

RESULTS OF PRELIMINARY TESTS ON
SECTIONS OF A DISK LASER
AMPLIFIER FOR A 44 mm DIAMETER
BEAM

EP-RR 35

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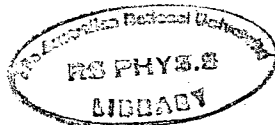
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CONTENTS

	Page
Summary	iii
1. Introduction	1
2. Gain and Loss Measurements	1
3. Interpretation and Comparison of Results	2
4. Measurement of Spontaneous and Stimulated Emission from a Disk.	5
References	8

SUMMARY

The gross and nett gains of eight disks of the 20 disk laser amplifier were measured for pump powers of 18 to 58 joules per cc. The maximum gross gain was 1.9 compared to a value of 2.7 expected from published data.

Measurements were made to show if the gain was reduced by depletion of the laser inversion as the result of laser action with individual disks. In fact, such oscillations did not occur.

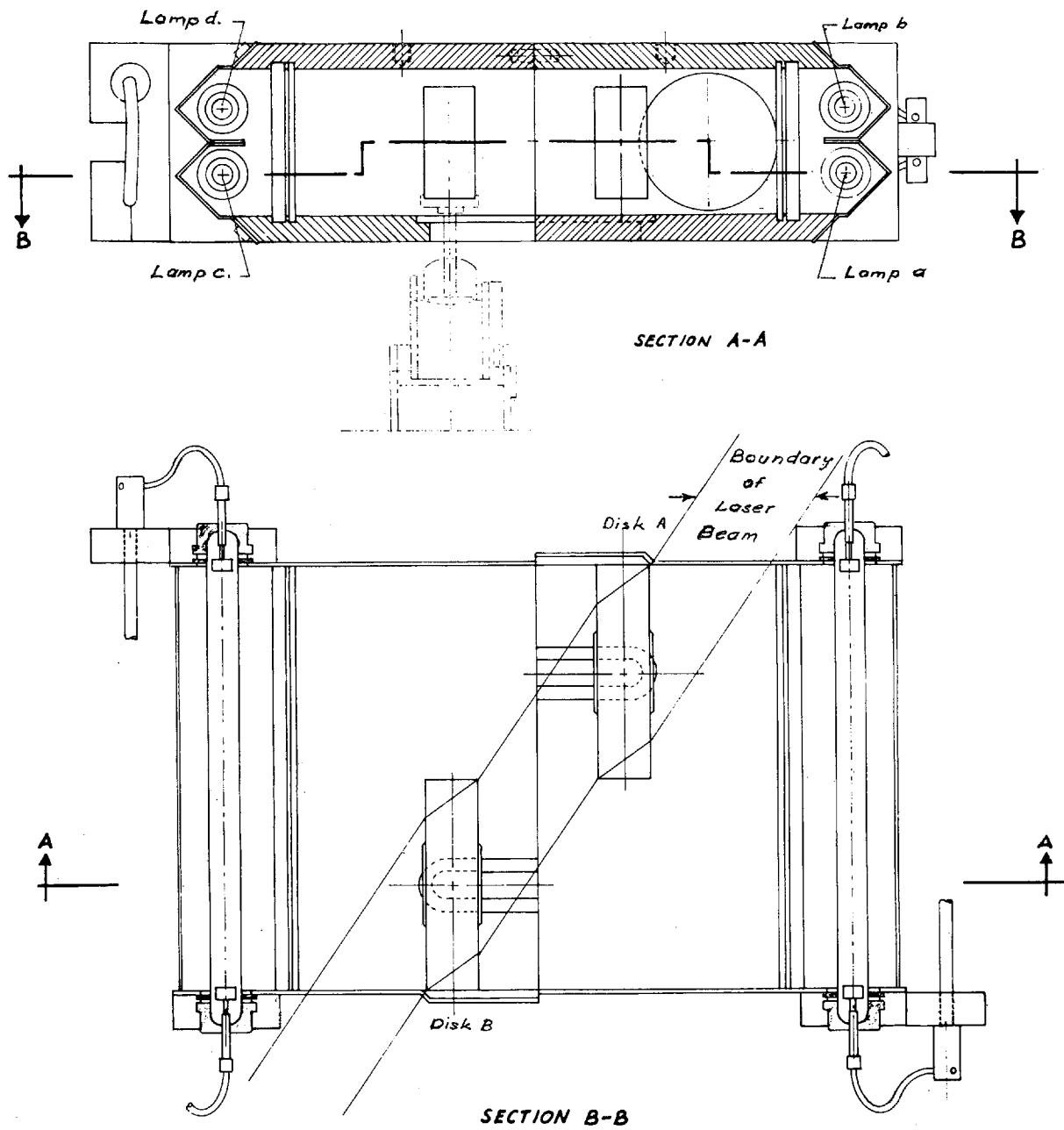


Figure 1. The laser disks and X e lamps mounted in enclosure with aluminium reflecting surfaces and glass filters to absorb ultra violet radiation.

1. INTRODUCTION

A laser amplifier, using disks of neodymium glass, has been built to demonstrate the feasibility of providing power from the homopolar generator in the Department⁽¹⁾ for driving large lasers and providing powerful laser beams for research. This prototype model incorporates disks large enough to amplify a beam 44 mm in diameter by a factor of ten if fully pumped. The maximum potential output is 100 GW in a nanosecond pulse or 20 TW for a picosecond pulse.

