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Physics

INFLUENCE OF HYDRODYNAMIC FLOWS ON THE OPTICAL PROPERTIES OF HYBRID ALIGNED NEMATIC LIQUID CRYSTALS

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In this work we study the influence of hydrodynamic flows on the optical properties of hybrid aligned nematic liquid crystals (NLC) structure caused by direct volume expansion mechanism for the case, when the direction of flow velocity is perpendicular to the angular distribution of the molecules in the cell. It has been shown that the hydrodynamic flow leads to reorientation of NLC molecules. The behavior of the polarized light passing through the NLC layer for two opposite directions of the flow was observed.

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Introduction. Nematic liquid crystals are of great interest due to ability of easy reorientation of their director. One of the methods of director reorientation is inducing hydrodynamic flow in NLC, which can be done by changing the external conditions affecting the NLC. The hydrodynamic flow can be generated due to volume expansion [1, 2] by heating the liquid crystal. This mechanism makes it possible to reorientate the director of NLC by using low power laser beams (mW).

The hybrid alignment of NLC, which can be obtained by giving homeotropic orientation to one of the substrates of the cell and planar orientation to another, has a particular interest due to the fact that it‘s director is pre-deformed. Hybrid orientated NLC structures have been investigated both experimentally [3, 4] and theoretically [5]. There is a big interest in these structures because of the ability of creating low threshold colored displays by using hybrid aligned cells [3]. The generation of hydrodynamic flow in hybrid aligned NLC structures caused by direct volume expansion has been studied both theoretically [6] and experimentally [7]. In particular, it has been shown that if we consider the hybrid orientation as a “flexible ribbon”, then the curvature of the “flexible ribbon” is being increased when the flow velocity gradient is directed outside the curvature. And if the gradient is directed into the “flexible

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ribbons", then change of the direction of the curvature may occur. In this work we study the influence of hydrodynamic flows on the optical properties of hybrid aligned NLC structure caused by direct volume expansion mechanism for the case, when the direction of flow velocity is perpendicular to the angular distribution of the molecules in the cell.

Experimental Setup. The experimental setup is shown on Fig. 1. The laser beam of Nd:YAG quasi-continuous laser with Gaussian distribution, $\lambda = 1.06\ \mu m$ wavelength and with $1.7 \pm 0.1\ mm$ beam width on the half-height of the intensity distribution falls on the sample through the prism. The sample consists of two parallel glass substrates, which are separated from each other with spacer. Round holes are made on the top substrate. Two vessels are fastened on that holes as an extra volume for liquid crystal. There is a space between two substrates, through which the liquid crystal can flow from one vessel to another. The sample was placed between crossed polarizers so that the director of NLC molecules on the planar oriented substrate makes 45 degrees angle with polarizers axes. A 640 *nm* wavelength probe beam of the diode laser is used to detect the change in the optical properties of the liquid crystal. The power of the pump beam after passing through the crossed polarizers and cell was measured by means of the Optical Power meter (PM 100, Thorlabs).

The hybrid orientation is achieved by covering one of the glass substrates with HTAB to get homeotropic alignment and another glass substrate was coated by Nylon 6/6 and rubbed with a cloth to get planar alignment. The thickness of the cell was $10.6\ \mu m$ which was given by Teflon spacer. A NLC of E7 type has been used in the experiment.

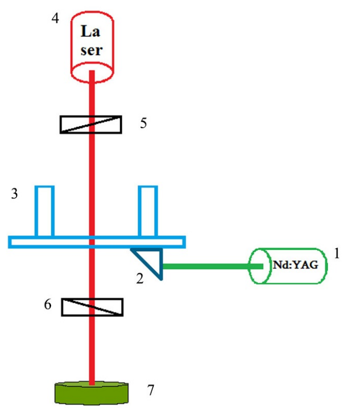

Fig. 1. Scheme of the experimental setup. 1 – Nd: YAG quasi-continuous laser; 2 – prism; 3 – cell; 4 – probe laser; 5, 6 – polarizers; 7 – power meter.

