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Interaction of Airy–Gaussian beams in Kerr media

Yulian Peng [a], Xi Peng [a], Bo Chen [a], Meiling Zhou [a], Chidao Chen [a], Dongmei Deng [a,b,*]

[a] Guangdong Provincial Key Laboratory of Nanophotonic Functional Materials and Devices, South China Normal University, Guangzhou 510631, China
[b] CAS Key Laboratory of Geospace Environment, University of Science & Technology of China, Chinese Academy of Sciences, Hefei 230026, China

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ABSTRACT

We study the interaction of the Airy–Gaussian (AiG) beams by using the numerical simulations with the split-step Fourier method. The results show that the single breathers and breather pairs can be formed in the condition with interaction. The breathers can be formed with the enough intensity of interactive beams. By adjusting the parameters of amplitude, interval, phase and χ_0, we find that the interaction of the two beams is the strongest with in-phase and out-of-phase cases, especially in the shorter distance. Moreover, both the interaction intensity and the location, the interaction happens, can be changed by adjusting the distribution factor χ_0 of the beams. It is notable that the various propagation directions of the beams can be obtained by changing the phase, at the same situation, when the interval of the two beams becomes narrower, the phase plays an important role of controlling the direction of the accelerated spot.

1. Introduction

Self-accelerating optical beams have become one of the most attractive researches in recent years. Airy beams as the self-accelerating [1–8], nondiffracting, and self-healing [9,10] beams have received widely attention in the past few years. This intriguing kind of wave packet, predicted initially by Berry and Balazs in 1979, has been realized by Christodoulides et al. theoretically and experimentally in 2007 [1,11]. After that, the researches about the self-accelerating beams propagating in the linear and nonlinear (NL) media [12] have continued to emerge.

For example, A.Lotti et al. have demonstrated the existence of an additional class of stationary accelerating Airy wave forms that exist in the presence of third order (Kerr) nonlinearity and nonlinear losses in 2011 [13]. Zhang et al. have investigated numerically the interactions between in-phase and out-of-phase Airy beams and nonlinear accelerating beams in Kerr and saturable nonlinear (NL) media of one transverse dimension and have found that bound and unbound soliton pairs, as well as single solitons, can form in such interactions in 2013 and 2014 [14,15].

As the Airy–Gaussian (AiG) beam carries finite power, retains the nondiffracting propagation properties within a finite propagation distance, and can be realized experimentally, Bandres et al. have studied the AiG beams to analyze in detail and realize numerically the Airy beams phenomenon [16]. D.M. Deng and H.G. Li have studied the propagation of the AiG beam in strongly nonlocal medium analytically and numerically [17]. They have found that the momentum of the analytical AiG beam solution of the Snyder–Mitchell model is not conservational and obtained the quasi-Airy–Gaussian soliton in the Gaussian-shaped response material. Chen et al. have exhibited the propagation of AiG beam in Kerr Medium [18]. Their study has showed that the self-acceleration effect of the AiG beam becomes weaker when the distribution factor increases and as the initial input power increases, they observe the quasi-breather finally. Chen et al. have investigated the propagation of Airy–Gaussian–vortex (AiGV) beams through slabs of right-handed materials and left-handed materials [19]. Their researches have showed that the optical vortex can destroy the center lobe of the AiGV beams, and the center lobe can reconstruct due to the fact that the acceleration of the vortex and the AiGV beam is not consistent.

However, there is few paper investigating the interaction of two AiG beams. In this letter, we demonstrate the interaction of the two AiG beams in Kerr medium with various parameters without loss of generality. This paper is organized as follows. After introducing the nonlinear Schrodinger equation, we study the basic characteristics of the beams transmitting in the Kerr medium and give the expression of two AiG beams in Section 2. We simulate the propagation of the AiG beams in the Kerr medium with the different parameters by using the split-step Fourier method in Section 3. Finally we summarize the characteristics of the

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* Corresponding author at: Guangdong Provincial Key Laboratory of Nanophotonic Functional Materials and Devices, South China Normal University, Guangzhou 510631, China.
E-mail address: dmdeng@263.net (D. Deng).