2. GAIN AND LOSS MEASUREMENTS

Four pairs of Nd⁺³ glass disks were used in these tests of the amplifier supplied with pump energy from the homopolar generator via a transfer inductor⁽²⁾. The lamps and disks were mounted as shown in Figure 1. Pulses of 3 joules in 8 nanoseconds were supplied from the 16 mm diameter rod amplifier. This beam was made to diverge by 4.5 mrad and it entered the first disk with a diameter of about 25 mm and reached the final disk with a diameter of 40 mm.

Loss of Power in Disks

Between amplifier pulses the loss of laser beam energy due to passage through the disks, was measured. The results were:

<u>Date</u>	<u>Measurements over 3 pairs of disks</u>	<u>Calculated over 10 pairs of disks</u>
14.11.72	I out/I in = 0.85	0.582
16.11.72	" 0.80	0.475

Rounding off - take at 0.5 for 10 pairs or 0.963 per disk.

The Gross Gain produced by the four pairs of disks was measured by energy meters and vacuum photodiodes. The results are plotted in Figures 2 and 3. The maximum energy supplied, up to the time of the laser pulse, was 6,400 joules per disk. The gross gain was then 1.9 for the four pairs of disks or 5 for the full amplifier of ten pairs. The loss for ten pairs would be 0.5, giving a nett gain of 2.5.

The very wide scatter on the results is mainly due to the small signal coupled into the input beam monitors which allowed the readings to be significantly affected by interference from the flash lamps.

GAIN MEASURED BY VACUUM PHOTO-DIODES.

