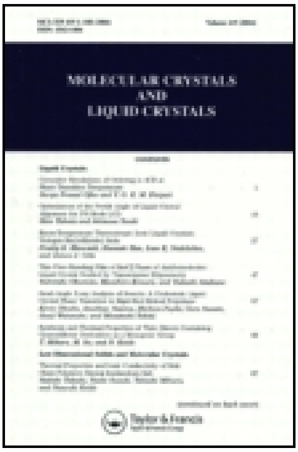

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CIRCULAR DICHROISM OF CHOLESTERIC LIQUID CRYSTAL LAYERS FOR NEODYMIUM LASER RADIATION

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Abstract The circular dichroism of cholesteric liquid crystal layers exhibiting selective reflection of neodymium laser radiation was investigated. The effect of temperature, CLC layer thickness and layer angle orientation on the circular dichroism was measured. The CLC materials exhibiting large circular dichroism independent on temperature in room temperature range were selected. These materials can be successfully used in circular polarizers for neodymium laser radiation and other liquid - crystalline elements of laser optics.

INTRODUCTION

Cholesteric liquid crystal (CLC) layers exhibit circular dichroism connected with selective reflection of light[1]. These optical effects are due to helical supramolecular arrangement of planar CLC layers. Such layers strongly reflect the radiation with waveleght λ_0 circularly polarized with the same sense as CLC helix rotates. The mode with an opposite sense of the circular polarization is transmitted almost without losses. The transmittances for these two modes are described as t^+ and t^- respectively. The effect takes place when the wavelength of light corresponds to spectral band of selective reflection. Outside this spectral band CLC layer transmits the radiation as a common medium.

Circular dichroism D of CLC layer is define as

$$D = \frac{t^- - t^+}{t^- + t^+} \qquad (1)$$

By calling the contrast ratio $K = t^-/t^+$ we have:

$$D = \frac{K - 1}{K + 1} \qquad (2)$$

This dependence is presented in Fig 1.

Circular dichroism value of a CLC layer depends on material parameters as the refractive indices, the helical pitch and the other physical parameters i.e. temperature, structure and thickness of CLC layer, and the angle of incidence of light. Theoretical[2] contrast ratio values of CLC perfect layers are about 10000 but in practice they are lower[2,3] (up to 100) due unperfect structure of liquid-crystalline layer, dielectric reflections on phase borders and applying not strictly monochromatic light. In this way circular dichroism value for real layer is lower than 1 and usually is about 0.95. These values give possibility to use CLC planar layers as circular polarizers of radiation with wavelenght corresponding to selective reflection spectral band of CLC layer.

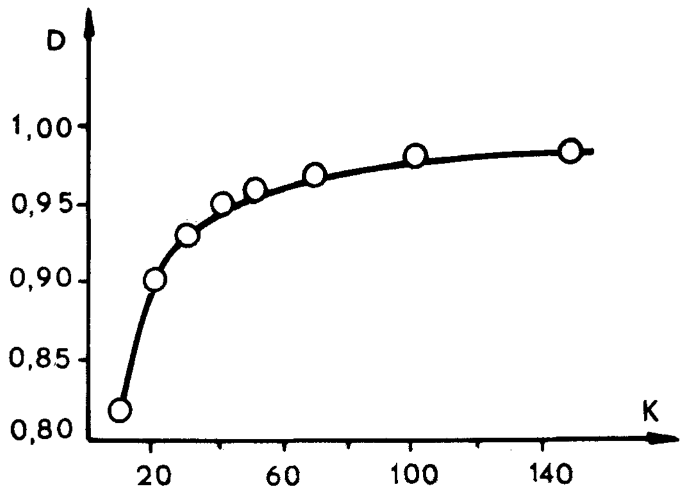

Fig.1. The circular dichroism dependence on transmittance contrast ratio calculated from Eq. (2).

In this paper we present the results of circular dichroism investigations of CLC layers. The aim of our work was to find the CLC mixture with the wavelenght of maximum of selective reflection equal to the neodymium laser radiation wavelenght (λ_0 = 1.06 μm).

