Exact stable vortex modes in two-dimensional Bose-Einstein condensates and in nonlinear optics

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Abstract:

We construct exact solutions for solitary vortices in 2D models of Bose-Einstein condensates and spatial-domain propagation in optics, with a spatially modulated nonlinearity of either sign and a harmonic trapping potential. In the context of Bose-Einstein condensates, the BEC dynamics at ultra-low temperatures is accurately described by the Gross-Pitaevskii equation (GPE), the cubic nonlinearity being determined by the s-wave scattering length of interatomic collisions, which can be controlled by means of the magnetic [1] or low-loss optical [2] Feshbach-resonance technique, making spatiotemporal management of the local nonlinearity possible through the use of time-dependent and/or non-uniform fields. A counterpart of the GPE, which is a basic model in nonlinear optics, is the nonlinear Schrödinger equation. In the latter case, the modulation of the local nonlinearity can be implemented too–in particular, by means of indiffusion of a dopant resonantly interacting with the light. We found that the number of vortex-soliton modes is determined by the discrete energy spectrum of a related linear Schrödinger equation. The vortex-soliton families in the system with the attractive and repulsive nonlinearity are mutually complementary. *Stable* vortex-solitons with vorticity $S \geq 2$ and those corresponding to higher-order radial states are reported for the first time, in the case of the attraction and repulsion, respectively.

References:

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