16-11-72

- Disks held by Al band.
- Black Fe band around disks

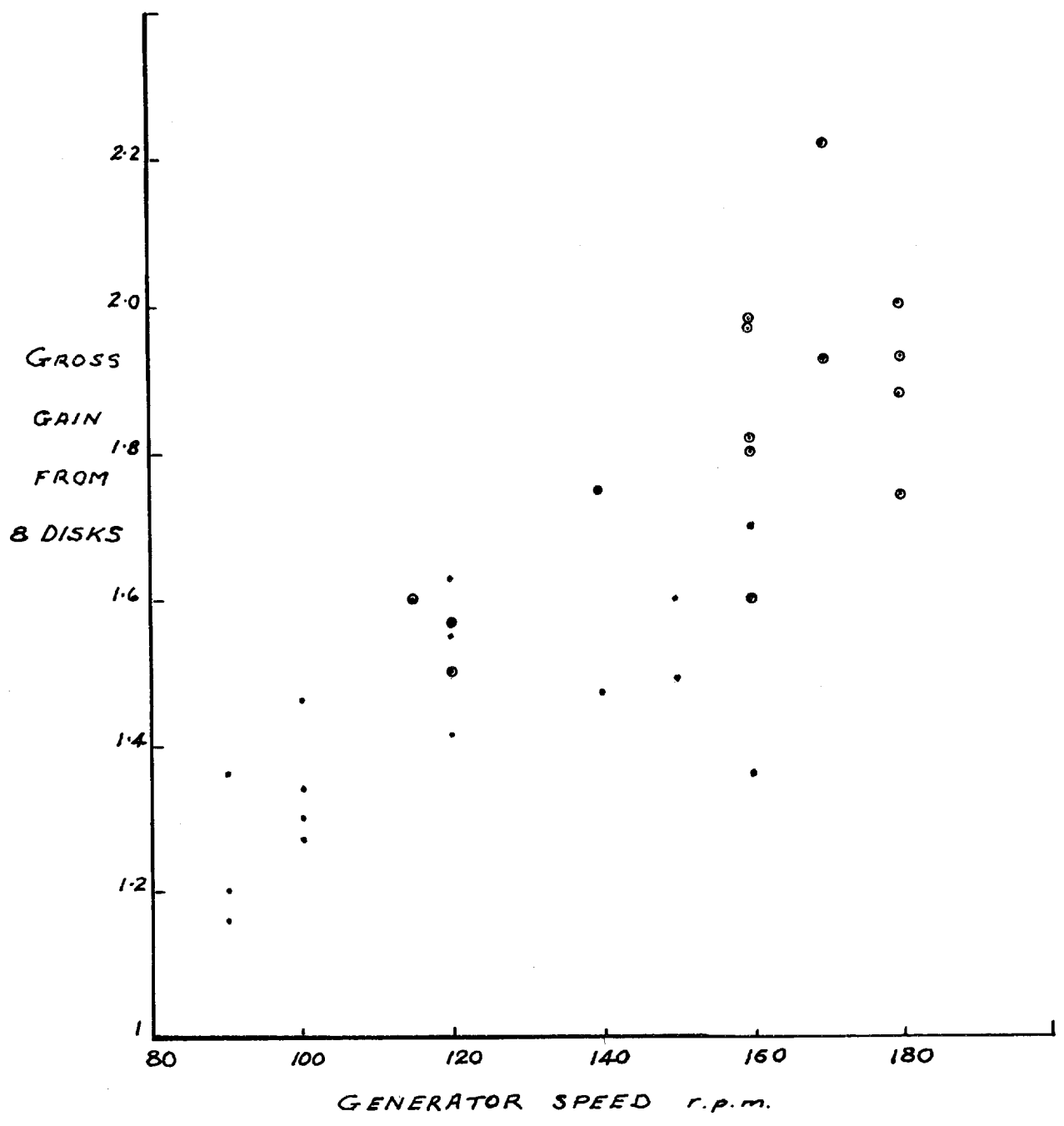


Figure 3. Gross gain from eight disks, measured by means of vacuum photodiodes and a high speed oscilloscope. Slight variations in the shape of the pulses were ignored and the peak readings were taken to obtain the gain.

3.

INTERPRETATION AND COMPARISON OF RESULTS

The laser pulse occurred 760 μ s. after the start of the flash lamps. The pump energy up to this time was calculated by summing the values obtained from the product of the current and voltage for 200 μ s. intervals, that is $\sum V_i I_i \delta t$. This showed the average power (from zero time to 760 μ s.) to be 0.76 x peak power, and the energy to be 0.5 x the energy initially in the inductor. The following Table 1 could then be calculated.

Table 1

Rotor Speed	Stored Energy joules	Pump Energy into 8 Disks in 760 μ s.	Energy per cc of glass, J per cc
100	31,800	15,900	18.2
120	45,800	22,900	26.3
140	62,300	31,100	35.7
160	81,400	40,700	46.7
180	103,000	51,000	58.5

Curves provided by American Optical indicate that a gross gain of 2.7 should have been observed when these disks were pumped at 58.5 J per cc, if the coupling between the lamps and the glass was as efficient as theirs, whereas a value of only 1.9 was observed.

