

Highly efficient optical director reorientation of liquid-crystalline polymer induced by dye additivesI. A. Budagovsky, V. N. Ochkin, S. A. Shvetsov,^{*} and A. S. Zolot'ko[†]
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Light-induced director orientation of polymeric liquid-crystalline systems was investigated. The materials under study were composed of a nematic liquid-crystalline polymer (NLCP) and a small amount (0.05–0.5 wt.%) of conformationally active (azobenzene) or stable (anthraquinone) dye impurity. Light action on the homogeneously aligned polymer films above glass transition temperature leads to the director reorientation and, consequently, to a change in the extraordinary refractive index. The effect is associated with the dye molecule excitation and related change of intermolecular forces. In the case of NLCP with conformationally active dye dopant, an extremely high orientational optical response was detected (nonlinear coefficient is $n_2 \sim 0.1 \text{ cm}^2/\text{W}$). In contrast, the efficiency of orientational light action on NLCP with conformationally stable dye dopant is of the same order of magnitude as that of dye-doped low-molar-mass liquid crystals. At the normal light incidence on the NLCP doped with azo-dye, the threshold director orientation is observed which is similar to the Fréedericksz transition under the action of magnetic and electric fields. The obtained high-orientational optical response of NLCP caused by azo-dye dopant in combination with the possibility of the recording of deformed structure in the glassy state, typical for polymer compounds, reveals new opportunities in photonics applications.

DOI: [10.1103/PhysRevE.95.052705](https://doi.org/10.1103/PhysRevE.95.052705)**I. INTRODUCTION**

Smart stimuli-responsive materials, among which are nematic liquid-crystalline polymers (NLCPs), attract much attention due to the wide variety of possible practical applications [1]. In this context, the light-induced orientation processes are of special interest, since light is a very convenient tool for the manipulation of structure and optical properties of condensed matter [2,3]. In these materials, high optical sensitivity is caused by the presence of light-absorbing fragments (chromophores). Due to the unique combination of photosensitivity and tendency to self-assembly the liquid-crystalline polymers are promising materials for developing optical memory systems, holographic materials, diffraction elements, etc. [4,5].

The first observation of a change in the orientation of the NLCP under the light action was reported in [6,7]. It was shown that the linearly polarized light incident on a planar film of NLCP with azobenzene light-absorbing fragments affects the polarization dependence of the absorption coefficient; the latter tends to minimum for the direction parallel to the light polarization. Although this resembles, at first glance, the director rotation of the absorbing NLCP, the phenomenon proved to be more complex. As shown in [8], the effect of linearly polarized light on an absorbing NLCP results in a decrease of the order parameter and, as in the case of amorphous azobenzene polymers, the formation of a negative optical axis (optical anisotropy $n_e - n_o < 0$) along the light field vector. Thus, the chromophore excitation leads to

significant distortion and rearrangement of angular distribution of mesogenic groups of NLCP.

Previously, studies of light-induced orientation of NLCP were performed on the highly absorbing systems containing large concentration (~ 10 wt.%) of azobenzene side-chain groups [3]. In our recent communications [9,10] the orientation processes in optically transparent NLCPs and weakly absorbing mixtures of NLCPs and a small amount (< 0.1 wt.%) of an azobenzene compound were reported. In this case, in contrast to highly absorbing NLCPs, the light-induced director reorientation without changing the order parameter was found in the NLCPs.

In the transparent (undoped) NLCP, the director rotates to the light field due to the positive dielectric anisotropy at the light frequency. In this case, the refractive index of the extraordinary wave increases. In the dye-doped NLCP, the director rotation is due to the excitation of dye molecules. The typical value of light intensity required for the director reorientation is 4 orders of magnitude lower than that for the undoped NLCP.

In this paper we report a detailed study of the optical orientation in NLCPs with low-concentration absorbing dopants. The influence of light polarization on optical director orientation is considered. Two types of dopants are used: the conformationally active azobenzene dye capable of trans-cis photoisomerizing and the conformationally stable anthraquinone dye. The comparison of light-induced response in the samples under study allows us to reveal features of orientational effects in polymeric systems.

