Trapped Supercontinuum and Multi-Color Gap Solitons

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Supercontinuum generation is a fascinating example of extreme nonlinear processes in which many colors are created from a narrow-band source.[1] It differs significantly from the light emitted by incoherent light sources, combining high spatial coherence and spectral brightness, and finds applications in optical frequency metrology, spectroscopy and tomography. Approaches have been developed for manipulating the temporal and spectral characteristics of supercontinuum generated in photonic crystal fibers (PCFs),[1] which allow for the engineering of the spectral dispersion and confinement of light through the underlying periodicity of their structure.

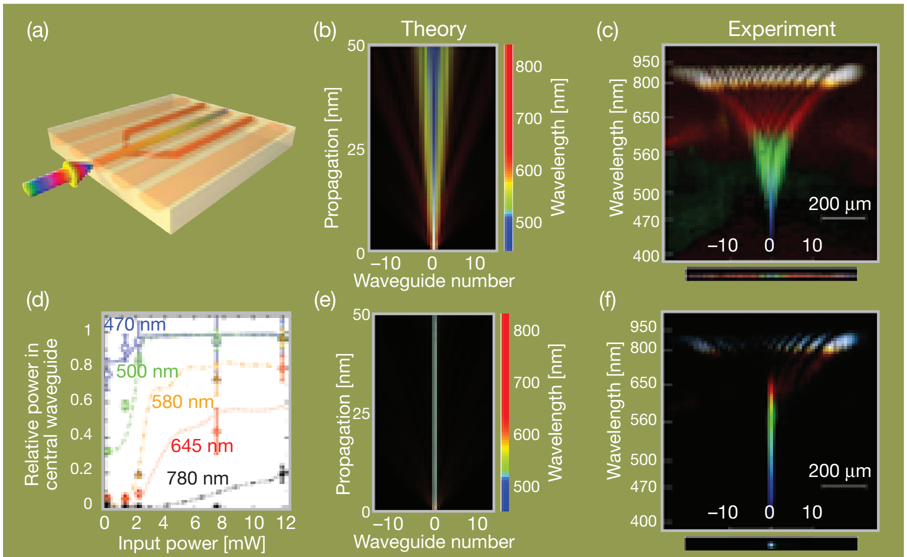
The ability to shape the supercontinuum light beams in the spatial domain is also desirable. Whereas various approaches for all-optical beam shaping have been developed for narrow-band light sources, we have demonstrated tunable control of supercontinuum beams in periodic photonic structures in the form of waveguide arrays. The arrays feature the refractive index modulation in the transverse spatial dimension [see (a)] with the characteristic period of several wavelengths, resembling the periodic cladding of PCFs.

In such structures, back-scattering is absent and transmission coefficients can approach unity simultaneously for all spectral components. In addition, 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 sharp spectral sensitivity in photonic crystals, where the refractive index is modulated in the propagation direction on wavelength scale.

Following the theoretical analysis,[2] we demonstrated 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.[3,4] At low laser powers, the supercontinuum light beam exhibits linear diffraction and the spectral components become progressively spatially separated along the propagation distance (b). At the output, red components dominate in the beam wings, while the blue components remain in the central region, as confirmed in experimental measurements (c).

As the laser power increases, the beam begins to localize, bringing more and more wavelength components into the central waveguide (d). This process is associated with the formation of polychromatic gap solitons,[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 remain delocalized (e,f).

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]



(a) 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) 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 input power for five spectral components. (e,f) Nonlinear localization of the supercontinuum inside the central waveguide at input power of 7.5 mW. (e) Numerical simulation of the beam propagation in the form of a polychromatic gap soliton. (f) Output profiles of the self-trapped beam.

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