Quantum Electronics **43** (5) 433–434 (2013)

LETTERS

PACS numbers: 78.15.+e; 42.70.Dr; 42.25.Gy
DOI: 10.1070/QE2013v043n05ABEH015152

Observation of two regions of selective light reflection from a thin film of a cholesteric liquid crystal

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Abstract. **Two regions of selective light reflection (in the short- and long- wavelength parts of the visible spectrum) from a thin film of a cholesteric liquid crystal (CLC), consisting of the mixture of two CLCs with opposite chirality and a nematic liquid crystal, are experimentally found for the first time. The spectral position of the reflection regions and the separation between them varies depending on the CLC composition and the temperature. The long-wavelength region of reflection corresponds to the region of Bragg reflection from the CLC helix, while the short-wavelength region is probably due to the defects in the structure of the CLC film.**

Keywords: *cholesteric liquid crystals, selective reflection, reflection regions.*

Due to their remarkable properties, cholesteric liquid crystals (CLCs) are widely used for fabrication of liquid-crystal indicators and compact optical elements [1]. CLCs are sometimes referred to as one-dimensional photon crystals, because they possess a periodic structure and reflect light with a certain circular polarisation within a certain interval of wavelengths [2]. This stop-band is called a region of selective reflection or a photonic band gap (PBG). It is interesting to examine a possibility to obtain several regions of selective reflection in a single CLC film [3–7].

In the present paper we report for the first time the fabrication and study of CLC films, consisting of the mixture of two CLCs with the opposite chirality and a nematic liquid crystal (NLC), that possess two regions of selective reflection. The possibility to control the spectral position of both regions of reflection is experimentally demonstrated. The long-wavelength region of selective reflection, observed in the experiment, appeared to correspond to the well-known Bragg reflection of light from the CLC helix. The short-wavelength region of spectral reflection was observed by us for the first time; probably, it is due to the appearance of defects in relatively thick layers of the CLC.

In the experiments we studied the temperature dependence of the spectrum of reflection of unpolarised light from a thin CLC layer. In this case the CLC layer consisted of the E7 NLC and two chiral additions with opposite chirality, cholesteryl pelargonate (CP) and cholesteryl oleate (CO). In the experiment the spectra of reflection of unpolarised light were recorded at different values of thickness and composition of the CLC. The approximate ratio CP : CO : E7 in three samples was the following: 50% : 30% : 20% (Sample I), 60% :30% : 10% (Sample II), and 20% : 40% : 40% (Sample III).

The CLC film was placed in a plane cell between the glass substrates, the separation between which was regulated by spacers of definite thickness. The planar orientation of the CLC molecules was achieved by rubbing one of the substrates. The surface of the second substrate was purposely not processed, so that the orientation of the CLC director at this substrate was free. To produce the CLC structure, the cell was filled with the CLC heated to the isotropic phase by means of the capillary method and was left in such a state for two days.

The experimental setup for measuring the spectrum of nonpolarised light reflection is shown in Fig. 1. In this case, use was made of the Stellar Net Black Comet fibre spectrometer (resolution ~1 nm) and the special (centred) reflection measurement fibre probe. The off-axis fibres of the probe delivered light from the tungsten-krypton lamp to the sample. Through the central fibre (diameter ~600 μm) a part of light, reflected from the CLC layer, was input into the spectrometer. The cell with CLC was placed in a thermostat, the temperature of which was measured with a thermocouple with the accuracy up to 0.1 °C and could be kept constant to the accuracy of 0.3 °C.

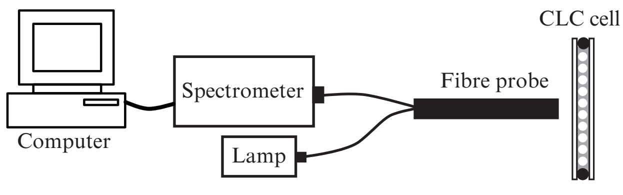

Figure 1. Scheme of the experimental setup.

Figure 2 presents the reflection spectra of three samples (I–III) of a 10-μm-thick CLC film at similar temperature and boundary conditions. In the reflection spectra of Samples I and II two regions with enhanced reflection of light were observed, one in the long-wavelength part of the spectrum and the other (with smaller reflection) shifted to the short-wavelength side with respect to the first one. The separation between the centres of both reflection regions was 225 nm for Sample I and 180 nm for Sample II. The cell with Sample III had only one region of reflection.

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Received 11 February 2013; revision received 9 March 2013
Kvantovaya Elektronika **43** (5) 433–434 (2013)
Translated by V.L. Derbov

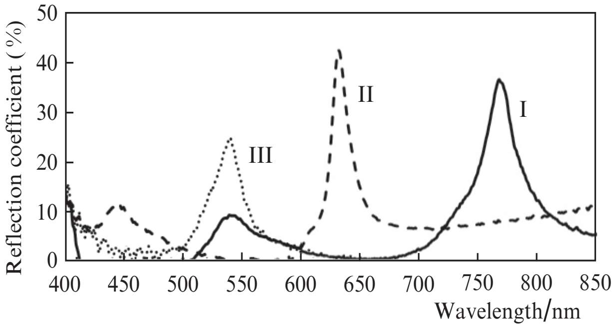

Figure 2. Unpolarised light reflection spectra of three samples with different CLC composition (mixtures I,II, and III). The thickness of the CLC layer is 10 μm, the temperature is 24 °C.

Figure 3 shows the temperature behaviour of the centre wavelengths of both reflection bands of the CLC cell with Sample II. With the increase in temperature both regions were shifted towards the short-wavelength part of the spectrum, and the separation between them decreased. Thus, at 21 °C the separation between the centre wavelengths was 200 nm, and at 45 °C it was only 170 nm. With the growth of temperature the short-wavelength region temperature shift was lower that the long-wavelength one.

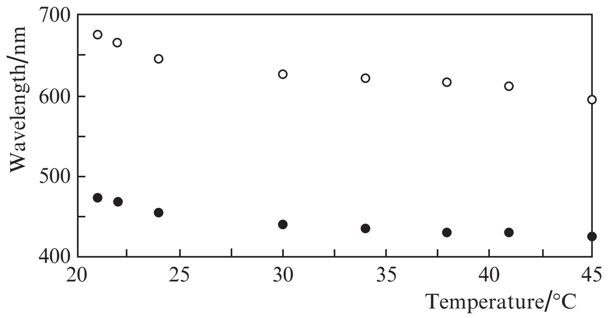

Figure 3. Temperature dependence of the spectral position of centre wavelengths of the (●) short- and (○) long-wavelength light reflection bands. The CLC layer thickness is 10 μm.

Thus, the reflection spectra of a ternary mixture of CLC films with different compositions and thickness were experimentally studied. It was established that in the CLC film two regions of selective reflection of light appear, the separation between which depends both on the film composition and on the temperature. With the growth of temperature both regions are shifted towards shorter wavelengths, the reflection in the more short-wavelength region changing weaker. Heating by 25 °C leads to the reduction of separation between the regions by 30 nm. The measurements of the CLC spiral pitch have shown that the long-wavelength region of reflection corresponds to the region of Bragg reflection, while the short-wavelength region is probably due to the defects in the structure of the CLC film.

Acknowledgements. The research was financed by the State Committee on Science of the Ministry of Education of Republic Armenia (Grant No. 11-1c194).

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