It was thought that the low gain was due to depletion of the excited state by stimulated emission reflected along a multiple path through the disks; that is, super-radiance with regeneration. Accordingly, a single light house with one disk was set up and powered from the electrolytic capacitors to study the emission of 1.06 μ m radiation from the disk, to determine what depletion mechanisms were involved.

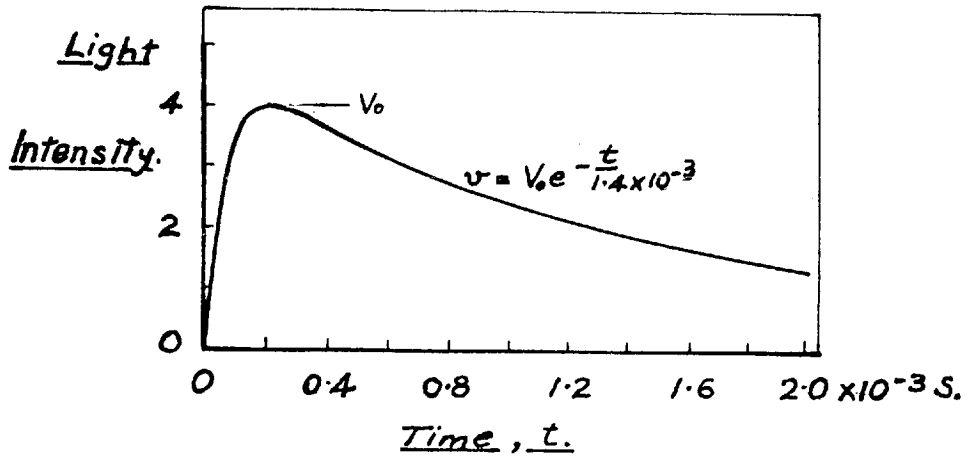


Figure 5. Flash lamp output as a function of time.

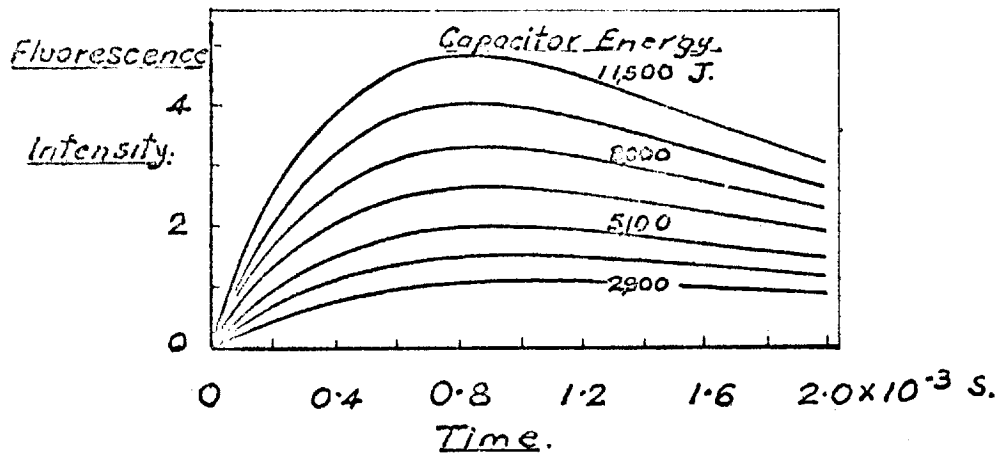


Figure 6. Fluorescent radiation with wavelength of $1.06 \mu\text{m}$ as a function of time for various pump power levels.

4. MEASUREMENT OF SPONTANEOUS AND STIMULATED EMISSION FROM A DISK.

One light house was mounted as indicated in Figure 4.

