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Vortex solitons in Bose-Einstein condensates with inhomogeneous attractive nonlinearities and a trapping potential

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Abstract

We demonstrate three-dimensional (3D) vortex solitary waves in the (3+1)D nonlinear Gross-Pitaevskii equation (GPE) with spatially modulated nonlinearity and a trapping potential. The analysis is carried out in spherical coordinates, providing for novel localized solutions, and the 3D solitary waves are built that depend on three quantum numbers. Our analytical findings are corroborated by a direct numerical integration of the original equations. It is demonstrated that the vortex solitons found are stable for the quantum numbers $n \leq 2$, $l \leq 2$ and $m = 0, 1$, independent of the propagation distance.

Keywords: Nonlinear optics; Spatial solitons; Transverse effects.

1. Introduction

There has been an intense research interest over the past twenty years in the physics of Bose-Einstein condensates (BECs)[1]. In the mean-field approximation, BEC dynamics at ultra-low temperatures is accurately described by the GPE. Distressingly, the GPE with the self-focusing cubic nonlinearity, describing evolution of the mean-field wave function in a BEC with attraction between atoms, gives rise to the wave collapse in two- and three-dimensional (2D and 3D) geometries, which makes the respective multidimensional solitons (MSs) unstable [3]. It has been established that, nevertheless, MSs can be stabilized by different means, such as optical lattices[4], spin-orbit in-

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