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Two-dimensional localized states in competing cubic-quintic nonlinear lattices

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Solitons are nonlinear solitary waves that can maintain their shape, amplitude and velocity during propagation and are robust wave structures under the balance between linear (dispersion) and nonlinear effects in various nonlinear systems. Till date, a great number of literatures, both theoretical (also numerical) and experimental works, have shown that the existence of soliton phenomena in diverse physical systems such as fiber optics, magnet, and biology (proteins and DNA). With the appearance and development of laser-cooling technology, the Bose-Einstein condensate (BEC) which is a new state of matter that was predicted as early as 1924 was finally realized in 1995 which, in a way, is one of the triumphs of modern atomic and condensed-matter physics. Such matter also provides a useful testbed for exploring new physical phenomena and the related new theory. Because of its inherent nonlinear effect, the BEC, if prepared properly, is an ideal setting for soliton research. Particularly in gross-Pitaevskii equation, the governing equation that describes the dynamics of BEC, in one-dimensional case, permits both bright and dark soliton solutions. There should be not exact or approximate solutions, however, in the relevant two- and three-dimensional (2D and 3D) coordinates because of the intrinsic critical collapse. To resolve this, it is necessary to dig out new method. Periodic potential such as photonic crystal and semiconductor crystals is a powerful tool to stabilize waves. In BEC, optical lattice, the artificial crystal of light, can be made easily and used to generate various soliton structures, both ordinary and gap solitons. Besides, the periodic potentials have been extended to nonlinear scenario, the nonlinear lattices in the past decade. This study aims to stabilize 2D solitons in BEC by merely introducing the nonlinear lattices in both the cubic- and quintic nonlinearities. This makes a competing cubic-quintic nonlinear lattice with focusing Kerr and defocusing quintic terms. We find that such model can support two types of localized states, fundamental and vortical solitons, and the stability of both types is checked in a numerical way.

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