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Numerical techniques for Rotating Two-Component Bose–Einstein Condensation

Chassib A-H.Emshary[1] Shaker I.Easa[1] and Arafat J.Jalil[2]
[1]Physics Dept., College of Education,
[2]Physics Dept., College of Science, Basrah University, Basrah, Iraq.

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Abstract

In the previous work, the dynamics of rotating one-component BEC was studied by introducing new (MTSP), (MHP), (MLP) and (MLHP) methods, where we applied them to one, two and three dimensional rotating GPE, respectively. Here, the investigation on single-component BEC is extended to two-component and applying these methods to another driven equations related to two component rotations. So, we propose new methods to solve the time-dependent coupled GPEs with a coupling term which describes the dynamics of rotating two-component BEC. The aim of this paper is to present an unconditionally stable numerical, MHP, MLP and MHLP methods with high-order accuracy for computing the dynamics of rotating two-component BEC. In addition, the numerical method is applied to verify the dynamic laws and to study the dynamics of quantized vortex lattices in rotating two-component BEC.

1. Introduction

In a previous work [1], we applied a new Modified fourth-order time-splitting pseudospectral (MTSP), Modified Hermite pseudospectral (MHP), Modified Laguerre pseudospectral (MLP) and Modified Laguerre-Hermite pseudospectral (MLHP) methods to study the dynamics of rotating one-component BEC, where we used these methods for one, two and three dimensional rotating GPE, respectively. In this paper, the investigation on single-component BEC is extended to two-component one and applying these methods after driving other equations related to two component rotation is studied. So, we propose new methods to solve the time-dependent coupled GPEs with a coupling term which describes the dynamics of rotating two-component BEC. Starting from the three-dimensional (3D) coupled Gross-Pitaevskii equations (CGPEs) with an angular momentum rotation term and an external driven field, are rescaled to obtain a dimensionless model, and further reduce them to the single GPE in certain limiting regime of particle numbers. The target is to compute the ground state solution of rotating two-component BEC. Theoretical models for the time-independent coupled GPEs with an angular momentum rotational term, is proposed to describe the equilibrium structure of rotating two-component BEC [2-5]. There are many solutions to the time-independent coupled GPEs, among which the ground state, symmetric state and central vortex state are perhaps of most interest. For the numerical works on time-independent coupled GPEs with the angular momentum rotational term, Garcí'a-Ripoll et al.[4] searched the ground state for rotating two-component BEC in the JILA experimental setup but focused on Josephson coupling effects. Mueller et al. [2] studied theoretically the rotating two-component BEC by assuming that the wave functions were an expansion of the Landau functions. They also found a rich vortex phase diagram. Kasamatsu et. al [3] work on finding ground state for BEC with equal intra-component and inter-component interactions. By changing the ratio between intra-component and inter-component coupling constants they revealed a rich vortex phase diagram for the ground state solution, but no numerical results were reported for the nonequal intra-component interactions. It was pointed out that when each component has different particle number or nonequal intra-component interaction, the ground state might have a different vortex phase diagram, which is not yet verified. Since the experimental observation of quantized vortices in alkali atomic BEC [6-10], there has been a growing interest in studying the dynamics related to quantized vortices in rotating two-component BEC. Under the mean field approximation, the time-dependent coupled GPEs with a coupling term have