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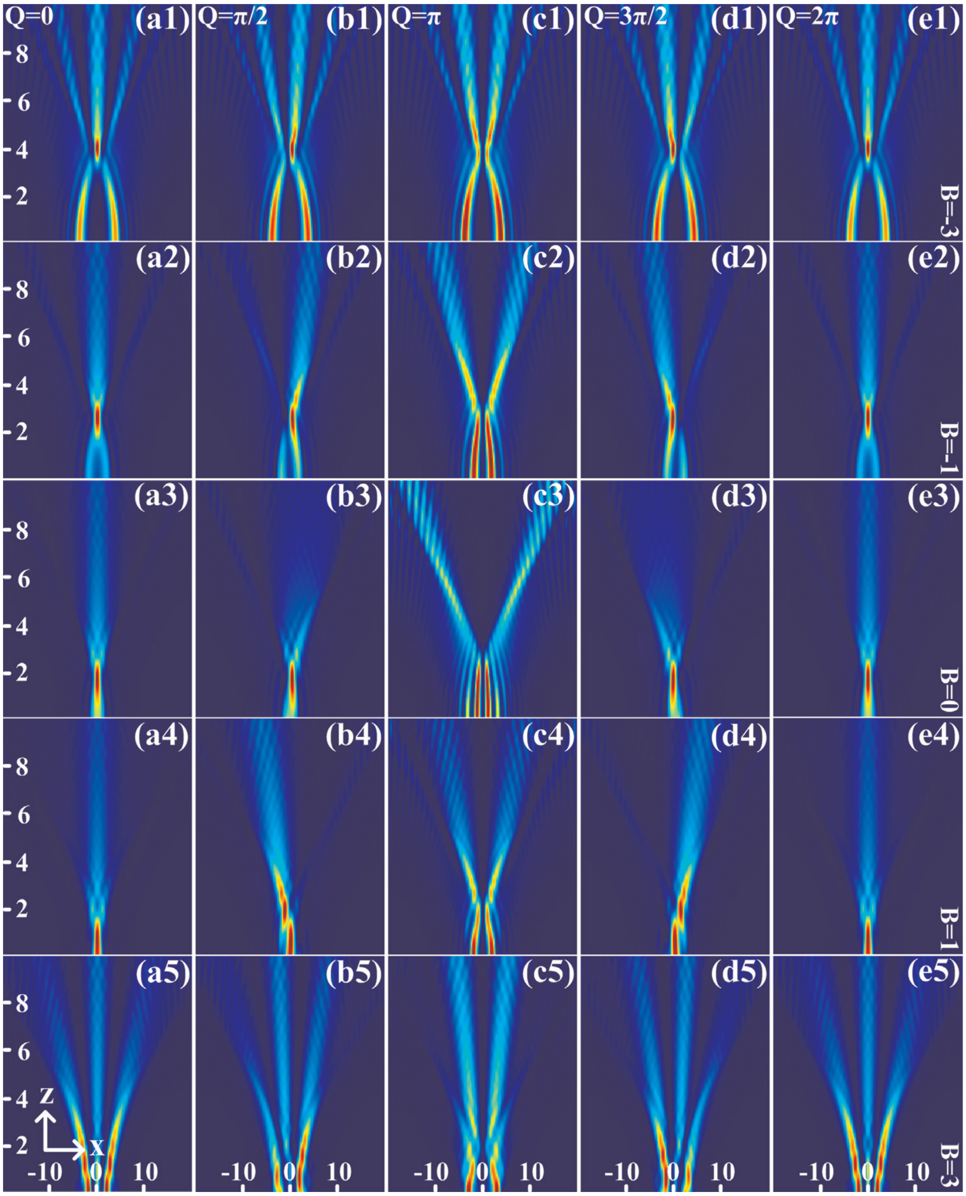

Fig. 1. The interaction of two AiG beams with changing the values of B and Q for $A_1 = A_2 = 1$ and $\chi_0 = 0.01$.

interaction between two AiG beams in Section 4.

2. Basic theory

For the (1+1)D model, the general form of the nonlinear Schrodinger equation can be expressed as [20]:

$$i\frac{\partial \Psi}{\partial z} + \frac{1}{2}\frac{\partial^2 \Psi}{\partial x^2} + \delta n \Psi = 0 \tag{1}$$

where Ψ represents the slowly varying envelope, δn stands for the nonlinear change in the index of refraction and the Kerr case can be expressed as $\delta n = |\psi|^2$, z and x are the propagation distance and the dimensionless transverse coordinate, respectively. Eq. (1) describes a model of a space beam propagating in the slab waveguide which is constituted by local Kerr nonlinear medium. In Kerr medium, the beams are self-focusing when the nonlinear refractive index is greater than zero and self-defocusing when the nonlinear refractive index is smaller than zero. In the (1+1)D structure, the phenomenon of beams focusing is discovered when the nonlinear effect is stronger than the diffraction effect. As the diffraction effect increases much faster than the nonlinear effect, the beam can diverge again. On the other hand, as the diffractive effect decreases much faster than the nonlinear effect, the beam can focus eventually. Consequently, the spatial solitons can be steadily transmitting in the (1+1)D local Kerr medium when the nonlinear effect balances the diffraction effect. Generally speaking, for an AiG beam, the initial field distribution is [18]:

$$\Psi(x) = AA_i\left(\pm\frac{x \mp B}{\chi_0 w}\right)\exp\left[\pm\frac{a(x \mp B)}{\chi_0 w}\right]\exp\left[-\frac{(x \mp B)^2}{w^2}\right] \tag{2}$$

where A represents the amplitude factor of the beam, B is the interval factor between the two beams, w stands for the width of the beam, a is an arbitrary positive real decay constant, χ_0 is a tunable parameter, which can be used to adjust the intensity distribution of the AiG beam. When χ_0 tends to be zero, the distribution of $\Psi(x)$ is close to the Airy distribution. While χ_0 tends to