II. EXPERIMENTAL

In the experiment, polyacrylate PAA (a comb-like polymer with mesogenic fragments; see Fig. 1) was used as an NLCP. Its degree of polymerization was 82; the polydispersity index

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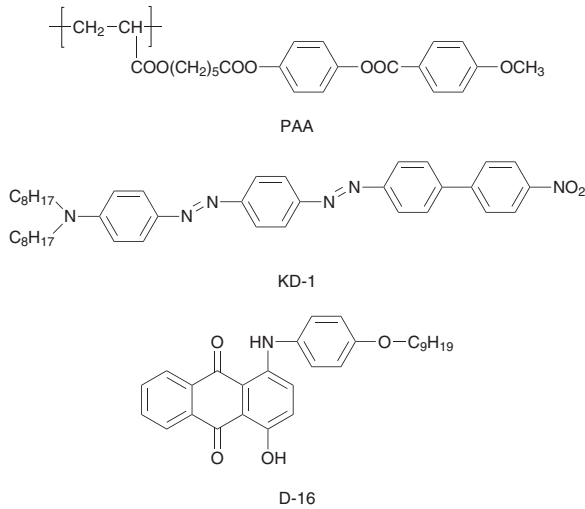


FIG. 1. Structural formulas of polymer PAA, azobenzene dye KD-1, and anthraquinone dye D-16.

was ~ 1.2 . PAA exhibits the nematic phase below 123°C ; the glass transition occurs at 26°C . We studied the samples of the PAA polymer doped with absorbing compounds of two types: the conformationally active azobenzene dye KD-1 (0.05 wt.%) and the conformationally stable anthraquinone dye D-16 (0.5 wt.%) (see Fig. 1). The homogeneous planar alignment of the samples was obtained using the cells with glass plates coated with rubbed polyimide layers. The polymer film thickness was $L = 50\ \mu\text{m}$. The absorption coefficients of the extraordinary (α_e) and ordinary (α_o) waves were measured with an MC-122 spectrometer (Proscan Special Instruments) at room temperature. The absorption coefficients of PAA+0.05% KD-1 were $\alpha_e = 173\ \text{cm}^{-1}$ and $\alpha_o = 29\ \text{cm}^{-1}$ at $\lambda = 473\ \text{nm}$. For PAA+0.5% D-16, we found $\alpha_e = 644\ \text{cm}^{-1}$ and $\alpha_o = 210\ \text{cm}^{-1}$ at $\lambda = 532\ \text{nm}$.

The nonlinear optical response of NLCPs was studied by the method of aberrational self-action of a light beam [11]. The influence of light on a nematic can give rise to the director reorientation or a change in the order parameter S . The wave front of the light beam becomes distorted, which results in the formation of the aberrational pattern shaped as a system of concentric rings. The number of rings N is simply related to the light-induced refractive index on the beam axis

$$|\Delta n| = \frac{N\lambda \cos \beta}{L}, \quad (1)$$

where β is the angle of refraction.

A schematic of the experimental setup is shown in Fig. 2(a). A light beam of a cw neodymium laser 1 ($\lambda = 473$ or $532\ \text{nm}$) was focused into the NLCP cell by the lens 4. The angle α of light incidence on the NLCP cell 5 could be varied by rotating the cell about the vertical axis OZ. The angle of the polarization plane rotation φ [see Fig. 2(b)] was changed with the help of the double Fresnel rhomb 3. The polarization behind the cell was analyzed by the polarizer 6. The aberration pattern was observed on the screen 7.

The light beam was attenuated by a neutral-density filter 2. The power of the beam incident on the NLCP cell was measured by an LP1 power meter (Sanwa Electric Instruments).

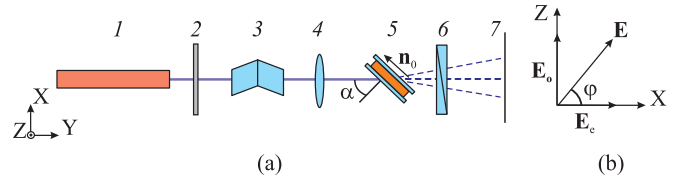


FIG. 2. (a) Schematic of the experimental setup: (1) cw neodymium laser ($\lambda = 473$ or $532\ \text{nm}$), (2) neutral-density filter, (3) double Fresnel rhomb, (4) lens, (5) NLCP, (6) polarizer, (7) screen; α is the angle of the light incidence on the sample. (b) E_e and E_o are electric fields of extraordinary and ordinary light waves, φ is the angle of the polarization plane rotation, and E is the light field incident on NLCP.