EXPERIMENTAL

Cell construction. The measurement cells were made by common LCD technology with special polyimide rubbed orientating layer (Fig.2). The cell was made by 1.1 mm thick glass with ITO electrodes. In some cases standard laser equipment 12 mm thick glass was used. The electrodes area was about 25 cm^2. The glass sheets were degreased washed in a detergent solution and rinsed thoroughly by deionized water. The purity of the electrode surface is very important for the device lifetime and the other functional parameters. The CLC layer thickness was 12 or 36 μm. The stability of a layer thickness was obtained by using glass distance globules. After filling by liquid-crystalline mixture the cell was hermetized by UV - sensitive epoxy glue. The thickness control was conducted by interference method using Beckman 5270 spectrophotometer.

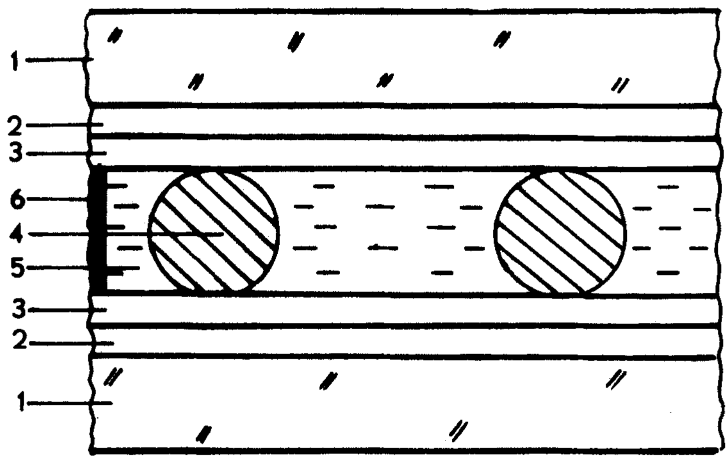

Fig. 2. The cross-section of a measurement cell. 1 - glass sheet, 2 - ITO layer, 3 - polyimide layer, 4 - glass distances, 5 - liquid crystal mixture, 6 - epoxy glue.

CLC mixtures. The composition of proper CLC material was selected by mixing cholesterol esters or adding mesogenic and non-mesogenic chiral dopants to nematics. The proper concentration of dopant has been found from the spectrophotometer spectral transmission characteristics obtained for CLC mixtures containing different quantity of dopant (Fig.3). Besides the fixed value of λ_0 a mixture ought to exhibit independence of circular dichroism on temperature in room temperature range. The studied mixtures are listed below.

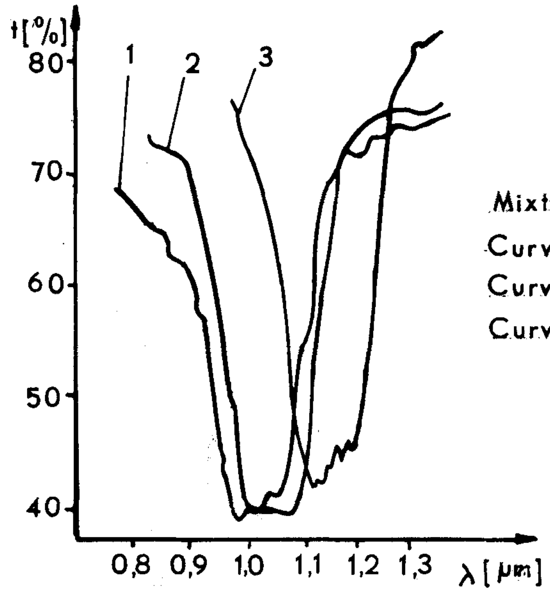

Fig 3. Spectral transmittance dependences of W-5 mixture for different concentrations of DMBAB: (1) - 12.3% bw., (2) - 10.3% bw., (3) - 8..1% bw. Cell thickness - 12 μm.

A - mixtures of cholesterol oleyl carbonate, cholesterol nonanoate and cholesterol chloride.

B - mixtures of hexylcyanobiphenyl (HCB) and cholesterol chloride.

C - mixtures of nematic ZLI-2457 obtained from Merck and non-mesogenic compound 4,4'-di(2-methylbutyl)azoxybenzene (DMBAB).

