비균일 위상 형태를 갖는 광보텍스의 진행 특성

Propagation Dynamics of Optical Vortices with Anisotropic Phase Profiles

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Controllable waveguide of optical vortex solitons is possible by using the rotational characteristics of optical vortices, while the relative phase difference across the soliton profiles can be used to steer the waveguide direction in case of two-dimensional dark solitons. It is important to understand in detail what sources contribute to the rotation of optical vortices to apply optical vortex solitons to the optical switchyard. Most of previous studies were focused on optical vortices with constant phase gradient along a circular path around the vortex axis. Since an optical vortex propagates in a direction perpendicular to the wavefront at its position with the phase function of this optical vortex subtracted, we think that the propagation dynamics of optical vortices is influenced by the phase function itself. In other words, we expect that an optical vortex experiences a large rotation when the wavefront by other optical vortices is deformed to have a steep slope at the vortex position. Such a non-uniform phase gradient can be considered by introducing the anisotropy that is one of the morphological parameters determining the internal structure of the vortex. We studied analytically the rotation rate of a pair of anisotropic optical vortices with the same charge and investigated numerically the effect of anisotropic phase profiles on the propagation dynamics of optical vortices with localized core function in the linear and nonlinear regimes.

Nonlinear propagation of a beam in an optical Kerr medium is described mathematically by (1+2)-dimensional nonlinear Schrödinger equation normalized by

$$i\frac{\partial A}{\partial Z}=\left(\frac{\partial^2}{\partial X^2}+\frac{\partial^2}{\partial Y^2}\right)A-2|A|A.$$

For numerical calculations, an initial field envelop of a beam containing a pair of anisotropic optical vortices with the separation distance of d may be expressed as

$$A(X,Y,Z=0)=\exp(-R^2/w_o^2)\tanh(R_1/w_v)\tanh(R_2/w_v)\exp[i(\Phi_1+\Phi_2)]$$

where R_j = $[(X\pm d/2)^2+Y^2]^{1/2}$ is the radial distance from the j-th vortex center, and $\Phi_j(X, Y)$ =

$\tan^{-1}(\sigma y_j/x_j)$ is the anisotropic phase function, σ is the anisotropy factor that is related with the deformation of phase profiles.

Analytical expression of the rotation rate of anisotropoic optical vortixes, including the contribution of the intensity gradient by other tanh-vortex and backgound beam, is given by

$$\frac{d\Phi}{dz}\Big|_{z=0} = -\frac{2}{k}\left[\frac{\sigma}{d^2} + \frac{1}{w_0^2} - \frac{2\cosh(2d/w_v)}{dw_v}\right].$$

We found analytically that the rotation rate is proportional to the anisotropy. Numerical results showed that the initial rotation is in good agreement with that from analytical approach. Modification of the field distribution changes the rotate rate, and even the rotational direction, during the propagation in the linear regime. However, in the nonlinear regime, the propagation dynamics is much different from our expectation, that large difference of the rotation angle was not observed.

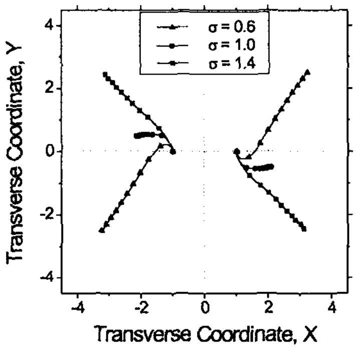

Fig. 1 Projection of vortex trajectories in the linear regime.

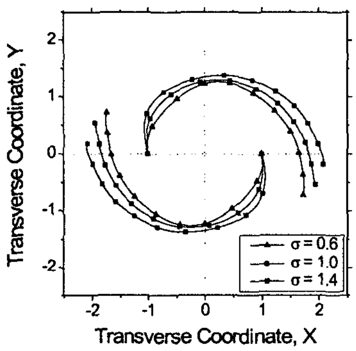

Fig. 2 Projection of vortex trajectories in the nonlinear regime

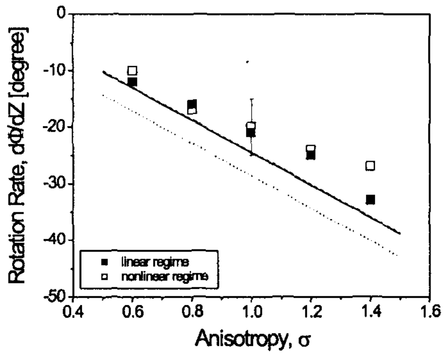

Fig. 3 Initial Rotation rate as a function of the anisotropy value

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