The samples were placed between heating plates. The temperature of the samples was set as $T = 110^\circ\text{C}$ and controlled by a thermocouple.

III. RESULTS

A. Light-induced director reorientation in NLCP doped with azobenzene dye

The effect of light beam on the orientation of the PAA+0.05% KD-1 cell was studied at a wavelength of $473\ \text{nm}$. The development of the aberration pattern in the form of the system of rings, the phenomenon well known for the orientational optical nonlinearity of low-molecular-mass nematic liquid crystals (NLCs), occurred under action of the extraordinary wave [Fig. 3(a)].

Irrespective of the geometry of light interaction with the NLCP, shifting the cell upward with respect to the light beam resulted in the disappearance of the upper portion of the aberrational pattern [Fig. 3(b)]. This corresponds to a “negative lens” formation in the medium; i.e., self-defocusing occurs in the medium [11]. When the ordinary component was added to the incident beam (by rotating the plane of the polarization by an angle φ), it passed through the NLCP without substantial divergence [Fig. 3(c)]. This excludes the contribution of the nonlinearities associated with the order parameter change, in particular, the thermal nonlinearity. The

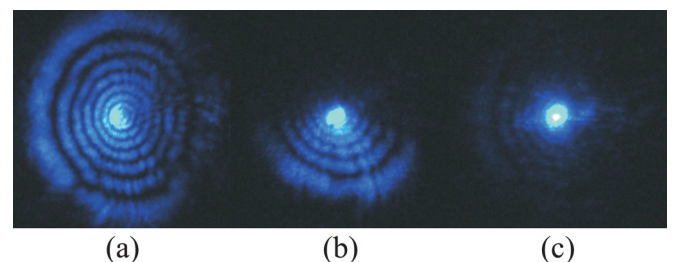


FIG. 3. (a) The aberrational pattern developed during 40 min under illumination of the PAA+0.05% KD-1 cell at 110°C with the normally incident light beam of the extraordinary polarization ($\varphi = 0^\circ$). The light wavelength is $473\ \text{nm}$; the light intensity on the beam axis is $I_e = 0.8\ \text{W}/\text{cm}^2$. (b) The pattern formed upon rapid upward shift of the cell with respect to the light beam. (c) The pattern formed upon rapid rotation of the polarization plane from $\varphi = 0^\circ$ to $\varphi = 90^\circ$. The angular size of the photographs is $\sim 0.2\ \text{rad}$.

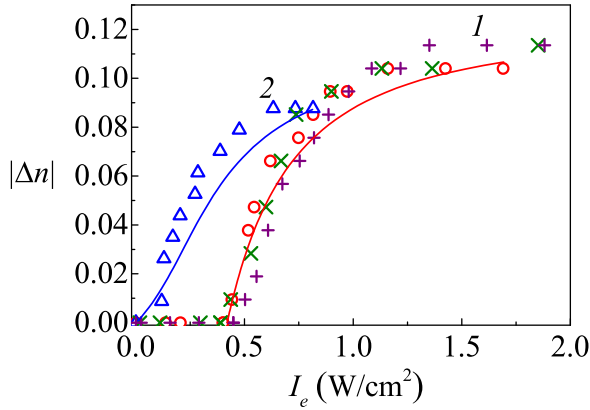


FIG. 4. Experimental dependencies of the steady-state magnitude of the light-induced refractive index $|\Delta n|$ on the intensity I_e of the extraordinary component of the light field at (o, x, +) normal and (Δ) oblique incidence ($\alpha = 40^\circ$) of the light beam on the PAA+0.05% KD-1 cell at 110 °C. The angle of the polarization plane rotation at the normal incidence φ is (o, Δ) 0°, (x) 30°, (+) 60°. Curves (1) and (2) for the normal and oblique incidence are constructed by formulas (5) and (8).

relaxation of the aberration pattern with a characteristic time of $t_0 \sim 17$ min (at 110 °C) was observed in a probe beam, the same light beam with lower intensity and illumination time about several seconds to avoid light action on the NLCP. The data obtained indicate the orientational nature of the observed negative optical nonlinearity: under action of the light field, the NLCP director rotates away from the light field direction thus decreasing the refractive index of the extraordinary wave. It is noteworthy that cooling of the sample to room temperature completely preserves the obtained aberrational pattern because the mesogen group’s rotational mobility is completely frozen in the glassy state [12].

