, and when you couple it to higher meanings there's tremendous interest in it, just on a physical level, but then on an intellectual level, you can tie it to much more sophisticated concepts.

Which also makes this feel quite difficult to often separate and push your own meaningfulness towards the conclusion that you're looking for. There are lots of times your sculpture will have meaning, depending on your background and your willingness to look, you know more deeply into what you're looking at. Assuming your artist is trying to get you to look deeper into some level. But yeah, yeah. It's a complex answer to what sounds like a simple question.

HS: No, I appreciate that. Thank you. That's very insightful. So, along the lines of like leading on from that, I'm wanting to know, are there particular techniques that you employ or have devised that expand upon the artistic application and inherent responsiveness of plasma illumination?

WS: That question could basically say, oh, that's the whole nature of my career.

HS: Yes.

WS: It is, oftentimes, you know I might be as an artist looking to illuminate, once again the relationship to light, aah certain concepts or ideas, but many other times I'm just playing with the light to see what's possible. And coming up with techniques that I don't

know where they're going to go, but they're, they're somehow meaningful or beautiful, and eventually they will come back around, “ooo, I can use that in this way”. It's like an, an artist who in the Middle Ages was experimenting with new pigments. “I don't know what I'm going to do with it, but I love this.” That's saying that's exactly what I’m doing with light and new techniques of creating light and color and movement.

HS: Yes. I appreciate that this particular question is the most ‘loaded’ in speaking with you because of your incredible background, yeah.

WS: It’s open ended, which is wonderful. You know, you're not asking me to pick a, b or c as an answer which is great.

HS: Thank you. I would like to ask you; how do you envisage the viewer or participant engaging with your work?

WS: I think an underlining assumption of that question is that there is a particular viewer, and that's my experience, there is no “particular viewer” with a given background. There are many people who just love to go over and play with the moving lights, and that's all they see. There are others who may have a technical background, and they'll be interested in some of the physics of things that they don't commonly encounter. And then they question that and gives them another level of appreciation. And there are others who have maybe have more of a historical context and see something you're trying to approach based on some historical things happening, or a meaningfulness maybe with the form of the piece might relate to something religious or inspirational.

So, it depends, when the mind comes to new learning, and new learning changes the mind, but the mind affects what's coming into it as well. That's a dynamic that, so there is no, unless you have a standard viewer in mind, it truly is dependent. And I've noticed that from the beginning. I love seeing people who have a little bit more depth in the background who can start asking deeper questions about these. And that's very rewarding for me because I put a lot of time and effort into it and if they're seeing it in

the very levels of you know expression that I'm trying to put into the piece. Assuming that the levels are there.

Well, sometimes I make pieces that are just visually interesting. Period.

HS: OK. That is interesting because you have that breadth within your practice where there are pieces that perform that function.

WS: Exactly right, and those are very base levels, a level of brightness or speed or pattern of movement. Now there's no deep ideas in that. It's exciting something, you know, in our sensation perception system.

It's like fire in a fireplace, there's no big meaning there, but you can watch it for hours. That's the original light art.

HS: I was wondering how you experienced the responsiveness within your plasma practice?

WS: How do I react to the way people reacting? So, to speak?

HS: More about how you maybe react to your own work or how you react to the, the plasma illumination as a sculptural medium.

WS: That's a good question, cause that changes all the time. I tend to get excited, have an idea, start working towards a piece and you might have the elements A + B + C by the time I'm done altering it, it's X + Y + Z and I don't have a certain look and what I normally do after I make the piece, I immediately walk away from it.

And I come back to it and have it on in a room and maybe come back in and look at it the next day and see how it hits me when I see it again.

And then I sometimes I will leave it and go off and work on other things and just keep coming back to it and seeing how I would react to it. Almost trying to see it anew and, how does that affect me seeing it?

And almost immediately, I'm on to the next idea. It's like...

HS: OK.

WS: People ask, ask me what's your favourite pieces? 'Like the one I'm working on now'

HS: Wow, thank you. I sort of snuck this question in because it's an adjunct interest to me. Does wonder play a role in your use of plasma illumination?

WS: Absolutely, yeah. **Essentially, we're crossing that border into using plasma. That's mistakenly called the fourth state of matter should be called the first state of matter, given its prevalence and the fact that it was around about 300 million years before the other states were.** But the rules are different. **The fact that it's illuminating and moving and we can't touch it there's always a barrier between us and the plasma and so we're, we're seeing into a different world and manipulating it to the best of our abilities, and it's fascinating and that if that isn't the definition of wonder, I don't know what it is.**

And as you've seen, effective reference section that in this in my shop there's a lot of things that I've discovered that they're fascinating to look at. That sense of wonder of electromagnetic waves and magnets, for example, spiral into some of my Mesmer pieces which are encapsulated light paintings using phosphorus that all look white in normal light but under UV are all the colors of the rainbow, they're being lit up various speeds and patterns with various gases. And yeah, it's all a sense of wonder.

HS: I love that. Thank you. And I just finally wanted to ask if there are any other insights that you might generously perceive as relevant to the interactive or effective dimension of plasma illumination?

WS: Oh boy, you know these questions ain't easy. Can you say that again?

HS: I'd welcome you to share any other insights you perceive as relevant to the interactive and effective dimension of plasma illumination.

WS: That's what I wrote in my write up ...**I didn't use in my latest book. There is a whole other dimension of the time dimension with a lot of plasma. It's not a static thing for many of these things. It's moving and changing and very interactive with ambient lighting. So, and also it has a time dimension a longer time dimension in all experienced plasma people know oftentimes the discharge changes over-time.**

And it can get better and get worse. It can go out completely so, there’s a longevity issue with many pieces and other pieces will last well beyond our lifetime. That there's so many dimensions of appreciation that it's good, because it offers lots of tools, but it also can be a confusing mess of appreciation when you're trying to go after one idea. But often-times people are seeing this just on one level. Oh, there's just some moving light, even though that, well, it's also in a particular form and things that you're trying to convey that they may not be getting so, you have to be quite careful in how you use these elements and as a level of experience is required.

For example, the simplest idea is the speed at which something is moving. I find that very critical. If you make things too fast, you can't live with them. People like slow, sensual, bright movement.

I sponsored a lecture where around meaningfulness in the body and we also like things and its certain angles and planes to, in scales that relate to our body sizes and which way we call up. There are a lot of informal things that are going on and if you're interested, you can look at for a long time. Without going that much deeper.

HS: Oh, thank you, Wayne, that's it.

WS: That's it. Easy.

HS: Thank you.