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Optical angular momentum conversion in a nanoslit: comment

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In a recent work [Opt. Lett. **37**, 4946 (2012)], the spin to orbital optical angular momentum conversion from a subwavelength slit having a circular shape has been reported. In particular, the conversion efficiency was claimed to be independent of the slit dichroism. Here, we correct such a statement and demonstrate that dichroism strongly influences the process of optical vortex generation.

OCIS codes: (050.4865) Optical vortices; (050.2555) Form birefringence; (310.6628) Subwavelength structures, nanostructures.

Recently, Chimento and coworkers investigated the effect of a circular subwavelength slit on the orbital angular momentum content of light [1]. A subwavelength slit indeed behaves as a birefringent retarder whose main axes are directed parallel and perpendicular to it [2]. This enables a circular slit to partially convert an incident circularly polarized light field into a contra-circularly polarized one carrying an on-axis optical phase singularity with a topological charge of two [1]. In particular, the efficiency η of the polarization conversion process has been claimed to be independent of the slit dichroism [1].

The aim of this Comment is to correct the latter statement. Dichroism indeed strongly influences the process, as demonstrated hereafter in the more general framework of so-called q -plates [3], which consist of slabs of inhomogeneous and optically anisotropic slabs of thickness L that have: (i) an azimuthal distribution of the orientation of their optical axis of the form $\psi(\phi) = q\phi + \phi_0$ with q integer, ϕ the usual azimuthal angle in the (x, y) plane of the slab, and ϕ_0 a constant and (ii) a uniform birefringent phase retardation $\Delta = k_0(n_{\parallel} - n_{\perp})L$ with k_0 the wavenumber in vacuum and $n_{\parallel, \perp}$ the refractive indices parallel and perpendicular to the optical axis.

Let us consider the case study of an incident circularly polarized plane wave that propagates through a dichroic q -plate of thickness L with an input facet located at $z = 0$ and with attenuation coefficients $\delta_{\parallel} = e^{-\alpha_{\parallel}L}$ and $\delta_{\perp} = e^{-\alpha_{\perp}L}$, where α_{\parallel} and α_{\perp} are the amplitude attenuation constants for the polarizations parallel and perpendicular to the optical axis, respectively. The

incident electric field ($z < 0$) is expressed as $\mathbf{E}_{\text{in}} = E_0 e^{-i(\omega t - k_0 z)} \mathbf{c}_{\sigma}$ where $\mathbf{c}_{\sigma} = (\mathbf{x} + i\sigma\mathbf{y})/\sqrt{2}$, $\sigma = \pm 1$, refers to the orthonormal circular polarization basis. Neglecting diffraction effects, the output light field at $z = L$ is obtained in the laboratory frame by using the Jones formalism,

$$\mathbf{E}_{\text{out}} = E_0 e^{-i\omega t} \begin{pmatrix} \cos \psi & -\sin \psi \\ \sin \psi & \cos \psi \end{pmatrix} \begin{pmatrix} \delta_{\parallel} e^{ik_0 n_{\parallel} L} & 0 \\ 0 & \delta_{\perp} e^{ik_0 n_{\perp} L} \end{pmatrix} \times \begin{pmatrix} \cos \psi & \sin \psi \\ -\sin \psi & \cos \psi \end{pmatrix} \mathbf{c}_{\sigma}. \quad (1)$$

Expressing \mathbf{E}_{out} in the circular polarization basis, one gets, up to a phase factor $e^{-i\omega t + i(\Delta/2) + ik_0 n_{\perp} L}$,

$$\mathbf{E}_{\text{out}} = \frac{E_0}{2} \left[\left(\delta_{\parallel} e^{i\frac{\Delta}{2}} + \delta_{\perp} e^{-i\frac{\Delta}{2}} \right) \mathbf{c}_{\sigma} + \left(\delta_{\parallel} e^{i\frac{\Delta}{2}} - \delta_{\perp} e^{-i\frac{\Delta}{2}} \right) e^{i2\sigma\psi(\phi)} \mathbf{c}_{-\sigma} \right]. \quad (2)$$

By introducing the dichroism parameter $\delta = \delta_{\perp}/\delta_{\parallel}$, if $\delta_{\perp} < \delta_{\parallel}$ and $\delta = \delta_{\parallel}/\delta_{\perp}$ if $\delta_{\perp} > \delta_{\parallel}$, the efficiency η is defined as the intensity ratio $\eta = (|\mathbf{E}_{\text{out}} \cdot \mathbf{c}_{-\sigma}^*|^2)/|\mathbf{E}_{\text{out}}|^2$, with the asterisk being a complex conjugation, expressed as

$$\eta = \frac{(1 - \delta)^2}{2(1 + \delta^2)} \cos^2(\Delta/2) + \frac{(1 + \delta)^2}{2(1 + \delta^2)} \sin^2(\Delta/2). \quad (3)$$

The spin-to-orbital optical angular momentum conversion thus strongly depends on the dichroism whatever is q , as illustrated in Fig. 1. The “usual” formula $\eta = \sin^2(\Delta/2)$ only applies without dichroism, i.e., $\delta = 1$. For the case of $\delta = 0$ in Fig. 1, this is a special case of a linear polarizer with an azimuthally varying axis.

References

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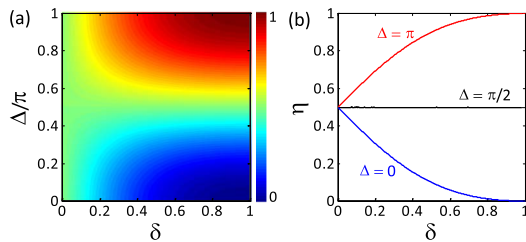


Fig. 1. (a) Map of polarization conversion efficiency η as a function of birefringent phase retardation Δ and dichroism parameter δ . (b) η versus δ for $\Delta = 0, \pi/2$, and π , which correspond to special cases of full wave, quarter wave, or half wave dichroic plates, respectively.