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.

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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 $\alpha_\parallel$ and $\alpha_\perp$ 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 $\mathbf{E}_{\rm in} = E_0 e^{-i(\omega t - k_0 z)}\mathbf{c}_\sigma$ 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,

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

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

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

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 $\eta = (|\mathbf{E}_{\rm out} \cdot \mathbf{c}^*_{-\sigma}|^2)/|\mathbf{E}_{\rm out}|^2$, 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.

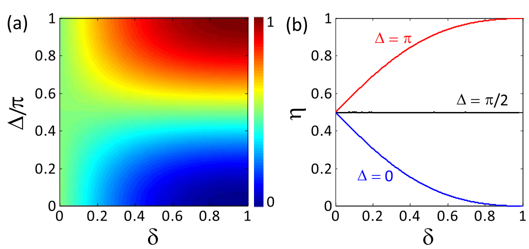

Fig. 1. (a) Map of polarization conversion efficiency η as a function of birefringent phase retardation Δ and dichroism parameter δ. (b) η versus δ for $\Delta = 0$, $\pi/2$, and π, which correspond to special cases of full-wave, quarter-wave, or half-wave dichroic plates, respectively.

References

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