The number of the steady-state aberrational rings N and thus the light-induced refractive index $|\Delta n|$ increased monotonically with the intensity of the light wave of the extraordinary polarization $I_e = I \cos^2 \varphi$ where I is the total intensity of light beam. At the normal light incidence on NLCP, the dependence of $|\Delta n|$ on I_e shows the threshold behavior (Fig. 4, curve 1). The threshold of the NLCP director reorientation was $I_e^{(th)} = 0.4$ W/cm² and did not change with an increase in the angle φ (i.e., with adding the ordinarily polarized component of the light beam). The time of the aberrational pattern development near the threshold is about 1 h. With a departure from the threshold, this time significantly decreases. The increase in the intensity by an order of magnitude leads to the reduction of the development time to several minutes.

At the oblique light incidence on NLCP, the dependence of the steady-state quantity $|\Delta n|$ on the intensity I_e has no threshold (Fig. 4, curve 2). In this case, the nonlinear optical response increased: the saturation of $|\Delta n|$ occurred near $I_e^{(th)}$. The steady-state value of $|\Delta n|$ is lower than at the normal incidence. This is explained by the smaller possible angle of the director rotation ($90^\circ - \beta$ instead of 90°).

Thus we can conclude that the light action on NLCP is similar to the action of low-frequency electric [13,14] and

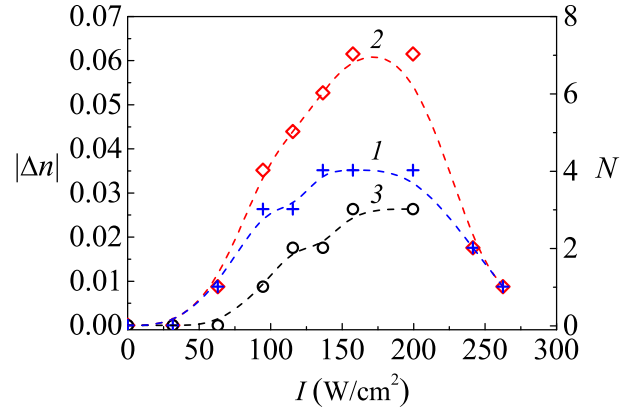


FIG. 5. Dependencies of steady-state magnitude of the light-induced refractive index $|\Delta n|$ and the number of aberrational rings N of the self-defocusing pattern on the intensity I ($\varphi = 0^\circ$) at the oblique incidence of the light beam ($\lambda = 532$ nm) on the PAA+0.5% D-16 cell at 110 °C; (1) the total number of rings N and corresponding $|\Delta n|$, (2) N and $|\Delta n|$ due to thermal effect, and (3) N and $|\Delta n|$ due to the orientational contribution to the self-defocusing.

magnetic fields [15]. In the case of the normal incidence of light beam on the NLCP cell, the threshold orientation occurs, which is similar to the Fréedericksz transition. In comparison with NLCs, we observed very strong optical nonlinearity. The nonlinear coefficient $n_2 \sim 0.1$ cm²/W, $|\Delta n| = n_2 I$ is at least one order of magnitude higher than the values for dye-doped NLCs [16].

B. Light-induced director reorientation in NLCP doped with anthraquinone dye

Polymer PAA doped with conformationally stable dye D-16 was illuminated with the obliquely incident ($\alpha = 40^\circ$) light beam ($\lambda = 532$ nm) of extraordinary polarization. Two stages were found in the development of the aberrational pattern. First, the fast development (during ~ 0.1 s) of the aberrational pattern occurred (Fig. 5, curve 1). Further illumination during ~ 10 min resulted in the slower increase in the number of aberrational rings (Fig. 5, curve 2). The relaxation of the aberrational pattern observed in the probe beam also involved two stages with similar characteristic times. The first stage of the aberrational pattern development is due to NLCP heating in the illuminated region. The heating decreases the order parameter S and the refractive index n_e of the extraordinary wave [17]. Further slower increase in the number of the aberrational pattern is due to the NLCP director rotation away from the light field direction. The decrease in the total number of aberrational rings at $I > 200$ W/cm² is related to the significant decrease in the order parameter S ; at $I > 300$ W/cm², the NLCP transition to the isotropic phase occurs in the illuminated region. By subtracting the thermal contribution from the total magnitude of the light-induced refractive index, we found the corresponding value due to the NLCP director rotation (Fig. 5, curve 3).