D - mixtures of nematic W-5 (WAT) and DMBAB.

The transmittance characteristics were measured by the same spectrophotometr as mentioned above.

Measurement setup. The transmitance values t^+ and t^- were measured using $YAG:Nd^{3+}$ or Nd : glass lasers. The scheme of the measuring equipment is presented in Fig 4. This equipment included laser with a power supply, a quarter wave-plate or Pockels' cell, a liquid -crystal cell, temperature indicator and an energy meter.

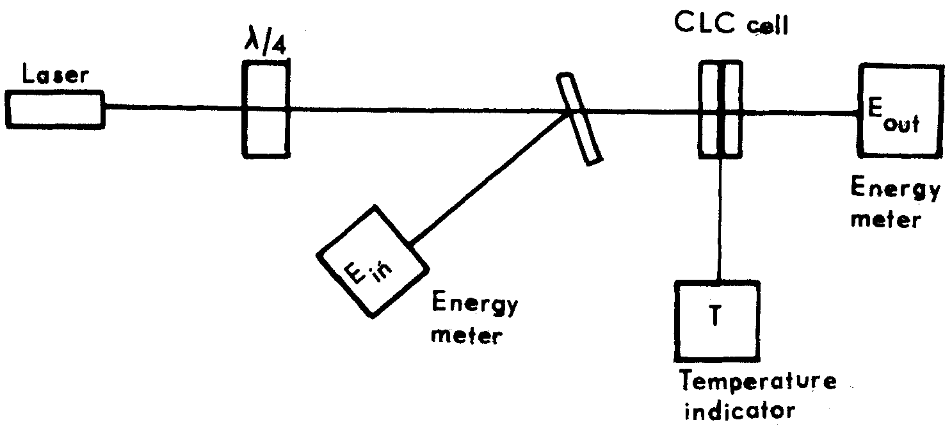

Fig 4. Scheme of laser experimental equipment.

The output energy of radiation was up to 400 mJ and the power density of it was up to 100 MW/cm^2. The energy of inciding and transmitted beams were measured by energy meter type 3230 (Laser Prec. Corp.) with the measurement error about 10 per cent. The repetition rate of laser pulse was 1 - 10 seconds. In these conditions laser light didn't change CLC layer temperature during the experiment more than 0.1 centigrade which was proved by means of thermocouple[3].

The proper sense of circular polarization of radiation was obtained using a quarter waveplate or Pockels' cell supplied with a quarter - wave voltage.

The measurements have been done after preparing the cell and after 3 and 6 months for the estimation of aging effects.

RESULTS AND CONCLUSIONS

The dependences of the CLC layers transmittance contrast ratio and circular dichroism on temperature were investigated. It was found that the layers of cholesterol ester mixtures exhibited selective reflection with temperature hysteresis and relatively low reflection coefficent. The layer of HCB with cholesterol chloride dopant exhibited circular dichroism independent on temperature in the room temperature range with temperature hysteresis, however. The layers of ZLI-2457 or W-5 nematics with DMBAB dopant exhibited transmittance contrast ratio, and so circular dichroism, independent on temperature from 287 to 308 K and stable for a long time (more then one and a half year). The contrast ratio dependence on temperature for the former substance doped by DBAMB is presented in Fig. 5.

The circular dichroism dependence on temperature for layer of W-5 doped by 11,5% of DMBAB is presented in Fig.6.

The effect of cell thickness and orientation of CLC layers on the D value was investigated, as well. It was found that circular dichroism of CLC layer in broad thickness range (12÷36 μm) changed not more than 20 percent. The CLC layer circular dichroism did not change when the direction of light incidence was deflected up to $\pm 7^{\circ}$ from normal. As a result of above studies CLC materials with large circular dichroism independent on temperature in the range of 14 - 36 $^{\circ}$C were obtained. The general view of liquid-crystal circular polarizer is presented in Fig. 7.