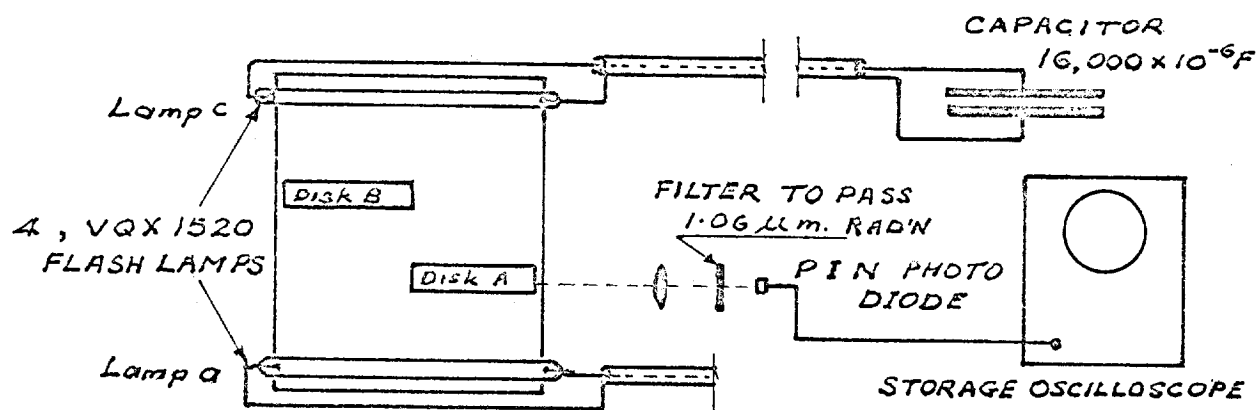


Figure 4. Showing a photodiode mounted to detect $1.06 \mu\text{m}$ radiation from a Nd^{+3} glass disk. The same diode was used to observe the flash light without the Nd^{+3} glass and filter.

The PIN* photodiode was used to measure the $1.06 \mu\text{m}$ radiation from the disk and when the disk and filter were removed the light from the flash tubes alone was recorded. The disks were mounted in the holders used in the laser amplifier with polished steel bands to secure them.

The wave form of the pump light is shown in Figure 5 which indicates a decay time constant of 1.4 ms.

Figure 6 shows the intensity of the $1.06 \mu\text{m}$ radiation for different pump energies as indicated by the values on the curves. The values measured from these traces are tabulated in Table 2.

* Semi-conductor photodiode consisting of P-type, intrinsic, and N-type layers.

TABLE 2

Capacitor Voltage Volts	Energy Into two disks Joules	Max. Intensity of 1.06 μ m Rad'n Arbitrary Units	Time to Max. Intensity ms	Ratio Max. Intensity Int. at 2 ms
600	2,900	0.82	1.1	1.26
700	3,900	1.15	1.05	1.31
800	5,100	1.42	0.98	1.29
900	6,500	2.05	0.90	1.41
1000	8,000	2.57	0.90	1.47
1100	9,700	3.15	0.87	1.54
1200	11,500	3.79	0.83	1.61

The Table shows two significant trends which indicate the origin of the radiation. Firstly the time from the start of the pump light to the maximum emission varies little for pump energy less than 5,000 joules, but as the energy increases from 5,000 to 11,500 joules, the time to the peak intensity of the radiation drops from 0.98 ms to 0.83 ms.

Secondly, the ratio of the peak intensity to the intensity at 2 ms is constant for pump energy less than 5,000 joules (22.9 joules per cc of glass) but it increases significantly at the higher energies.

If the spontaneous fluorescence decay time constant for this glass is 750 μ s and the pump light has the wave form shown in Figure 5, the inversion of the levels in the Nd³⁺ would follow the points plotted in Figure 7. The intensity of the fluorescence observed when the capacitor was changed to 700 V is represented by the curve in Figure 7. Thus the lower three traces of Figure 6 are produced by spontaneous emission. When the total pump energy per pulse exceeded 5,000 joules, some stimulated emission (super-radiance) occurred, leading to an earlier maximum and more rapid reduction towards the spontaneous decay curve. The effects are small up to the maximum pump energy shown in Table 1, namely 58.5 joules per cc supplied from the homopolar generator when running at 180 r.p.m. If a regenerative path occurred within the disk a sharp burst of radiation would be emitted, lasting for less than a μ s. If this did not occur in the direction of observation its intensity would be such that scattered radiation would have been observed and the depletion of the inverted population would lead to a reduction of the subsequent spontaneous emission in the direction of observation. Such discontinuities were not observed even when curves such as those shown in Figure 6 were recorded on a faster time base.