Thus, in NLCP doped with conformationally stable anthraquinone dye, two types of nonlinear optical response were observed. The first one, the “thermal” response, is caused by the order parameter decrease at laser heating. The second

one, the orientational optical response, is due to optical torque produced by dye dopant excitation.

C. Estimation of the enhancement factors of NLCPs

To quantitatively describe the effect of dye on the orientation response, we shall use the enhancement factor [18] η that is the proportionality coefficient between the optical torques Γ_{tr} and Γ_{dye} on undoped and dye-doped nematics,

$$\Gamma_{\text{dye}} = \eta \Gamma_{\text{tr}}. \quad (2)$$

The magnitude of the enhancement factor can be experimentally estimated as the ratio of light intensities required for inducing the same magnitude of the refractive index $|\Delta n|$ in undoped and doped NLCPs. At the oblique ($\alpha = 40^\circ$) incidence of the light beam with the wavelength $\lambda = 532$ nm and intensity $I = 5$ kW/cm² on undoped NLCP the change in the refractive index magnitude was $|\Delta n| = 0.02$ [10]. The same value of $|\Delta n|$ was obtained for similar experimental conditions at the intensity $I = 0.2$ W/cm² for NLCP doped with KD-1 and at $I = 130$ W/cm² for NLCP doped with D-16. Thus, the enhancement factors for NLCPs doped with KD-1 and D-16 are $\eta^{(\text{KD-1})} \sim -3 \times 10^4$ and $\eta^{(\text{D-16})} \sim -40$.

To compare the effect of different absorbing dopants, it is convenient to use the ratio of the enhancement factor to the sample absorption averaged over the director orientation [$\eta_\alpha = \eta/(\alpha_e + 2\alpha_o)$] [19]. The quantity η_α is -10 cm and -0.04 cm for KD-1 and D-16, respectively.

IV. DISCUSSION

A. The effect of dye dopants on nonlinear optical response

Under light action on NLCPs doped with azobenzene and anthraquinone dyes, the refractive index of the extraordinary wave decreases, which is due to the NLCP director rotation away from the direction of the light field of the extraordinary wave. As in the case of the dye-doped NLCs, the rotation originates owing to the orientationally selective excitation of dye molecules and related change in the interaction with host molecules [18].

At the normal light incidence on the PAA+0.05% KD-1 cell, a threshold director reorientation similar to the Fréedericksz transition in low-frequency fields is observed. The threshold light-induced director reorientation is also inherent in undoped and dye-doped NLCs [19,20]. In the latter case, the threshold intensity is $I^{(\text{th})} \sim 10$ W/cm². At the same time, the $I^{(\text{th})}$ value for the polymeric PAA+0.05% KD-1 system is at least one order of magnitude lower.

Now, let us compare the efficiencies of the light influence on the orientation of various liquid-crystalline systems. To this end, we consider the values of the enhancement factor normalized to the sample absorption η_α . The quantity $|\eta_\alpha|$ for NLCP doped with KD-1 dye exceeds by two orders of magnitude the corresponding value of 0.1 cm for the low-molecular-mass system with the same dye determined from data of [21] and exceeds by one order of magnitude the maximum value of 2.3 cm for NLC doped with an azobenzene-containing side-chain polymer [19]. At the same time, the quantity $|\eta|/\alpha_o = 0.14$ cm for NLC doped with the conformationally stable dye D-16, measured in [22], is

comparable to the value for NLCP doped with the same dye ($|\eta|/\alpha_o \sim 0.2$).

