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Photonics of two-dimensional structures formed by cholesteric liquid crystals

P. V. Dolganov[+*1)], *K. D. Baklanova*[+*], *V. K. Dolganov*[+], *E. I. Kats*[×]

[+] *Osipyan Institute of Solid State Physics, Russian Academy of Sciences, 142432 Chernogolovka, Russia*

[*] *National Research University Higher School of Economics, 101000 Moscow, Russia*

[×] *Landau Institute for Theoretical Physics, Russian Academy of Sciences, 142432 Chernogolovka, Russia*

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Chiral liquid crystal materials can self-organize into modulated structures with multilevel arrangement formed by curved cholesteric helixes and spatially ordered defects. We managed to prepare periodic two-dimensional cholesteric domains with remarkable structure and photonic properties. They are formed due to geometrical frustration. Complex optical patterns with non-trivial dependence of the images on light polarization and on observation geometry were found and investigated in transmission and reflection. The obtained photonic structures of two-dimensional ordered confocal domains and their optical properties are a challenge both for theory and experiment.

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Investigations of defects constitute an important part of the studies of different materials, including liquid crystals [1–9]. Focal conic domains are peculiar types of defects observed in thin films or near surfaces in smectic and cholesteric liquid crystals [1–3]. Investigations of focal conic structures date back to the seminal works of Friedel [10, 11]. Rosenblatt et al. [12] proposed the structure from parabolic defects to explain experimental observations of periodic defect pattern. In spite of numerous investigations the nature of focal conic domains and periodic patterns in cholesterics and their relation to optical properties are not completely clear. One of the reasons is that investigations of these structures are often performed on unordered samples.

In a recent work [13] we found two-dimensional (2D) periodic photonic structure which can be related to ordered focal conic domains in planar optical cells. They spontaneously appeared near the cholesteric–isotropic phase transition. In this paper the peculiarities of photonic properties and structures in mixtures composed by various liquid crystal ingredients and chiral dopants are studied. We pay special attention to the dependence of the optical pattern on polarization of light and analyze similarities of the structure in different materials.

The 2D photonic structures obtained and studied in our work are structures with multilevel ordering where the building blocks are not atoms or molecules but one-dimensional cholesteric photonic crystals. Their spatial ordering gives rise to structures of higher level both with respect to complexity and functional possibilities. We investigated photonic properties of the periodic 2D structure in optical cells using cholesteric with different pitch value, materials composed by different nematic hosts and chiral dopants. A regularly arranged system of domains appeared on slow heating (typically at a rate about $0.1\,^\circ$/min) near the transition to the isotropic phase. The domains are stable near the cholesteric–isotropic transition and metastable at low temperature (far from the transition). Wonderful images revealing nontrivial structure and properties were obtained in reflection and transmission. Figure 1 shows photographs of a region of the 2D structure in mixture of nematic liquid crystal E7 and chiral compound CB15 ($\sim 40\,\%$ wt) in transmission with a single polarizer along x axis (Fig. 1a), between parallel polarizer and analyzer (Fig. 1b) and between crossed polarizer and analyzer (Fig. 1c). The images of the same region in reflected light are given in Fig. 1d, e.

The existence of complementary structures near the two surfaces of the cell was demonstrated by circular polarized light. We found that polarization of light transmitted through the sample substantially varies from region to region. We relate complex optical patterns observed in transmission to selective reflection and rotation of the plane of polarization of light. Our measurements allow to describe polarization state of transmis-

[1)] e-mail: pauldol@issp.ac.ru

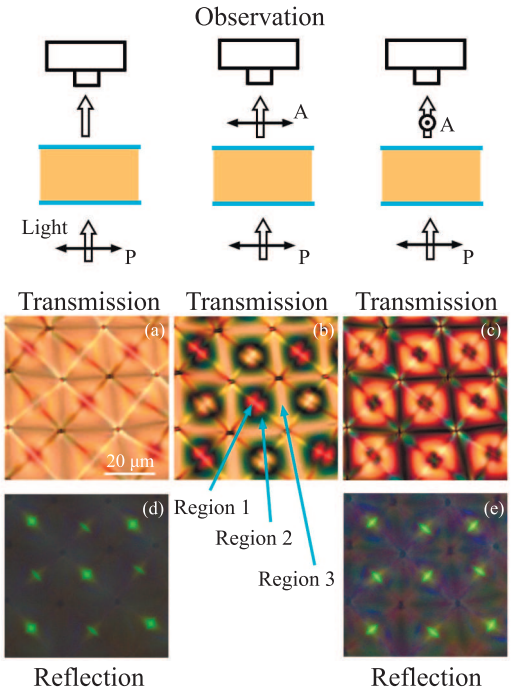

Fig. 1. (Color online) Periodic texture with square ordering viewed in transmission in linear polarized incident light (a)–(c). The photographs were taken with a single polarizer parallel to x axis (a), between parallel polarizer and analyzer (b) and with crossed polarizer and analyzer (c). The polarization of light passing through regions 1, 2 and 3 is substantially different at the exit of the sample, as indicated by the images with parallel and crossed polarizer and analyzer (b), (c). Frames (d) and (e) show images of the structure in reflected light with one polarizer along x axis and with crossed polarizer and analyzer. Rubbing direction on the cell surfaces is close to horizontal

sion modes in the whole unit cell of the structure. The domain structure is an interesting example of photonic crystal with square ordering in the plane of the film. We may state that the intrinsic properties of the periodic 2D domain structure are determined by chirality in confined geometry. Up to now there are only several publications about optical and spectral properties of the 2D domain structure. It is found that the structure is formed near the cholesteric–isotropic phase transition and by materials with reflection in visible and near infrared spectral ranges. We observed the periodic structure in a number of compounds with the cholesteric phase. In mixtures composed by different ingredients but with a close value of the helical pitch the structure and its optical properties are similar. We can conclude that the observed peculiarities have general character. Further investigations will show which additional conditions are necessary for the formation of the 2D domain structure.

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Conflict of interest. The authors of this work declare that they have no conflicts of interest.

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