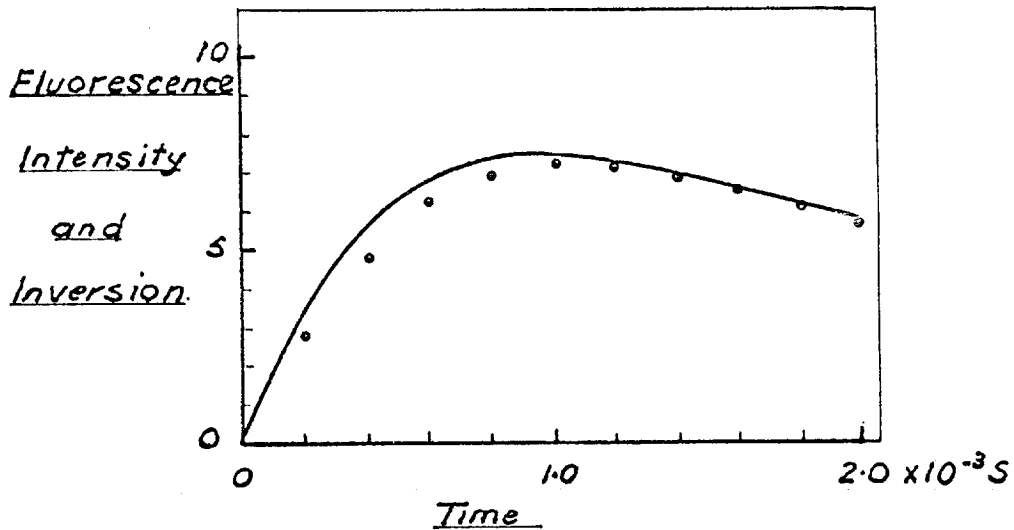


Figure 7. The points show the calculated values for the inversion (in arbitrary units) produced by a light pulse of the form shown in Figure 5, and a fluorescence decay constant of 750 μ s. The curve is the fluorescence measured when the lamp energy was 4,000 joules.

If strong super-radiance were excited the duration of the emission would contract, and the peak intensity would be high compared to the spontaneous emission. Figure 8 shows the peak values, measured from Figure 6, plotted against total pump energy. It is clear that, over that energy range, super-radiance was not great, and no regenerative amplification was occurring. The super-radiance could reach spectacular magnitude at higher pump energy as illustrated by Figure 5.8 in Röss's book "Laser Light Amplifiers and Oscillators", page 83, where super-radiance having 10^5 times the power level of the spontaneous emission from a ruby rod is recorded.

Since these measurements show that the disks were not pumped to a level where severe super-radiance occurred, the loss of gain must indicate that the lamps are not well coupled to the disks. This has prompted further work to improve the design of the lamp enclosures.