The experiment was performed at room temperature. During the experiment, the two vessels were heated in turn. The heated vessel was hermetically sealed and the other one was released so that the pressure there had been atmospheric. Temperature changes in the heated vessel were recorded through a thermocouple attached to the vessel.

During the experiment, the NLC was warmed up, and after a while, when the current processes stabilized, the laser was turned off and the results were recorded for the NLC cooling process.

Experimental Results. In the experiment, after turning the pump Nd:YAG laser on, a Poiseuille flow of NLC can be seen from the heated vessel to another one in the hybrid aligned cell. Because of the absorption of the laser beam energy, an extra pressure occurs in the heated vessel, which results in the formation of pressure difference in the two vessels of the cell. This difference in pressures leads to the formation of the flow, which results in the reorientation of NLC molecules. To detect the reorientation of molecules a probe laser‘s beam is used. The change in optical properties of NLC is registered by the change of probe laser‘s beam intensity.

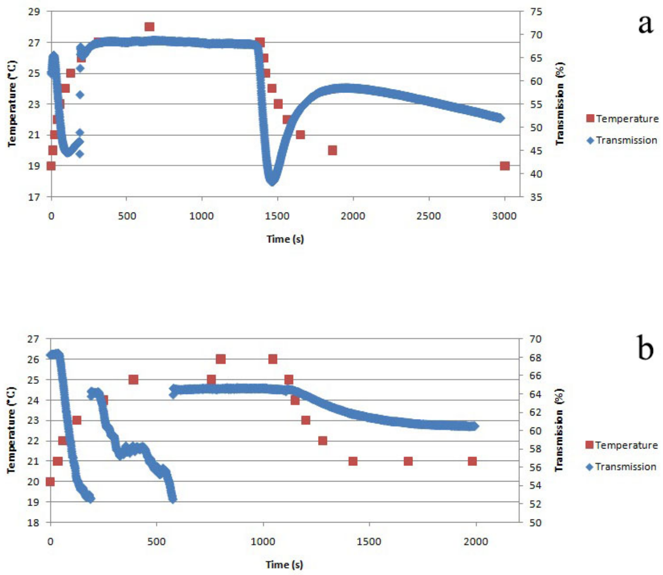

Fig. 2. Dependence of temperature and transmittance coefficient of probe beam on time. In a) and b) cases the directions of hydrodynamic flows are opposed to each other.

The change of cell’s transmittance coefficient for probe laser in case of two opposite directions of the hydrodynamic flow is shown in Fig. 2. In both cases, the liquid crystal was first heated, and then, when the pressure in two vessels became balanced, the pump laser was turned off and the change of probe laser‘s transmittance coefficient was recorded for NLC cooling process. The power of pump laser was 700 mW.

As it can be seen from the results presented in the graphs, the reduction of the probe laser’s transmittance coefficient is first observed. The reason is the emergence of difference in pressures in two vessels, which leads to formation of a hydrodynamic flow. In both cases, 180 s after the start of the experiment, when the temperature of NLC increased by $5°C$ compared to the initial temperature, a jump-like change of transmittance coefficient can be seen. That means that hydrodynamic flow caused reorientation of NLC molecules. In some cases, after the first jump, when the temperature of NLC rises by $1^{\circ}C$, another jump-like change of transmittance coefficient occurs. It is assumed that in these cases, after the first jump, the molecules rotate so the flow velocity gradient is directed into the "flexible ribbon", which leads to the change of the angular distribution of NLC director to the opposite direction. This phenomenon has been observed for different values of laser power.

Conclusion. In this work it has been experimentally shown that the hydrodynamic flows generated by the direct volume expansion mechanism in the hybrid aligned NLC structure cause reorientation of NLC molecules, when the direction of flow velocity is perpendicular to the angular distribution of the molecules in the NLC cell. The reorientation of NLC molecules was detected for both flow directions. In some cases, a secondary jump of transmittance coefficient was observed. It is assumed that it can be the result of change of the angular distribution of the NLC director to the opposite direction.

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