A Helmholtz Model for Two-Colour Nonlinear Light Beams

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Abstract

The propagation of a light beam at a single optical frequency – or *colour* – in a Kerr-type planar waveguide is an elementary configuration in photonics [1,2]. Under two classic assumptions: (i) that the transverse extent of the beam is much greater than the carrier wavelength, and (ii) that the field envelope varies slowly on the wavelength-scale in the longitudinal direction, the governing equation turns out to be of the cubic nonlinear-Schrödinger (NLS) class. When diffraction (a beam's innate tendency to spread out) is exactly opposed by self-lensing (a light-medium feedback loop), spatial solitons can emerge as dominant electromagnetic modes of the system. These special types of optical beam propagate with a stationary intensity profile.

When two overlapping beams at distinct optical frequencies are present, the soliton formation process becomes more involved [3–5]. Diffraction is largely unaffected, but each beam now experiences a *net* induced waveguide – the channel written by itself into the host medium, *and* the superposed channel written by the second beam. In this configuration, and under the right conditions (e.g., when the constituent beams propagate in the same direction), two-colour spatial solitons can arise. These new mutually-trapped bound states comprise two components, each of which is associated with localized optical energy of a particular colour.

With few exceptions [6], theoretical analyses of two-colour solitons, and their potential technological applications, have been constrained by the slowly-varying envelope approximation (SVEA) [3,5]. To complement this, experiments have tended to be performed in regimes where one expects paraxial evolution to dominate [4,7]. By relaxing the SVEA, one instead arrives at a pair of coupled nonlinear-Helmholtz equations. This generalized model opens up more interesting physical regimes to explore. For instance, we are now in a position to investigate, for the first time, the oblique-propagation aspects of two-colour solitons. New families of exact analytical solitons will be presented, and their stability properties discussed in detail. This research further paves the way to the design of novel photonic device architectures exploiting multi-component optical beams in non-trivial angular geometries.

References

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