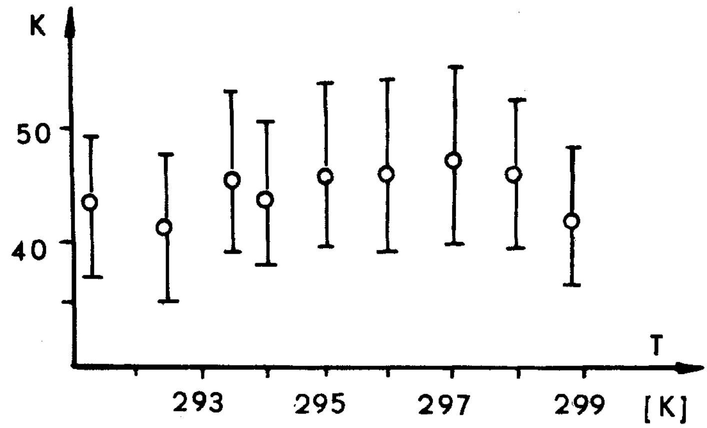

Fig.5. The contrast ratio dependence on temperature for C mixture. Concentration of dopant was 13,7 per cent by weight, cell thickness - 12 μm.

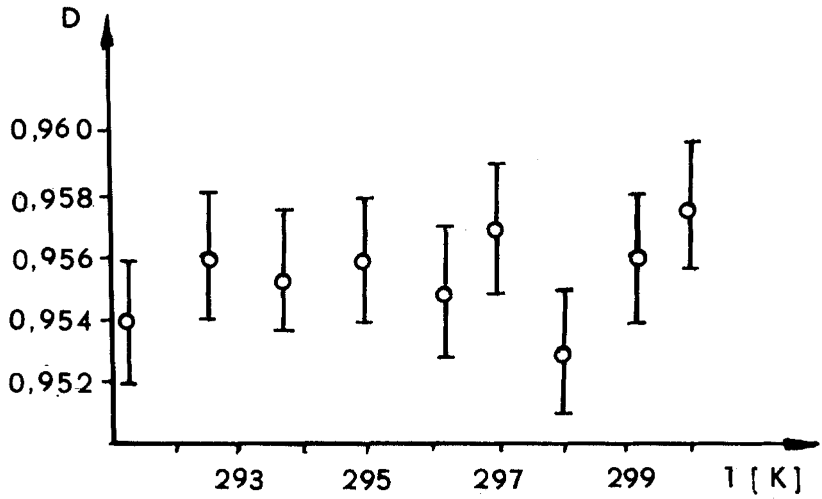

Fig 6. Circular dichroism dependence on temperature for the layer of D mixture with concentration of DBAMB = 11,5% by weight and cell thickness = 12 μm.

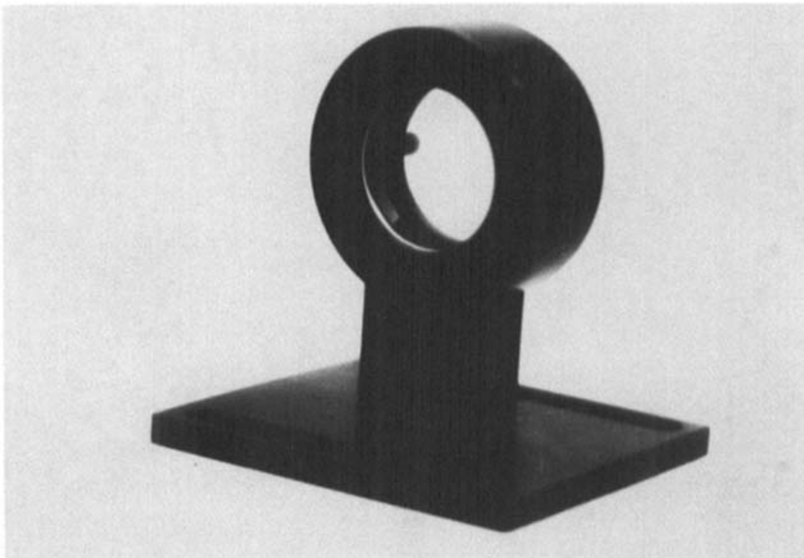

Fig. 7. The view of liquid-crystal circular polarizer.

As it was mentioned above the K value is independent on layer thickness and an orientation angle in wide range of these parameter values. Therefore CLC planar layers can be successfully used as circular polarizers and other elements of laser optics for neodymium laser radiation.

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