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Ferroelectric liquid crystals with sub-wavelength helix nanostructure pitch for the generation of axial-symmetric vortex light fields

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Abstract. Experimental results of the formation of axially symmetric vortex light fields with a frequency of up to 2 kilohertz are presented. The results were obtained by using a 12-sector spiral phase plate (SPP) based on a planar-oriented layer of a 50 μm-thick ferroelectric liquid crystal (FLC), having the spiral nanostructure pitch substantially less than 100 nm.

Phase spatial light modulators (SLM) are actively used in many fields of optics, including adaptive optics, laser tweezers, quantum communication systems. The traditional way to implement purely phase spatial modulation is to use the S-effect in nematic liquid crystals, whose characteristic relaxation frequencies of orientational perturbations are several tens of Hz, which limits the range of the SLM applications. An increase in speed is possible due to orientational effects in ferroelectric liquid crystals (FLC) with a sub-wavelength pitch of the spiral structure [1-2]. The paper presents the results of experimental studies of the formation of axially symmetric vortex fields by using a 12-sector spiral phase plate (SPP) based on a planar oriented FLC (i.e. the axis of the spiral is parallel to the substrates) with a sub-wavelength pitch of the helix p_0 <100 nm, with a layer thickness of 50 μm . Such structures are simple to manufacture, but they have not yet been used for continuous phase modulation due to concomitant modulation of the state of polarization of light (ellipticity) caused by the biaxial transformation of the ellipsoid of the refractive indices and the rotation of its main optical axis in an electric field relative to the plane of polarization of the incident light [3].

Both the calculated and experimentally obtained intensity distributions of light fields with different topological charge for a control voltage frequency of 1 KHz are shown in the figure. The calculations were performed by standard numerical methods using the Fourier transform in the Scilab package. In the experiments, the sector spiral phase plate based on the FLC 587-F7 was illuminated by a linearly polarized collimated He-Ne laser beam, the electric vector of light coincided with the direction of the axis of the helix. An alternating supply voltage was applied to the cell, the frequency of which varied from 100 to 4000 Hz. To eliminate distortions in the intensity distribution pattern caused by scattering during transients, the duration of which is about 150 microseconds, an electro-optical shutter synchronized with the cell power frequency was used. The diameter of the illuminated area on the sector spiral

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phase plate was 4 mm. The intensity distributions were recorded in the focal plane of the lens with a focal length of 2 m. Good agreement is observed between the calculated and experimental intensity distributions.

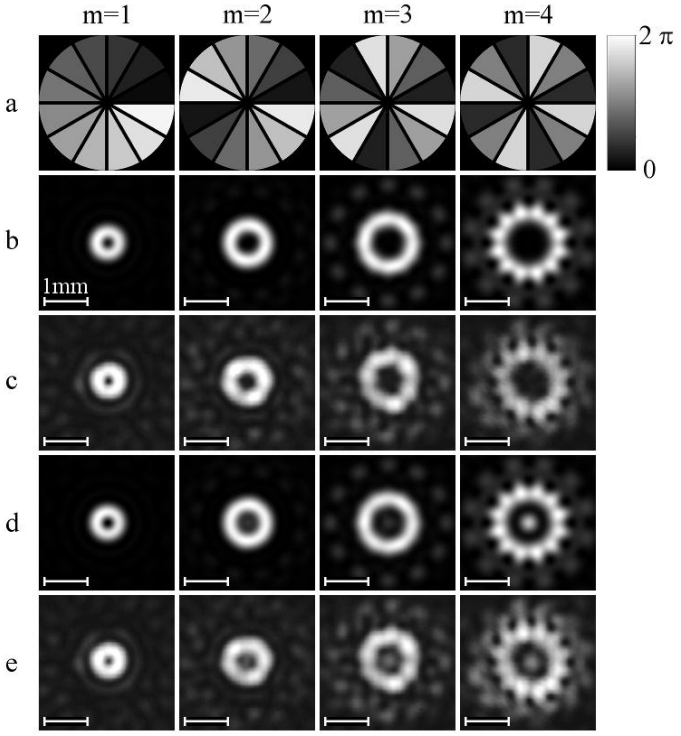

Fig. 1. The formation of axially symmetric vortex fields with a topological charge m from 1 to 4 by using a 12-sector spiral phase plate based on a FLC-587-F7: (a) specified phase distributions on the spiral phase plate in gray gradations; calculated (b) and experimentally measured (c) intensity distributions in the far field in the presence of a polarizer; calculated (d) and experimentally measured (e) intensity distributions in the far field without a polarizer.

The effect of the concomitant modulation of the polarized state of transmitted light is visually demonstrated by the difference in patterns in the presence and absence of a polarizer behind a spiral phase plate. In the presence of a polarizer, additional amplitude modulation of light practically does not affect the structure of the generated field. According to calculations, light losses in this case do not exceed 10%. Thus, the orientational Kerr effect in planar aligned liquid crystal ferroelectrics with a sub-wavelength pitch of the helix can be used to form axially symmetric vortex fields at the frequency of reconfiguration of the mentioned light fields up to 2 kHz.

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