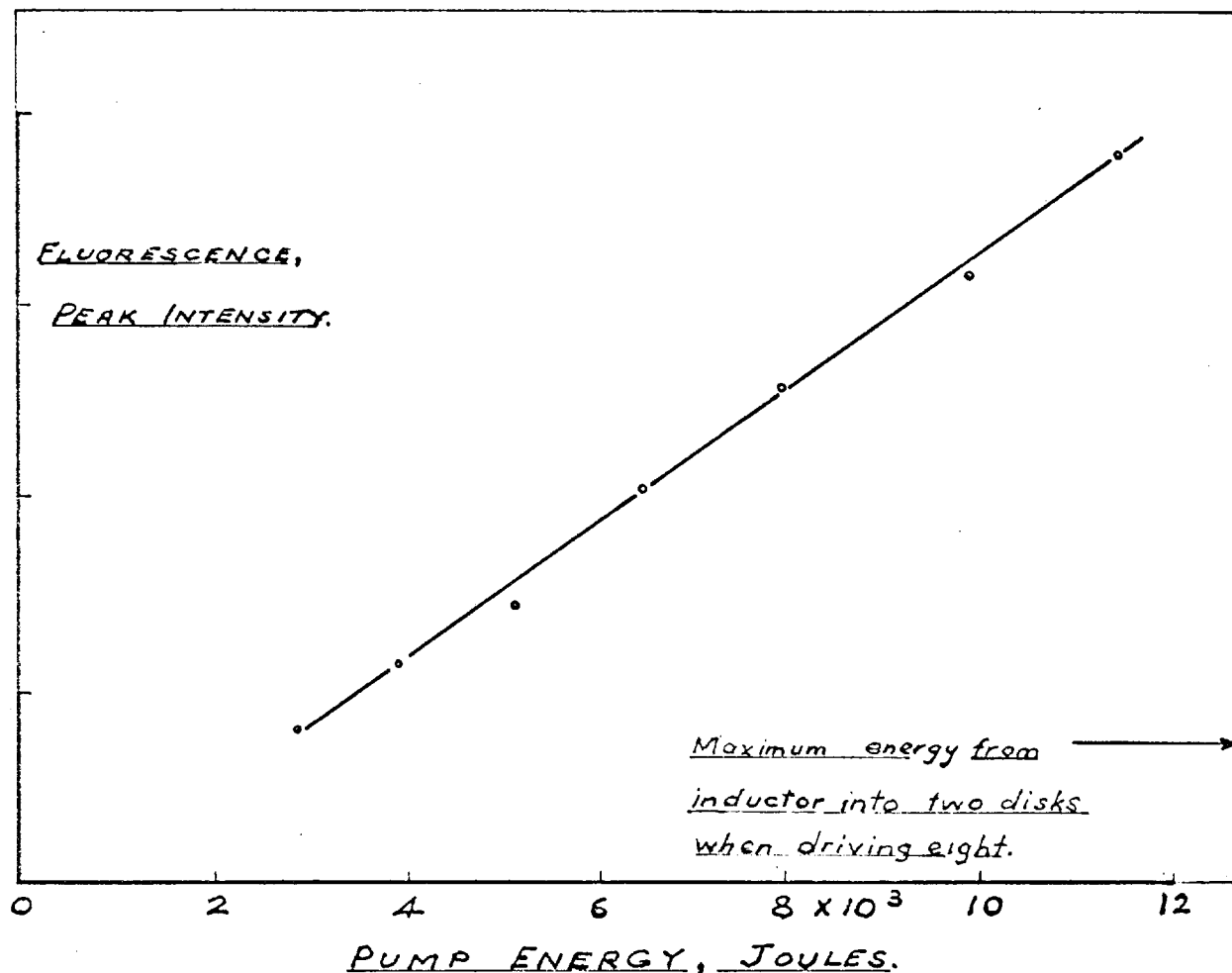


Figure 8. Shows the linear relationship between peak intensity of fluorescence and pump energy.

REFERENCES

1. INALL, E.K. : "Modifications to the Canberra Homopolar Generator", Atomic Energy in Australia, Vol. 8, No. 2, pp 2-5, 1965.
2. INALL, E.K. : "Fast Circuit Breaker for the Discharge of a Storage Inductor", Nat. Phys. Sc., Vol. 231, No. 22, pp. 111-112, May 31, 1971.

Publications by Department of Engineering Physics

No.	Author	Title	First Published	Re-issued
EP-RR 1	Hibbard, L. U.	Cementing Rotors for the Canberra Homopolar Generator	May, 1959	April, 1967
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EP-RR 35	Inall, E.K.	Results of Preliminary Tests on Sections of a Disk Laser Amplifier for a 44 mm Diameter Beam.	April, 1973	
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