Discrete solitons and vortices in dipolar Bose-Einstein condensates

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Abstract:

The problems of existence, stability and dynamics of discrete localized modes in dipolar Bose-Einstein condensates (BEC) confined in the cigar-shaped and disk-shaped traps in the presence of the one-dimensional (1D) and two-dimensional (2D) optical lattices, respectively, are presented. Assuming the very deep optical lattices, the dipolar BECs are modelled by two difference-differential equations of the corresponding dimensionality, both derived from the underlying 3D Gross-Pitaevskii equations developing the corresponding dimension reduction and dicretization procedures [1-4]. These are the discrete Schrdinger equations with local cubic and nonpolinomial nonlinearities, and with an additional nonlocal term accounting for the dipole-dipole (DD) interactions. The existence and stability of fundamental unstaggered solitons in 1D and 2D BECs and vortices of the topological charge 1 and 2 in dipolar BECs are studied for attractive and repulsive signs of both the local and nonlocal interactions. In 1D BEC with both cubic and nonpolinomial nonlinearity, the DD forces strongly affect the shape and stability of on-site and inter-site discrete solitons. In the second case the collapse threshold is effected by the nonlocal DD interactions. The corresponding existence and stability regions in the parametric space are summarized in the form of diagrams, which feature a multiple stability exchange between the on-site and intersite soliton families. The study is extended to the 2D BEC [3]. The analysis is focused on the influence of the DD interactions on fundamental localized modes (2D discrete solitons). The repulsive isotropic DD interaction 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. These solutions are unstable, evolving into robust breathers which exist on an oscillating background. In the presence of the repulsive contact interaction, fundamental localized modes exist if the DD interaction (attractive isotropic or anisotropic) is strong enough. They are stable in the narrow regions close to the anticontinuum limit, while unstable solitons evolve into breathers. Finaly, within the framework of the 2D BEC model with cubic nonlinearity, the analisys of the existence, stability and dynamics of discrete vortices with topological charge S = 1 and S = 2 is presented [4]. Various species of discrete vortices, which are known in the model of the condensate with local interactions only, are found to exist in the presence of the DD interaction too. In locally self-attractive condensates, the isotropic DD repulsion, which corresponds to the orientation of atomic dipoles perpendicular to the confinement plane, extends the region of the vortex stability, while in the case of anisotropic DD interactions, corresponding to the in-plane orientation of the dipoles, vortices are unstable. In the former case, those vortices which are unstable may evolve into robust ring-shaped breathers. The attractive isotropic DD interaction can create localized vortices in the condensate with the local self-repulsion, but they all are unstable, evolving into

single-peak asymmetric structures.

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