

DEFECTS IN CHOLESTERIC LIQUID CRYSTALS

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Рассмотрены основные типы дефектов в холестерических жидких кристаллах (ХЖК). Приведены спектры пропускания для волн правой и левой круговых поляризаций. Показаны новые качественные возможности использования ХЖК с дефектом структуры.

Every day we are using devices based on liquid crystals. Generally, these are optoelectronic devices: displays, colour indicators of temperature and pressure, the elements of laser technique, etc.

The peculiarity of liquid crystals structure is that their molecules have an elongated shape, so that the optical properties of the molecules differ in different directions. This is called anisotropy. There are three types of liquid crystals - nematic, smectic and cholesteric. The most interesting are cholesteric liquid crystals (CLC). Their molecules are arranged in layers, each layer is rotated relative to the previous one at a certain angle. As a result, molecules form a spatial helix.

The most important property of the CLC - is that the passage of light through the crystal depends on the polarization of the incident radiation. CLC has photonic band gap (the region of wavelength at which light is totally reflected from the structure) for the circular polarization, whose direction coincides with the direction of twist of the CLC (right-hand spiral - right circular polarization). Light waves of the opposite circular polarization pass through the crystal without change. In reflection from the CLC no change of the polarization sign occurs.

Ideal liquid crystals have many uses, but their impurity options are of more application. The defect implantation in the crystal structure gives rise to additional resonance modes inside the forbidden zone. There arise additional bands of transmission and reflection in the band gap and unique possibilities appear. In such a way narrow-band filters and low-threshold lasers operate. This article describes the main geometry options and types of defects in the CLC.

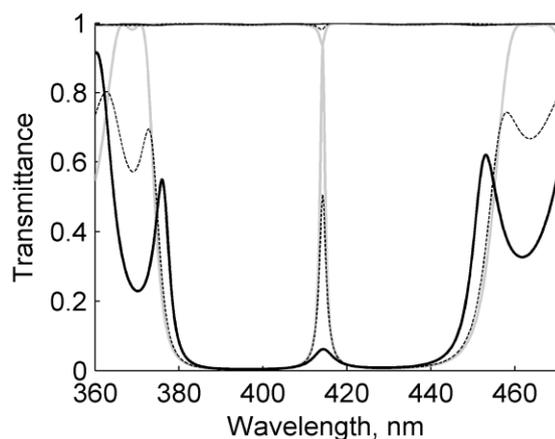


Fig.1. Transmission spectrum of CLC with isotropic defect. Defect in the center of CLC – grey line, the defect is shifted to the right – dotted line and black line.

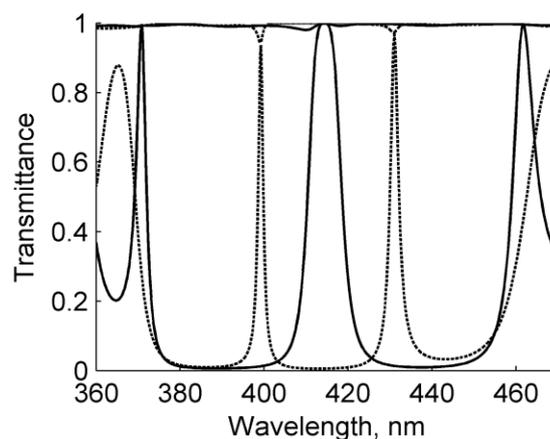


Fig.2. Transmission spectrum of CLC with two isotropic defects. Defects are separated – grey line, defects are shifted to the center – dotted line.

1. A thin layer of isotropic material is embedded between two layers of CLC. Transmission peak for one polarization peak reflection for the other in the band gap are induced (Fig.1). Both peaks have contact at one point. When shifting to the edge of the defect, the maxima of the peaks are reduced, their contact disappears. For oblique incidence of light, both peaks are shifted to shorter wavelengths and their intensity is significantly reduced.

By varying the thickness of defect layer, we can obtain the presence of several peaks in the transmission spectrum, as well as to change their position easily.

By introducing an additional defect in the liquid crystal layer we get two transmission peaks and two reflection peaks (Fig.2). By increasing the distance between the defects, the peaks merge into one broad band. This is due to the degeneracy of the frequencies of electromagnetic modes localized at defects.

Nanoparticles introduction into the defect gives new possibilities for light transmission control. There is a frequencies splitting of the defect modes. In the band gap there are two transmission peaks (Fig.3). The distance between them can be changed by increasing the concentration of nanoparticles. It is possible to create an additional reflection band in the continuum (Fig.4).

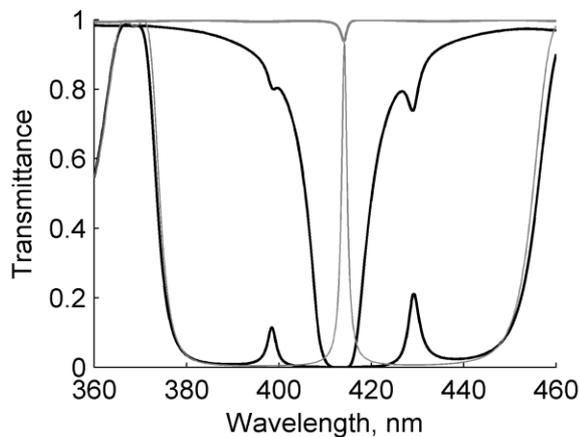


Fig.3. Transmission spectrum of the structure for the waves of left and right circular polarizations at a concentration of nanoparticles $f=0$ - grey line, $f=0.02$ - black line.

