Trapped supercontinuum and multi-color gap solitons

Andrey A. Sukhorukov[1], Dragomir N. Neshev[1], Alexander Dreischuh[2], Robert Fischer[1], Sangwoo Ha[1], Jeremy Bolger[3], Lam Bui[4], Wieslaw Krolikowski[5], Benjamin J. Eggleton[3], Arnan Mitchell[4], Michael W. Austin[4], and Yuri S. Kivshar[1]

[1] *Nonlinear Physics Centre, Australian National University, Canberra ACT 0200, Australia*
[2] *Department of Quantum Electronics, Faculty of Physics, Sofia University, Bulgaria*
[3] *School of Physics, University of Sydney, Sydney NSW 2006, Australia*
[4] *School of Electrical and Computer Engineering, RMIT University, Melbourne, Australia*
[5] *Laser Physics Centre, Australian National University, Canberra ACT 0200, Australia*

The generation of supercontinuum radiation is a fascinating example of extreme nonlinear processes where many colors of light are created from a narrow-band source [1]. Supercontinuum radiation differs significantly from the light emitted by incoherent light sources, combining high spatial coherence and spectral brightness; it has found various applications in diverse fields of physics, including optical frequency metrology, spectroscopy, tomography, etc. Efficient approaches have been developed for the manipulation of temporal and spectral characteristics of supercontinuum generated in photonic crystal fibers (PCFs) [1]. PCFs allow for engineering of the spectral dispersion and confinement of light through the underlying periodicity of their structure.

The ability to perform tunable shaping of the supercontinuum light beams in the spatial domain would be beneficial for applications. Whereas various approaches for all-optical beam shaping have been previously developed for narrow-band light sources, we have demonstrated tunable control of supercontinuum light beams in periodic photonic structures in the form of waveguide arrays, shown schematically in Figure (a). The waveguide arrays feature the refractive index modulation in the transverse spatial dimension with the characteristic period of several wavelengths, resembling the periodic cladding of PCFs. In such structures the back-scattering of light is absent and transmission coefficients can approach unity simultaneously for all spectral components. Additionally, the spatial beam propagation in waveguide arrays tends to change smoothly as the optical wavelength is varied by hundreds of nanometers, in contrast to the presence of sharp spectral features in photonic crystals where the refractive index is modulated in the propagation direction on the scale of the optical wavelength.

Following the theoretical analysis [2], we demonstrated experimentally [3,4] spatio-spectral reshaping of supercontinuum light achieved through nonlinear interaction of spectral components in an array of optical waveguides fabricated in a $LiNbO_3$ crystal. At low laser powers, the supercontinuum light beam exhibits linear diffraction and the spectral components become progressively spatially separated along the propagation distance as illustrated in Figure (b). At the output the red components dominate in the beam wings, while the blue components remain in the central region, as confirmed in experimental measurements presented in Figure (c).
As the laser power is increased, the beam begins to localize, bringing more and more wavelength components into the central waveguide, see Figure (d). This process is associated with the formation of polychromatic gap soliton [2], supported by the defocusing photorefractive nonlinearity of $LiNbO_3$ crystal. Spectral components below the threshold wavelength are trapped in the central waveguide, while longer wavelength components are delocalized. A representative example for supercontinuum power of 7.5mW is shown in Figures (e) and (f), where all spectral components below 600nm are trapped. The reshaping of polychromatic signals is performed without generating new wavelengths, since the coherent four-wave-mixing processes are

suppressed due to the relatively slow photorefractive nonlinear response [5]. Additional flexibility in optically-tunable spatial shaping and spectral filtering of supercontinua is available through the beam interaction with the edges of periodic waveguide arrays [3] or optically-induced defects [4].

References

[1] See a review in: J. M. Dudley, G. Genty, and S. Coen, Rev. Mod. Phys. **78**, 1135 (2006).
[2] K. Motzek, A. A. Sukhorukov, and Yu. S. Kivshar, Opt. Express **14**, 9873 (2006).
[3] A.A. Sukhorukov, D.N. Neshev, A. Dreischuh, R. Fischer, S. Ha, W. Krolikowski1, J. Bolger, A. Mitchell, B.J. Eggleton, and Yuri S. Kivshar, Opt. Express **14**, 11265 (2006).
[4] D.N. Neshev, A.A. Sukhorukov, A. Dreischuh, R. Fischer, S. Ha, J. Bolger, L. Bui, W. Krolikowski, B.J. Eggleton, A. Mitchell, M. W. Austin, and Yu.S. Kivshar, Phys. Rev. Lett. (2007) in press.
[5] M. Mitchell and M. Segev, Nature **387**, 880 (1997).

