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Focal shift of radial varying polarized Bessel-Gauss beam with radial phase modulation

Bei Wu[a], Xiangyu Zeng[a], Yu Miao[a], Yongtao Fan[b], Xiumin Gao[a,*], Songlin Zhuang[a]

[a] University of shanghai for Science and Technology, Shanghai 200093, China
[b] Shanghai Institute of Optics and Fine Mechanics, Shanghai 201800, China

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ABSTRACT

Focusing shift of Bessel-Gauss (BG) beam with radial varying polarization is investigated by vector diffraction theory in this article. The radial phase modulation is given by a function of radial direction angle θ and m. It was found that the focal shift only can be altered considerably by the phase modulation parameter m, and the focus region intensity shape is variable with the change of the others parameters except m, turning into different shapes such as multiple intensity rings, dark hollow focus without the focus shift. There is an interesting phenomenon that the focus shifts along with the horizontal axis when the phase modulation parameter m is changing, and the shifts distance is linearity to the variation of the phase modulation parameter m.

1. Introduction

It is known that Bessel-Gauss (BG) beams provide valid solutions to Helmholtz equation, having attracted many researchers to study it's properties [1–7] for their non-diffracting characteritics, and BG beams represent a class of solutions to the Helmholtz equationhave been researched extensively, especially which had been modulated by some kinds of polarization parameters or beam parameters [8].

The distribution in focal region plays a crucial role in many optical systems [9–14]. Such as, in optical trapping system, the particle would be forced by two kinds of forces, one is the optical gradient force, the other kind of force is scattering force.Two kinds of forces both have complex forms, because the two forces are not only related to the optical intensity, but also the properties of the trapped particles [15]. According to this phenomenon, a particle may be transported from one poit to another point by controlling the optical intensity distribution in focal region, which had been known as optical trap [8].

In addition to this, the focusing properties of BG beams had been widely investigated,especially the focusing shift of various laser beams have been an interesting and practical topic, and many researchers had been tracing the movement of the point of absolute maximum intensity along optical axis for several decades [16–20]. Gao, Li, Dong et. al [21–28] have done so much going and painstaking studying on the focus shifts properties, such as the focal shift of radially polarized Bessel-modulated Gaussian beam by phase shifting. Li.etal have studied the focal shift by radial cosine phase masks.Further more, the focal shift with rotational tunable phase also be researched. In addition to theses, the focus shifting with three-portion concentric piecewise cylindrical vector beam, and with apodized truncated hyperbolic-cosine-Gaussian beam figured out

* Corresponding author.
E-mail address: gxm@usst.edu.cn (X. Gao).

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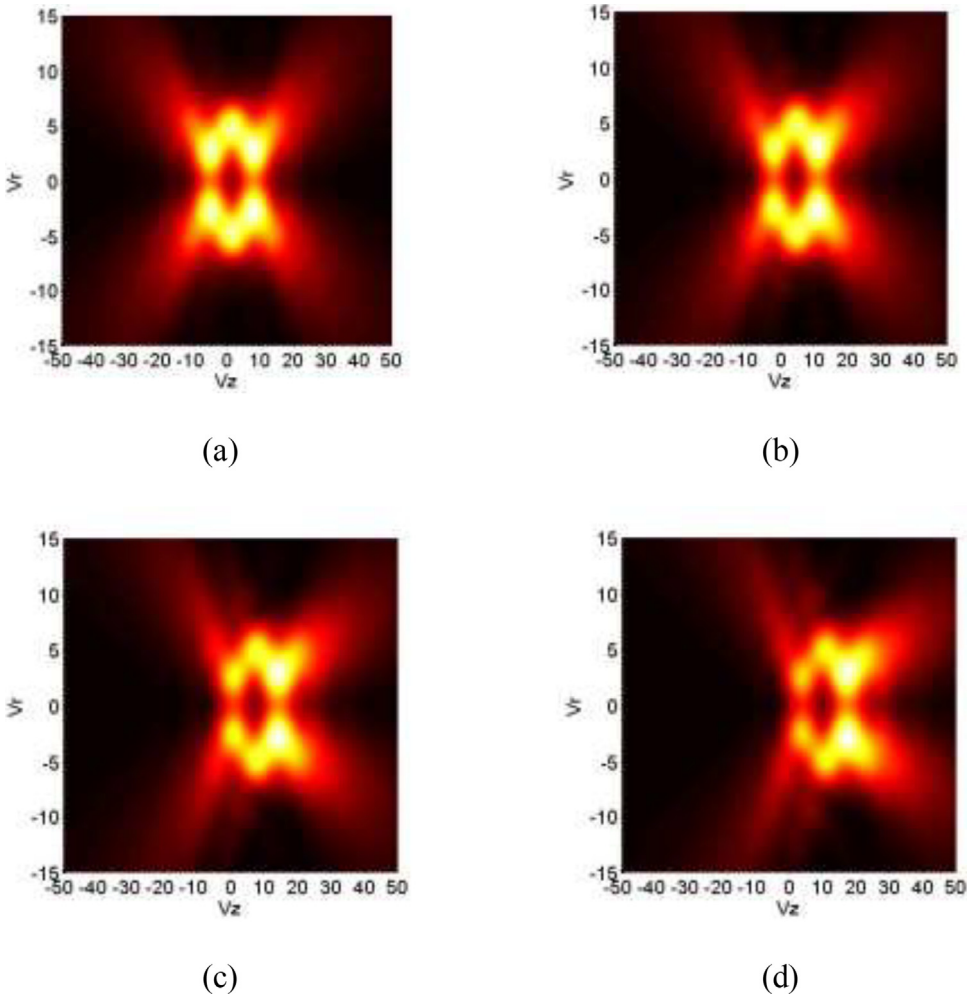

Fig. 1. Intensity distributions in focal region for $NA = 0.95$, $\beta_2 = 1$, $\beta_1 = 2.5$, $C = 0.4$and (a) $m = 1$, (b) $m = 3$ (c) $m = 5$, (d) $m = 7$, respectively.

some interesting phenomenoa of focal shift. Above these researches, the focal shift of cylindrical vector axisymmetric Bessel-modulated Gaussian beam with radial variance phase wavefront, and the focal shift in radially polarized hollow Gaussian beam also been studied.Sometimes, the focal point of absolute maximum intensity does not coincide with the geometrical focus but shifts along the optical axis,this phenomenon always be called as focal shift [10]. Actually, the phase shifting modulation in this aticle is a function of the radial direction angle. Calculation results show that intensity distribution in focal region can be altered considerably by the topological charge of BG beam and the phase parameter, but the focus shifting only related to the numbers of the topological charge of BG beam. More interesting, the focal shift may be incontinuous in certain case.

In this article, focusing shifts of radial varying polarized Bessel-Gauss beam with radial phase modulation are investigated in detail. In section 2, the principle of the focusing systemis given. Simulation results and discussions are shown in section 3. Conclusions are summarized in section 4.

2. Focusing radial varying polarized BG beam with radial phase modulation

The incident beam that we investigated is radial varying polarized BG beam with radial phase modulation, and the electric field distribution in the focal region can be written in the form of [8,21–28].

$$\vec{E}(r, z, \phi) = E_r \vec{e}_r + E_z \vec{e}_z + E_\phi \vec{e}_\phi \tag{1}$$