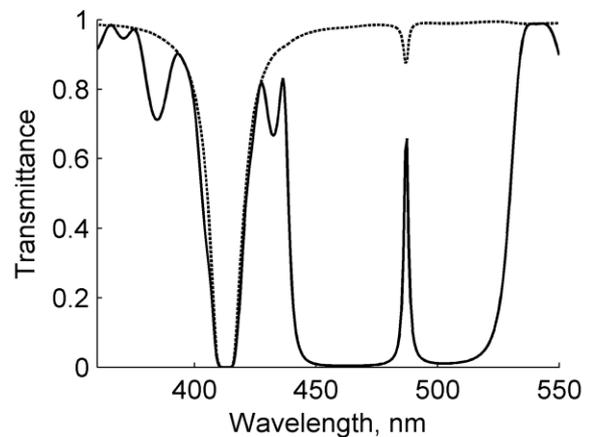


Fig.4. Transmission spectrum of the structure for the waves of left (dotted line) and right (black line) circular polarizations at a concentration of nanoparticles $f=0.01$.

2. A layer of anisotropic material between two CLC layers.

In the presence of such defects, cholesteric may lose its main property - the dependence of reflection on the direction of polarization of the light wave. Under certain conditions, there are forbidden zones for the two circular light polarizations, so all the incident light is reflected from the starting structure.

3. The defect caused by a spiral phase jumps at the interface of two liquid crystals. The crystal consists of two parts. One part is rotated relative to each other at a certain angle (Fig.5). While the incident wave passes this boundary there occur phase fails. There are peaks in the reflection and transmission. The transmission spectrum is similar to the CLC spectrum with its defect in the form of a thin dielectric layer.

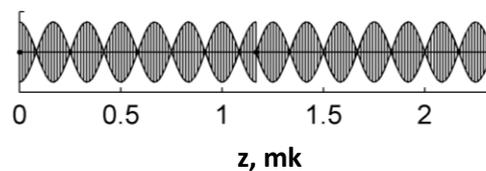


Fig.5 CLC with phase jump

4. The defect in the form of a local change in the helix pitch. In the crystal there is a region in which the pitch of the cholesteric helix is differs from the CLC pitch. Thus, the band gap of the peak reflection occurs. The width of this peak is easily varied by changing the pitch of the defect. In this case, the defect is not a foreign material, and it is not the same crystal.

5. A defect in a CLC layer with a different twist direction of the helix. The structure consists of three layers of the CLC, but the middle layer has the opposite direction of the cholesteric helix twist. In this case, the transmission spectrum of the structure has a different view, not the same as in the previous cases. Forbidden zone is available for both circular polarizations of light (Fig.6). For light with a polarization coinciding with the outer layers of a twist, there are two transmission peaks in the forbidden zone. Weakamplitude changes for the other polarization of light are observed at frequencies of defect modes (Fig.7). The light supposed to pass through the structure without reflection, begins to be reflected partially at a certain frequency. A similar situation is observed for the cholesteric liquid crystal with an anisotropic defect.

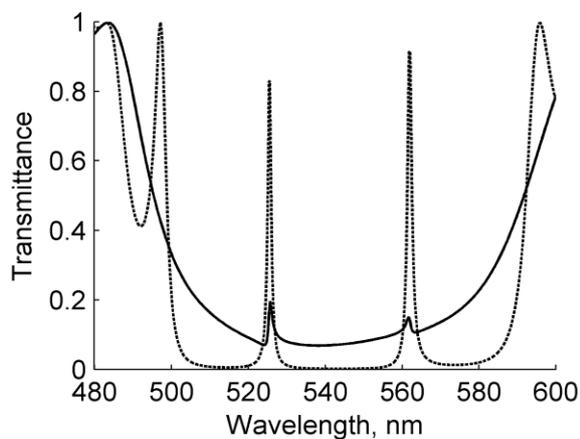


Fig.6. Forbidden zone in the transmission spectrum of the structure. The dotted line - the left polarization. Solid line - right polarization.

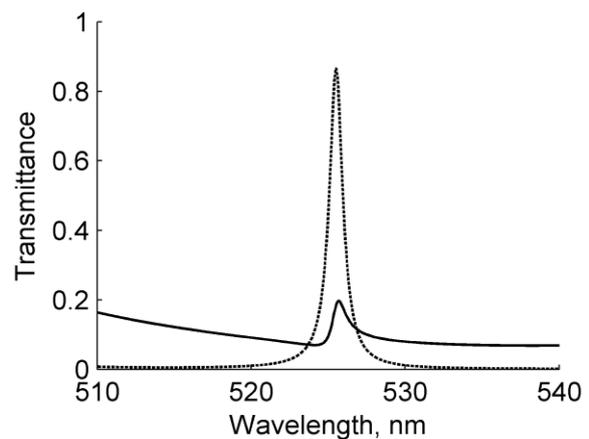


Fig.7. Part of the forbidden zone in the transmission spectrum. Dotted line - the left defect mode polarization. Solid line - weakamplitude curve of the right polarization.

In this paper we have presented the main types of defects in cholesteric liquid crystals. The basic effects that arise because of the structure are not ideal. Some of the results are obtained by the author personally.