Nonlinear Sciences > Pattern Formation and Solitons

Two-dimensional discrete solitons in dipolar Bose-Einstein condensates

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We analyze the formation and dynamics of bright unstaggered solitons in the disk-shaped dipolar Bose-Einstein condensate, which features the interplay of contact (collisional) and long-range dipole-dipole (DD) interactions between atoms. The condensate is assumed to be trapped in a strong optical-lattice potential in the disk's plane, hence it may be approximated by a two-dimensional (2D) discrete model, which includes the on-site nonlinearity and cubic long-range (DD) interactions between sites of the lattice. We consider two such models, that differ by the form of the on-site nonlinearity, represented by the usual cubic term, or more accurate nonpolynomial one, derived from the underlying 3D Gross-Pitaevskii equation. Similar results are obtained for both models. The analysis is focused on effects of the DD interaction on fundamental localized modes in the lattice (2D discrete solitons). The repulsive isotropic DD nonlinearity extends the existence and stability regions of the fundamental solitons. New families of on-site, inter-site and hybrid solitons, built on top of a finite background, are found as a result of the interplay of the isotropic repulsive DD interaction and attractive contact nonlinearity. By themselves, these solutions are unstable, but they evolve into robust breathers which exist on an oscillating background. In the presence of the repulsive contact interactions, fundamental localized modes exist if the DD interaction (attractive isotropic or anisotropic) is strong enough. They are stable in narrow regions close to the anticontinuum limit, while unstable solitons evolve into breathers. In the latter case, the presence of the background is immaterial.

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