Conical diffraction cascades and interplay with linear and nonlinear material properties

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Introduction

Internal conical diffraction is a well-known singular phenomenon observable whenever a tightly focused wave is incident with its wavevector along one of the two optical axes of an optically biaxial crystal [1]. The effect gives rise to a vector type wave with the Poynting vectors associated to each linear polarization component lying on a slanted cone surface with circular base. The number of these cones can be multiplied by a factor $2^{N\text{-}1}$ if a cascade of N biaxial crystals with perfectly aligned optical axes is considered. When observed on a plane perpendicular to the optical axis, these structures have a circular form. However, as it will be discussed in this contribution, a dramatic change in the shape of the conical diffraction vector beams can be achieved if a proper manipulation in wavevector space is performed between the different crystals in a cascade. Highly peculiar non-circularly shaped vector beams can be obtained, some of which associated to a reversed curvature as compared to the one proper to circles [2].

Results

Figure 1 illustrates the concept, the schematic set-up and two examples of obtained conical diffraction beams for a cascade of two crystals. In the case of Fig. 1(c) only the magnitude, but not the direction, of the transverse component of the wavevector is being manipulated (by means of a spherical lens between the two biaxial crystal). This correspond to the so-called "variable cascade" introduced earlier by Peet [3] and leading still to circularly shaped structures. In contrast, the use of two crossed cylindrical lenses permits an anisotropic imaging in the transverse x and y directions between the planes FIP1 and FIP2 in Fig. 1(b). This leads to the mentioned non-circular vector beams, as seen in the example of Fig. 1(d). For such patterns the type of curvature can be predicted on the base of the material optical properties, the sample lengths, and the x and y magnification factors M_x and M_y provided by the cylindrical lenses. The same is true for the positions of the intersection points of the structures with the x and y transverse axes.

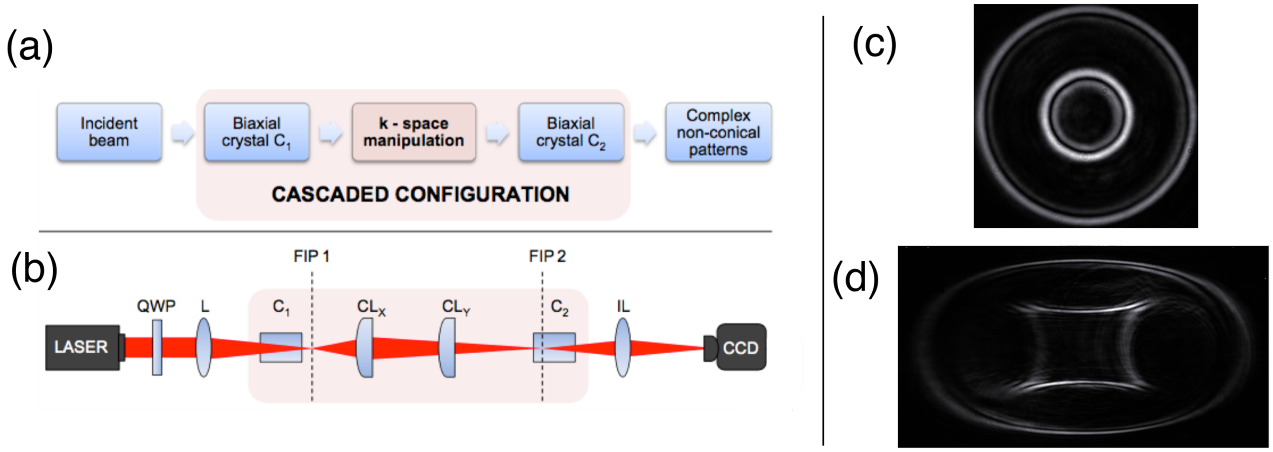

Figure 1: Concept (a) and experimental set-up (b) of a cascaded conical diffraction with manipulation in wave-vector space between two optically biaxial crystals (C_1, C_2) in cascade. QWP is a quarter-wave plate, L and IL are a focusing and imaging spherical lens, respectively, and CL_x and CL_y are crossed cylindrical lenses. Panel (c) shows an example of the obtained pattern (at plane FIP 2) when the two intermediate cylindrical lenses are replaced by a single spherical lens (variable cascade), what conserves the pattern circular symmetry. In (d), in contrast, a wave-vector manipulation by the crossed cylindrical lenses leads to peculiar non-circular patterns with the internal structure having a reversed curvature (see [2] for more details and theoretical approach).

In the standard circular case with only one crystal, the circle radius is uniquely determined by the values of the three principal refractive indices of the biaxial crystal and by the length of the sample. However, conical diffraction in both single step and cascaded configurations can be influenced also by other linear and eventually nonlinear optical properties of the involved crystals (optical activity, photoinduced effects, …). Such an interplay is discussed in the case of photorefractive $Sn_2P_2S_6$ crystals [4], as compared to standard materials commonly used for conical diffraction, such as centrosymmetric $KGd(WO_4)_2$. The potential role of photorefractivity in view of a conical diffraction holography will also be discussed.

References

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