A significant increase of the quantity $|\eta_\alpha|$ for NLCP doped with KD-1 can be explained as follows. The value of the optical torque induced by a dye is determined by the shortest of the two times: the time of the rotational diffusion t_D or the lifetime of the excited state t_{exc} [23,24]. The rotational diffusion time varies from $t_D \sim 0.1$ ns for the NLCs to $t_D \sim 0.1$ μ s for NLCPs [25]. For the conformationally active azobenzene dye, its metastable cis form can be taken as the “excited” state. The lifetime of the cis form t_{cis} of different azobenzene-containing compounds at room temperature varies in a wide range from milliseconds to several days [26]. In the case of KD-1, from measured activation energy $E_a = 120$ J/mol, the t_{cis} is estimated to be 10^{-3} s at the temperature of 110°C . Thus, the orientational response of liquid-crystalline systems with azobenzene dopant is determined by the rotational diffusion time of the dye t_D and significantly increases in passing from low-molar-mass to polymeric nematic matrices. It also shows the way to increase the efficiency of light action on azo-dye-doped nematics by inhibition of the rotational diffusion of chromophores. In particular, this can be the reason for an increase of orientational optical response of NLCs doped with a polymeric azo-compound instead of a low-molar-mass one [27].

It should be noted that the effect of rotational diffusion time on nonlinear optical response reveals itself also in guest-host systems which consist of an isotropic medium and dye dopant. The increase of the nonlinear optical response at increasing the viscosity with lowering the temperature was observed in dye-doped glycerin [28] and dye-doped NLCs in the isotropic phase [29–31].

For the conformationally stable anthraquinone dye D-16, the orientational response of the anisotropic medium is determined by the lifetime of the excited electron state $t_{\text{exc}} \sim 1$ ns [32] and does not depend on the viscosity of the nematic matrix. This fact explains the similar optical response induced by anthraquinone dye in NLCP and NLC.

B. The effect of light polarization on nonlinear optical response

Another feature of the orientational light influence on NLCP doped with the azobenzene dye KD-1 is the fact that the ordinary component of the light wave does not affect the NLCP director reorientation. At the same time, the dependence of the nonlinear optical response on the angle between the light field and director (sign-inversion nonlinearity) is typical of the NLCs doped with azobenzene dyes, including KD-1 [21,33]. Namely, in a planar NLC doped with KD-1, the director rotates to the light field increasing the refractive index of extraordinary light waves n_e at the angle of incidence $\alpha < 26^\circ$, and at higher values of α , the director rotates from the light field decreasing n_e [21]. The sign and value of the nonlinear optical response can also be controlled by the changing of light polarization [34,35].

The influence of light polarization on light-induced NLC director orientation is associated with the peculiarity of azobenzene dopants. The nonlinear optical response of NLCs is specified by the ratio of cis and trans isomers in the light field [36,37]. The ratio of isomers depends on polarization and intensity I of the light beam and its interaction geometry

with the nematic medium. At the intensity $I \gg I_{st}$ ($I_{st} = \hbar c / \lambda \sigma_{cis} t_{cis}$; σ_{cis} is the absorption cross section of cis isomer), the isomer ratio approaches the saturation value and ceases to depend on I . For the NLCP with KD-1 dopant, the magnitude of light intensity used in experiment is one or two orders lower than the value of I_{st} . This leads to a low concentration of cis isomers and, consequently, the dominating excitation of the trans isomers, which, according to [36], induce the negative nonlinearity ($\Delta n < 0$). Thus, the light-induced reorientation is determined by trans isomers of the dopant and qualitatively does not differ from the light action on nematics with conformationally stable dye dopant. This means that the enhancement factor is $\eta = \text{constant}$, and the optical torque acting on the NLCP depends only on the intensity of the extraordinary wave I_e .

A similar mode of dye-doped NLC orientation at light intensities lower than the value for cis-trans photoisomerization saturation was observed in [38].

C. Calculation of optical director reorientation

Let us give the theoretical description of the observed orientation phenomena. We use the equation of torque balance in the one-constant approximation and assume the rigid boundary conditions for the director field. Equating the sum of the viscous, elastic, and optical torques [35], we obtain

$$-\frac{\partial \psi}{\partial \tau} + \frac{\partial^2 \psi}{\partial \zeta^2} + \eta \delta_e \sin(\psi + \beta) \cos(\psi + \beta) = 0, \quad (3)$$

where $\tau = t / \tau_0$ ($\tau_0 = \gamma L^2 / \pi^2 K$) is the dimensionless time, $\zeta = \pi y' / L$ is the dimensionless coordinate y' along the normal to the cell layers, $\delta_e = \Delta \varepsilon \eta |A_e|^2 L^2 / 8 \pi^3 K$ is the dimensionless intensity of the extraordinary component of the light beam, ψ is the angle of the director rotation, γ is the rotational viscosity coefficient, K is the Frank elastic constant, A_e is the amplitude of the extraordinary component \mathbf{E}_e of the light field, and $\Delta \varepsilon$ is the dielectric anisotropy of NLCP at the light frequency.

