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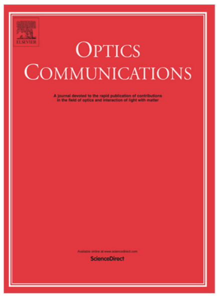

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Study of the nonparaxial propagation of asymmetric Bessel-Gauss beams by using Virtual Source method

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ABSTRACT

The virtual source method, which is also known as the complex source point method, was used to study the nonparaxial propagation of asymmetric Bessel-Gauss (aBG) beams. According to optical independence transmission and superposition principles of beam propagation, an aBG beam was expanded into superposition of the infinite Bessel-Gauss beams. Superposition of infinite virtual source points of the expanded aBG beams was used to correspond to electric rings generating an aBG beam. Then Fourier-Bessel transform theory was used to derive the nonparaxial integral expression of aBG beams. Finally, the analytic expression of axial optical field amplitude of an aBG beams was derived when they are kept to third-order nonparaxial correction term.

Keywords: Asymmetric Bessel-Gauss beams; virtual sources; Helmholtz equation

1. Introduction

Since theoretically introducing Bessel beams [1], nondiffracting beams have been a hotspot research subject in the past 30 years due to their propagation-invariant characteristics. However, although being important theoretical model, the ideal nondiffracting beams cannot be actually generated because they are characterized as carrying infinite energy and having infinite extent. Hence, the quasi-diffraction-free beams which can be actually generated are indeed a valuable research subject. However, because of the complexity of mathematics, it is very difficult to accurately and analytically give propagating expression of quasi-diffraction-free beams, especially the expression of near-field propagation or nonparaxial propagation.

The problem of beam propagation is essentially an optical diffraction problem. Diffraction problem is one of the most difficult problems encountered in the optical field. In the classic writings "Principles Of Optics, 7ed" [2], M. Born and E. Wolf ever pointed out that 'Diffraction problems are amongst the most difficult ones encountered in optical solutions, which, in some sense, can be regarded as rigorous are very rare in diffraction theory', and 'Since then rigorous solutions of a small number of optical diffraction problems have been found, but because of mathematical difficulties, approximate methods must be used in the cases of practical interest'. Based on diffraction theory, a strict solution about beam propagation or optical diffraction in some sense rarely exists, especially in the case of complex nonparaxial propagation of optical fields.

In the past, in order to analytically study propagation characteristics of quasi-diffraction-free beams, several kinds of analytic expressions of important quasi-diffraction-free beams propagation have been obtained by establishing virtual source point (or called as complex source point) [3-17], such as Laguerre-Gauss beams [12], Bessel–Gauss beams [13,15], Hermite–Gauss beams [16], cosh-Gaussian beams [17], et al.

Since ideal Bessel beams cannot be actually generated, as one of important members of quasi-diffraction-free beam family, generation of Bessel-Gauss beams with quasi-diffraction-free propagation is of great practical significance [18]. At present Bessel-Gauss beams have been extensively applied to laser drilling [19], capturing and manipulation of microscopic particles [20], medical imaging [21] and other research fields. Bessel-Gauss beams are of enormous application value in practice, facilitating accurately studies on their propagation characteristics [6-7, 13, 15]. The structure of classical Bessel beams is centrosymmetric. In 2014, Kotlyar