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Physics

ON THE BEHAVIOR OF POLARIZED LIGHT IN TWIST-ORIENTED NEMATIC LIQUID CRYSTALS WITH ANISOTROPIC ABSORBENT DYE

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In this work we study the propagation of light in a twist-oriented pleochroic nematic liquid crystal with pleochroic dye. The dependence of the intensity of transmitted light on the azimuthal angle of the linearly polarized incoming light has been investigated experimentally. As a result, the role of absorption anisotropy has been identified.

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***Keywords*:** anisotropic absorption, polarization, liquid crystal.

Introduction. Light propagation in media with natural or induced anisotropy is currently one of the well-studied sections of optics, with a large number of published monographs [1, 2]. The problem is further complicated by the inhomogeneity of anisotropy. In particular, in a twist-oriented nematic liquid crystal (NLC) the director (optical axis unit vector) is distributed in a spiral pattern. In a number of works [3, 4] it has been shown that adding dye to NLC facilitates the management of devices based on them. Therefore, the interest of researchers in such systems is quite explicable. In particular, the properties of the propagation of linearly polarized light in a nematic liquid crystal-pleochroic dye mixture were theoretically studied in [5,6]. In the rotating coordinate system, it was possible to obtain an analytical solution to the problem and to theoretically investigate the peculiarities of the propagation of linearly polarized light in such mixtures.

The objective of this paper was the experimental investigation of the behavioral characteristics of polarized light in nematic liquid crystals enriched with an anisotropic absorbent dye.

Experimental Setup. Suppose, light propagates in a mixture of an anisotropic absorbent dye and a twist-oriented nematic liquid crystal (Fig. 1). The z axis of the laboratory coordinate system is perpendicular to the glass faces of the sample, the x and y axes are parallel to the main axes of the NLC.

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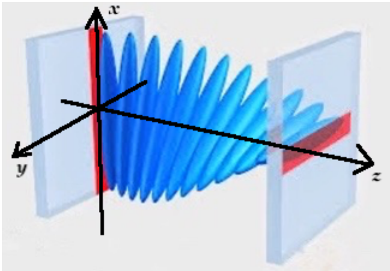


Fig. 1. Aligment of mixed molecules inside the cell.

In the mixture, according to the guest-host phenomenon [7,8], the dye molecules (guest) have the same orientation as the NLC (host) molecules. As is known, linearly polarized light in a twist-oriented NLC follows the pattern of the director (effect of adiabatic following) [1, 8]. Naturally, the phenomenon of adiabatic following is also maintained by the presence of dye molecules (in our case, Methyl Red Crystals molecules which provide absorption anisotropy) [5,6]. However, there are also some peculiarities.

The following experiment was set up to study these peculiarities (Fig. 2). As a light source, a 3b solid-state laser (1) with semiconductor diode impulse was used, delivering 532 *nm* wavelength light. To obtain pure linearly polarized light, the laser beam passed through polarizer (2). To smoothly change the azimuthal angle of the incoming beam, a $\lambda/4$ slab (3) was used which converted linearly polarized light to circularly polarized one. Afterwards, a polarizer (4) was used to filter the required azimuthal angle. A mirror (5) and a recorder (9) were mounted to test the polarization of light during the experiment. A cell containing a mixture of liquid crystal and dye (6) was inserted between polarizer (4) and analyzer (7). (Fig. 2).

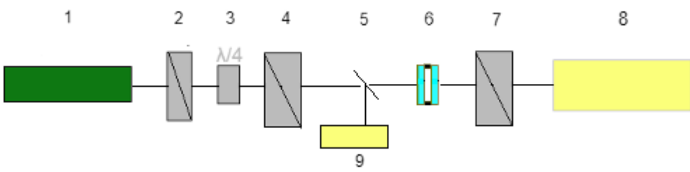


Fig. 2. The experiment diagram. (1) Diode-pumped solid-state LASER, (2) $\lambda/4$ slab, (3) circular pole, (4) linear pole, (5) mirror, (6) cell, (7) analyzer, (8), (9) recorders.

For the preparation of the cell (Fig. 2), a thin polymeric layer was applied on the inner walls of the glass preforms. The twist nature of the cell was ensured by making scratches on the polymeric layers, which also ensured hard boundary conditions. As a result the molecules acquired the arrangement shown in (Fig. 1). The thickness of the cell was ensured by two plastic spacers, placed between the glasses (3, 4 in Fig. 3).

In the experiments the dependence of components of the output intensities I_x and I_y on the azimuthal angle of the input wave was measured. For this purpose, the angle of the molecule at the entrance to the sample and the polarization vector of the incoming light wave were being smoothly changed. The dependence of the components of the output wave intensities I_x and I_y on the azimuthal angle was recorded. In order to demonstrate the characteristics of the adiabatic following more obviously, both pure and dye-doped mixtures were investigated.

