Poliarizacinių dislokacijų formavimas parametriškai stiprinant šviesos sūkurius

Generation of polarization singularities by parametric amplification of optical vortices

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We present a new method to obtain beams with polarization singularities. The proposed method is based on superposition of two optical vortices with opposite topological charges [1]. The vortices can be conveniently obtained during the process of optical parametric amplification.

The experimental setup is shown in Fig. 1. The signal and pump beams are combined in a collinear fashion by a wavelength-selective mirror M. The signal beam, which is an optical vortex of topological charge *l*, is amplified by a Gaussian pump beam in a nonlinear crystal (NLC). This way, due to the topological charge conservation in nonlinear optical processes [2], the idler wave is formed with the opposite topological charge -*l*. After filtering off the remaining pump beam, the combined signal-idler beam is transformed into a beam with a polarization singularity by a λ/4 waveplate (QW).

It is important to note that this experiment uses a crystal with type-II phase matching in order to obtain two orthogonally polarized vortices at the output of the crystal. In addition, to achieve the superposition of the vortices, they have to be of the same wavelength, therefore the nonlinear interaction has to be degenerate with respect to the wavelength.

The type of the formed singularity will depend on the orientation of the λ/4 waveplate as well as the phase shift between the signal and idler waves at the output of the crystal. Therefore a phase retarder (PR), has been put in the path of the signal beam to control the initial phase shift between the signal in pump waves. The phase retarder is a thin glass plate, which can be rotated to change the optical path of the signal beam. The signal, idler and pump waves are connected by certain phase relations during the optical parametric amplification [3], therefore introducing a phase to the signal beam will result in a corresponding phase shift of the idler beam.

By manipulating the orientation of the λ/4 waveplate and the phase of the signal beams, it is possible to generate various types of beams with polarization singularities, including the radially and azimuthally polarized beams.

The experiment was carried out using an 8 mm long KTP crystal. The topological charge of the signal beam (Fig. 2 (b)) was *l*=1 and the amplification in the crystal was about 500 times. This way, a radially (Fig. 2 (c)) and azimuthally polarized beam has been obtained. The output beam was analyzed using a birefringent calcite crystal to ensure the correct polarization structure of the beam (Fig. 3).

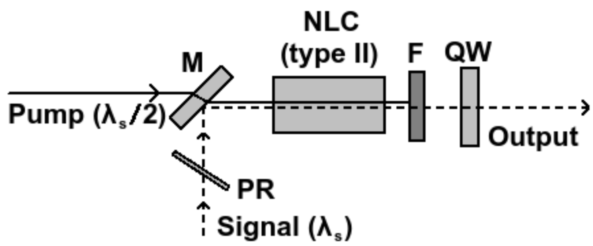
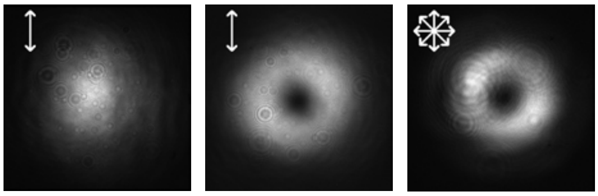
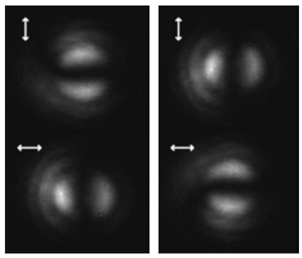


Fig. 1. The experimental setup. NLC – nonlinear crystal with type-II phase matching, M – wavelength-selective mirror, PR – phase retarder, F – filter, QW – λ/4 waveplate.



(a) (b) (c)

Fig. 2. The intensity distributions of the initial pump (a) and signal (b) beams and the radially polarized output beam (c). The arrows indicate the polarization states of the beams.



(a) (b)

Fig. 3. The split vertical (top) and horizontal (bottom) polarization components of a radially (a) and azimuthally (b) polarized beam.

Keywords: optical vortices, radial polarization, polarization singularities, optical parametric amplification.

References

[1] C. H. Yang, Y. D. Chen, S. T. Wy, A. Y .W. Fuh, Scientific reports **6,** (2016).

[2] M. S. Soskin, M. V. Vasnetsov. Pure Appl. Opt. **7**(2), 301 (1998).

[3] Y. R. Shen. *Principles of nonlinear optics*, (New York, 1984)