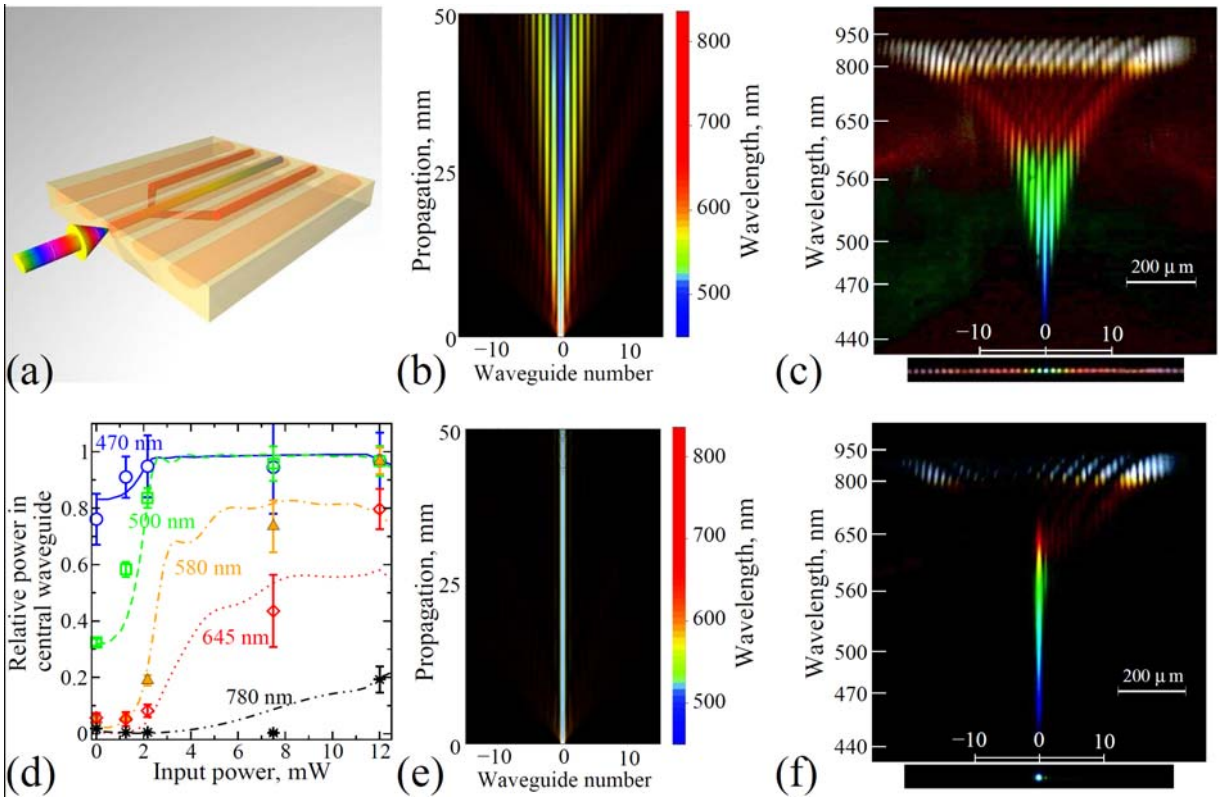

Figure: (a) Schematic of beam propagation inside the waveguide array sample. (b,c) Polychromatic diffraction at a low laser power (0.01 mW): (b) Numerical simulation of progressive color separation inside the array; (c) experimentally measured beam profiles at the output face of waveguide array: spectrally resolved (top) and real-color image (bottom).
(d) Measured (points) and calculated (lines) relative spectral power in the central waveguide as a function of the input power for five different spectral components. (e,f) Nonlinear localization of the supercontinuum inside the central waveguide at input power of 7.5mW: (e) numerical simulation of the beam propagation in the form of polychromatic gap soliton; (f) experimentally measured output profiles of the self-trapped beam.