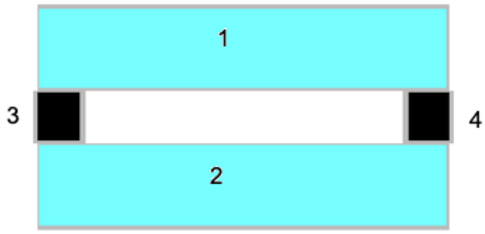
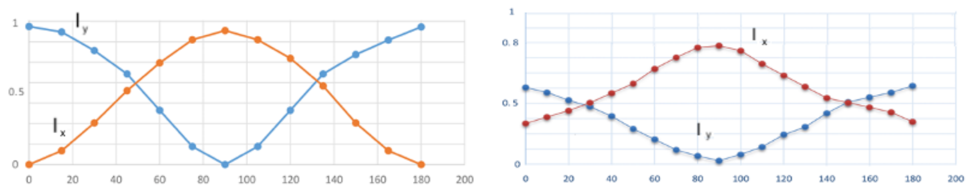


Fig. 3. Cell appearance of 1.2 glass stands 3 and 4 plastic spacers.

Experimental Results. Now let us look at the results. Fig. 4 shows the dependence of the components of the output wave intensities $I_x(\alpha)$ and $I_y(\alpha)$ on the azimuthal angle α. As seen from Fig. 4, a, in the pure NLC adiabatic following is observed, that is, the change of the azimuthal angle of input light results in an equivalent rotation of the polarization of output light. The fact that the sum intensity $I_x(\alpha)+I_y(\alpha)$ is constant is an evidence of the equivalence.



(a) (b)

Fig. 4. Dependent-wave number of the components of the output wave intensities $I_x(\alpha)$ and $I_y(\alpha)$ on the azimuthal angle α: a) twist-oriented pure NLC; b) twist orientation NLC and dye mixture. Specimen thickness is 20 μm.

With the presence of a dye mixture, adiabatic following is still observed, as shown in Fig. 4,b. But there is also a certain peculiarity. Due to the presence of the absorption component, both $I_x(\alpha)$ and $I_y(\alpha)$ are reduced as expected. However, due to the absorption anisotropy, this decrease is different. If the input channel polarization is parallel to the x axis, the output polarization is zero within the accuracy of the experiment. Accordingly, the component $I_y(\pi/2)$ differs from zero at the output, but slightly. A similar picture is observed when the input channel is polarized parallel to the y axis ($\alpha = \pi/2$). Due to adiabatic following, a difference $I_x(\pi/2) > I_y(0)$ arises (see Fig. 4, b). Note, that such a difference is absent in case of pure NLC. Such behavior is due to the absorption anisotropy. When the input channel is polarized parallel to the x axis, due to adiabatic following it always propagates with a large absorption coefficient, so the component I_y is small. In the other case, the light during propagation always stays parallel to the component with a small absorption coefficient, and as a result, the component I_x becomes large. The results obtained are in good agreement with the theoretical results obtained in [5, 6].

Conclusion. Thus, this work demonstrates that the phenomenon of adiabatic following is observed not only in pure twist-oriented nematic liquid crystals, but also in the presence of anisotropic absorbing dye mixtures. However, in the mixture the phenomenon observed has some peculiarities. In particular, the change in the intensity of the light passing through the sample is directly dependent on the polarization state of the incoming wave, which is a result of the competition between the twist-oriented nature of the given phenomenon and the absorption anisotropy.

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ԱՆԻԶՈՏՐՈՊ ԿԼԱՆՄԱՄԲ ՆԵՐԿԱՆՅՈՒԹՈՎ ՀԱՐՍՏԱՑՎԱԾ ԹՎԻՍՏ ԿՈՂՄՆՈՐՈՇՄԱՄԲ ՆԵՄԱՏԻԿ ՀԵՂՈՒԿ ԲՅՈՒՐԵՂՈՒՄ ԲԵՎԵՌԱՑՎԱԾ ԼՈՒՅՍԻ ՎԱՐՔԸ

Այս աշխատանքում հետազոտվել է բևեռացված լույսի տարածումը պլեոքրոիկ ներկանյութային խառնուկ պարունակող թվիստ կողմնորոշմամբ նեմատիկ հեղուկ բյուրեղում: Փորձարարական հետազոտությամբ ուսումնասիրվել է նմուշն անցած լույսի ինտենսիվության կախվածությունը մուտքային ալիքի գծային բևեռացման ազիմուտային անկյունից: Արդյունքում բացահայտվել է կլանման անիզոտրոպության դերը:

А. О. ОВАКИМЯН

ИССЛЕДОВАНИЕ ПОВЕДЕНИЯ ПОЛЯРИЗОВАННОГО СВЕТА В НЕМАТИЧНОМ ЖИДКОМ КРИСТАЛЛЕ, ОБОГАЩЕННОМ АНИЗОТРОПНЫМ ПОГЛОЩАЮЩИМ КРАСИТЕЛЕМ

Исследовано распространение поляризованного света в твист-ориентированном нематическом жидком кристалле, содержащем молекулы плеохроничного красителя. Экспериментально исследована зависимость интенсивности света на выходе образца от азимутального угла линейной поляризации входного света. В результате была выявлена роль анизотропии поглощения.