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Detailed Studies on Optical Singularities in the Superposition of Two Vector Laguerre-Gaussian Beams

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Singularities in optical field play an essential role in many optical phenomena. Different kinds of optical singularities exist in the scalar and vector optical fields, which can be used to describe the field structure [1]. Spatially varying polarization states and associated singularities have many important applications, for example, crystal optics, photonic nano-structures, laser microscopy, and atom optics. According to the spatial distribution of the polarization, Laguerre-Gaussian (LG) beams can be classified into scalar and vector LG beams. A vector LG beam has a spatially varying polarization distribution with a cylindrical symmetry. For the specific azimuthal index m, a vector LG beam can have four different polarization distributions. These four polarization distributions have different angular dependence of the local polarization direction that provides unique properties to the beam. Resultant field obtained from a superposition of two vector LG beams has many interesting intensity and polarization properties [2]. The objective of the present work is to perform comprehensive study of the superposition of two vector LG beams and compare it with that of the superposition of two scalar LG beams [3].

Following our earlier work [2], here we present detailed analysis of the optical singularities in the superposition of two vector LG beams. Figure 1 shows calculated field distributions for the superposition of two vector LG beams. As can be seen, different kinds of singularities are evolved in the vector LG beam superposition. Characteristic inhomogenous polarization distribution of the vector LG beam appears in the form of azimuthally modulated intensity and polarization distribution. General expression for the intensity distribution of superposition of the two vector LG beams is derived. The bright and dark points generated in the resultant fields are associated with C-point and V-point singularities [1]. Simple relations for the radial and angular positions for C-points in the resultant fields are obtained. C-points generated in the superposed vector LG beam show the similar behavior as that of the phase vortices in the superposition of the scalar LG beams. It is observed that the beam waist possesses only V-points, which exhibit dark points. Such a V-point is transformed into a pairs of C-points with opposite handedness during the propagation of the field. The morphologies of polarization structure surrounding the singular points not only depend upon the azimuthal index but also on the orientation of the local polarization states of the two superposed beams. The superposition of two vector LG beams has many subtleties that are not present in the scalar LG beam superposition. Present study may find important application in the field of optical lattices, optical tweezers, and single molecular imaging.

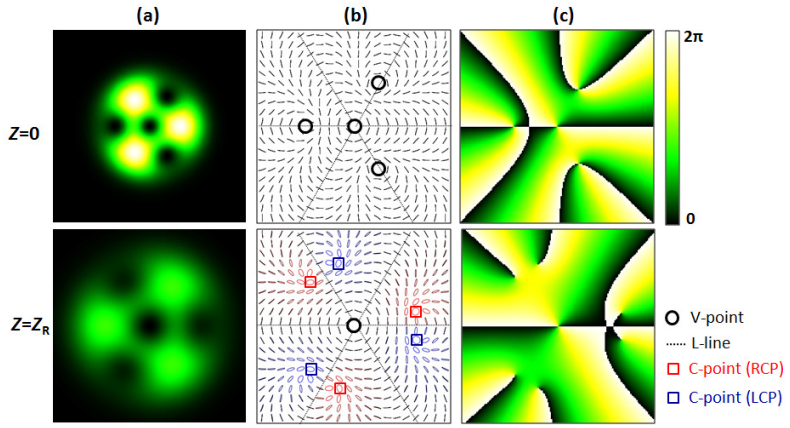

Fig. 1 Calculated field distribution for the superposition of two vector LG beams having different azimuthal indices m_1=1 and m_2=4 respectively. (a) total intensity distribution, (b) polarization distribution, (c) Stokes field distribution. Top row correspond to field distribution at beam waist ($z = 0$), bottom row correspond to field distribution at Rayleigh length ($z = z_R$).

References:

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