Spatial solitons and instabilities in two-colour Helmholtz light fields

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Abstract

Two-colour optical beams comprise a pair of light waves at two well-separated temporal frequencies, and which are coupled through system nonlinearity (e.g., the Kerr-type response in the host material of a planar waveguide) [1]. In addition to their fundamental theoretical interest, these types of two-colour configurations have huge potential for future photonic device applications (e.g., multi-channel waveguiding) [2]. However, analyses to date have largely been within the paraxial domain, with all its advantages and disadvantages.

Our research goes beyond the paraxial approximation, with two-colour light fields being governed by a pair of coupled nonlinear *Helmholtz* (as opposed to *Schrödinger*) equations [3]. This more general system involves a highly complex interplay between many distinct feedback loops, each of which is a combination of linear (two-dimensional diffraction) and nonlinear (self- and cross-focusing) processes. The interaction between the wave pair is strongest when they overlap in the propagation plane. The feedback loops may then reach an equilibrium point where they support stationary localized states (vector spatial solitons) when the constituent light-beam profiles have the correct transverse shape.

We will present, to the best of our knowledge, the first analysis of two-colour Helmholtz light fields. Modulational instabilities have been quantified by deploying linearization techniques [4], and our generalized approach [5] has uncovered new qualitative behaviour. Four families of exact analytical vector soliton have been derived, each of which has co- and counter-propagation classes (related by geometrical transformation). Numerical computations, alongside mathematical analyses, have investigated the robustness of the new Helmholtz solutions (see Fig. 1).

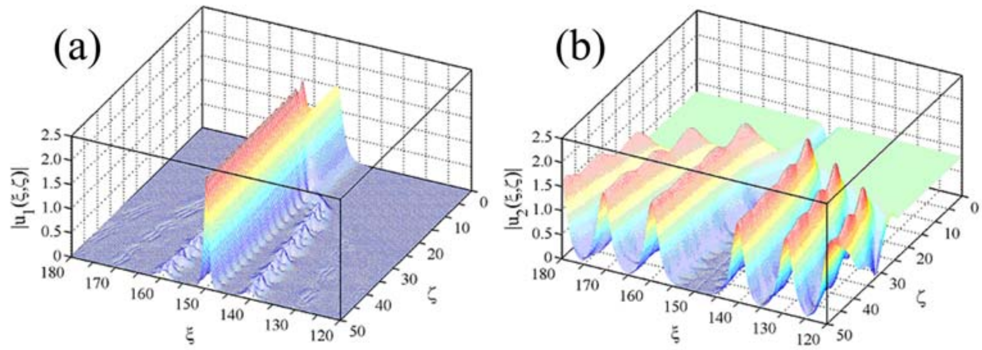

Figure 1. Modulational instability of the bright-dark Helmholtz soliton family [bright component in (a), dark component in (b)] in a focusing Kerr medium. Instability develops initially on the plane-wave background of the dark component, leading to filamentation. Nonlinearity provides a mechanism whereby this instability subsequently feeds through the system to destabilize the bright component.

References

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