Assuming the sinusoidal distribution of the angle of the director rotation over the NLCP thickness

$$\psi = \psi_m \sin \zeta, \quad (4)$$

where ψ_m is angle of director rotation in the layer midplane ($y' = L/2$), multiplying (3) by $\sin \zeta$, and integrating over the interval $0 < \zeta < \pi$, we arrive at

$$\frac{d\psi_m}{d\tau} = -\psi_m + \delta_e [J_1(2\psi_m) \cos 2\beta + E_1(2\psi_m) \sin 2\beta], \quad (5)$$

where $J_1(x)$ and $E_1(x)$ are the Bessel and Weber functions of the first order.

For the normal light incidence on NLCP, Eq. (5) linearized in ψ_m takes the form

$$\frac{d\psi_m}{d\tau} = \psi_m (\delta_e - 1). \quad (6)$$

Equation (6) has a stable zero solution at $\delta < \delta_{th} = 1$ and describes the threshold-type director reorientation at $\delta > \delta_{th}$. To relate the director rotation angle and the light-induced refractive index, we use the approximate formula

$$|\Delta n(\psi)| = \delta n \sin^2 \psi, \quad (7)$$

where $\delta n = \sqrt{\varepsilon_{\parallel}(\varepsilon_{\parallel} - \varepsilon_{\perp})} / 2\varepsilon_{\perp}$ (ε_{\parallel} and ε_{\perp} are the principal values of the permittivity tensor of NLCP). Integrating (7) over the NLCP layer thickness with regard to (4), we obtain the average change in the index of refraction

$$\begin{aligned} |\Delta n(\psi_m)| &= \frac{1}{\pi} \int_0^{\pi} |\Delta n_{\psi}(\zeta)| d\zeta \\ &= \frac{\delta n}{2} [1 - J_0(2\psi_m) \cos 2\beta - E_0(2\psi_m) \sin 2\beta], \end{aligned} \quad (8)$$

where $J_0(x)$ and $E_0(x)$ are the Bessel and Weber functions of the zero order.

Curves in Fig. 4 represent the steady-state solutions to Eq. (5) with regard to (8) for the normal (curve 1) and oblique (curve 2) incidence on NLCP. In calculation, the value of δn was taken as 0.15. The obtained results are in good agreement with experiment. However, the calculated values of $|\Delta n|$ are somewhat lower in the saturation region, which is owing to the sinusoidal approximation (4) of the light-induced director rotation angle.

Thus the light-induced director reorientation in NLCP can be described as the elastic deformation under assumption of rigid boundary conditions.

V. CONCLUSIONS

The light-induced director orientation of NLCPs doped with azobenzene and anthraquinone dyes has been studied. The NLCP doped with conformationally active (azobenzene) dye demonstrates extremely high orientational optical response with respect to low-molar-mass NLCs doped with the azobenzene dye. In particular, the enhancement factor of the optical torque related to the chromophore excitation is more than one order of magnitude higher than the corresponding value for the dye-doped NLCs, whereas the threshold intensity is more than one order of magnitude lower. This increase is explained by an increase in the rotational diffusion time of the azobenzene dye in the polymeric matrix. In the case of conformationally stable (anthraquinone) dye dopant, the orientational optical response of NLCP was of the same order of magnitude as in the case of NLC doped with the same dye.

The orientational optical response of NLCP doped with azobenzene dye does not change at the addition of the ordinarily polarized component of a light wave, in contrast to NLC with the same dopant. This feature is due to a small concentration of dye cis isomers in the light beam of low intensity ($\sim 1 \text{ W/cm}^2$).

A very important advantage of the polymer systems in comparison with NLCs is the possibility of fixation of photoinduced spatial director distribution in the solid glassy state, which makes possible the recording of stable patterns promising for different photonics applications.

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