Physics Letters A ••• (••••) ••••••

Contents lists available at ScienceDirect

Physics Letters A

www.elsevier.com/locate/pla

Controlled self-similar matter waves in PT-symmetric waveguide

Shailza Pathania [a], Harneet Kaur [a,b], Amit Goyal [c,*], C.N. Kumar [a]

[a] Department of Physics, Panjab University Chandigarh 160014, India
[b] Department of Physics, Government College for Women, Karnal 132001, India
[c] Department of Physics, GGDSD College, Chandigarh 160030, India

ARTICLE INFO

Article history:
Received 2 April 2020
Received in revised form 11 May 2020
Accepted 13 May 2020
Available online xxxx
Communicated by B. Malomed

Keywords:
Matter waves
Self-similar solutions
PT-symmetry
Gross-Pitaevskii equation

ABSTRACT

We study the dynamics of Bose-Einstein condensate coupled to a waveguide with parity-time symmetric potential in the presence of quadratic-cubic nonlinearity modelled by Gross-Pitaevskii equation with external source. We employ the self-similar technique to obtain matter wave solutions, such as bright, kink-type, rational dark and Lorentzian-type self-similar waves for this model. The dynamical behavior of self-similar matter waves can be controlled through variation of trapping potential, external source and nature of nonlinearities present in the system.

1. Introduction

Bose-Einstein condensate (BEC) is a macroscopic quantum state of matter in which all atoms in the bosonic gas condenses into a single ground state of the system [1,2]. The coherent matter-wave formed via this population of atoms is depicted by a macroscopic wave function which is also a solution of nonlinear Schrödinger equation (NLSE). The mean-field equation used to describe the dynamics of BEC is the Gross-Pitaevskii (GP) equation or NLSE with a trapping potential [3]. Basically, the GP equation is a three-dimensional equation which can be reduced to a one- or two-dimensional equation by confining the condensate to two or one directions in an effective potential [4,5]. In BECs, the formation of soliton solutions is resultant of the interactions among atoms and the geometry of the trap used to confine the BEC. Here, nonlinearity arises due to interatomic interactions of the condensate measured by the scattering length 'a'. In BEC, Feshbach resonance gives a way to control the strength of how atoms interact with each other [6]. Experimental work has been done to show the existence of bright solitons for attractive interactions ($a < 0$) [7] and dark solitons for repulsive interactions ($a > 0$) [8]. Authors have also studied the dynamics of BEC in the presence of competing cubic-quintic nonlinearity [9–15] and quadratic-cubic nonlinearity [16–20]. Over the past several years, there is a considerable interest on the existence of matter wave solutions for GP equation with time-dependent coefficients or generalized nonlinear Schrödinger equation (GNLSE) [21–25]. Earlier, Paul and his collaborators [26–28] numerically studied the resonant transport of interacting BEC through a symmetric double barrier potential in a waveguide for the modified GP equation. Coupling of the waveguide to a reservoir of condensate from which matter waves are injected into the guide is modelled by source term. Later, Yan et al. [29] studied the nonautonomous matter waves in a waveguide for the modified GP equation driven by a source term. Recently, R. Pal et al. [20] obtained the matter wave self-similar solutions for the driven nonautonomous GP equation with quadratic-cubic nonlinearity. Apart from it, the GNLSE with external source has also been studied to obtain self-similar solution in the context of fiber optics [30–32].

In this work, we have studied the dynamics of BEC coupled to a waveguide with parity-time (PT) symmetric potential modelled by GP equation with inhomogeneous source, $S(t)e^{i\theta(x,t)}$ where $S(t)$ and $\theta(x,t)$ are amplitude and phase terms [27,29]. The source term simulates the coherent injection of matter waves from an external reservoir to the waveguide. In recent years, a significant work has been done on the evolution of soliton [33–36] and self-similar solutions [37–39] for the GNLSE with PT-symmetric potential. According to quantum mechanics, Hamiltonian of a system should be Hermitian since the eigenvalues corresponding to Hermitian operators are always real. In 1998, Carl Bender and S. Boettecher [40] proposed that even non-Hermitian Hamiltonians exhibit real spectra provided Hamiltonians respect PT-symmetry. The necessary but not sufficient condition for Hamiltonian to be PT-symmetric is that

* Corresponding author.
E-mail addresses: amit.goyal@ggdsd.ac.in (A. Goyal), cnkumar@pu.ac.in (C.N. Kumar).

https://doi.org/10.1016/j.physleta.2020.126574
0375-9601/

Hans