Exploring Ground States and Excited States of Spin-1 Bose-Einstein Condensates by Continuation Methods

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Abstract

A pseudo-arclength continuation method (PACM) is proposed and employed to compute the ground state and excited state solutions of spin-1 Bose-Einstein condensates (BEC). A pseudo-arclength continuation method (PACM) is employed to compute the ground state and excited state solutions of spin-1 Bose-Einstein condensates (BEC). The BEC is governed by the time-independent coupled Gross-Pitaevskii equations (GPE) under the conservations of the mass and magnetization. The coupling constants that characterize the spin-independent and spin-exchange interactions are chosen as the continuation parameters. The continuation curve starts from a state obtained from a ground state or an excited state that has very small coupling parameters. The proposed numerical schemes allow us to investigate the effect of the coupling constants and study the bifurcation diagrams of the time-independent coupled GPE. Numerical results on the wave functions and their corresponding energies of spin-1 BEC with repulsive/attractive and ferromagnetic/antiferromagnetic interactions are presented. Furthermore, we reveal that the component separation and population transfer between the different hyperfine states can only occur in excited states due to the spin-exchange interactions.