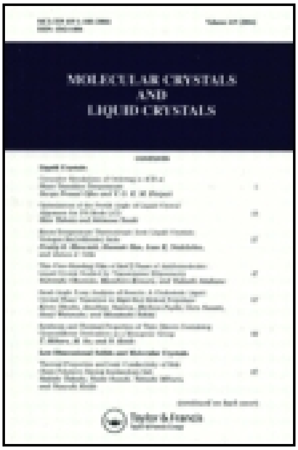

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Relaxation of Reactive Index Grating Caused by Short Laser Pulses in Oriented NLC

Anatoliy A. Kovalev [a], Natalia A. Usova [a], Vladimir N. Sadovsky [a] & Svetlana V. Serak [a]

[a] Institute of Electronics, Belarus National Academy of Sciences, Logoisky Trakt 22, Minsk, 220090, Belarus

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Anatoliy A. KOVALEV, Natalia A. USOVA, Vladimir N. SADOVSKY and Svetlana V. SERAK
Institute of Electronics, Belarus National Academy of Sciences,
Logoisky Trakt 22, Minsk, 220090, Belarus

The effect of flow-reorientation coupling on to the relaxation process of refractive index grating in nematic liquid crystals has been theoretically investigated. It is shown that in case of oblique incidence of the two beams onto the homeotropic cell the shear flow induced by the electromagnetic field can enhance the amplitude of the director reorientation to about ten times.

Keywords: liquid crystals; nematic; flow-reorientation coupling effect

INTRODUCTION

The investigations of the interaction of laser radiation with liquid crystals is an important problem of fundamental and applied physics because of the variety of physical mechanisms responsible for the refractive index changes[1-5] and rather high constants of optical nonlinearities. Most of the traditional nonlinear optical phenomena such as forced light scattering, multiwave mixing, phase conjugation and so on [5-9] were demonstrated and investigated in liquid crystal mesophase. Light-induced director reorientation is one of the important and well investigated mechanism with very high (giant) nonlinear constant. It allows to use low power cw lasers to demonstrate nonlinear effects [5]. Such a big nonlinear constant is closely connected with slow response time (up to seconds) of this effect. For the observation of the reorientation effects in short time range (ns, ps) in substantially nonstationary regime one must use more traditional for nonlinear optic devices such as ruby and Nd:YAG lasers with pulse energy from 10^{-3} -1 J [6,7,10-12]. In this case the magnitude of nonlinear effects become of the same range as nonlinear effects in ordinary liquids, but fast reorientation broadens possible application of liquid crystals in nonlinear devices. For this reason transient phenomena in liquid crystals have been intensively investigated within a last decade by means of dynamic grating technique [2,4,11,12]. The experiments show that dynamic response of liquid crystals to the short intense laser pulses is rather complex and depend on the geometry of experiment. Mutual arrangement of the director, wave vectors and wave polarizations are important. The theory of refractive index changes connected with the collective motion of molecules in liquid crystals is based on the full hydrodynamic set of equations, because they arise due to the modulation in density, temperature and the director reorientation. In the case of nematic liquid crystals the set of Ericksen-Leslie equations consist of 7 coupled equations for 7 variables: density, temperature, two independent components of the nematic director, and three components of flow velocity. In the case of small deviations of hydrodynamic variables from equilibrium values the linearization of nematodynamic equations is correct. In a linear system any motion can be expressed as a sum of simple motions which are eigenmodes of the system. Each eigenmode contributes to the total motion with the amplitude depending on the forces acting onto the system and geometry of excitation. The set of NLC eigenmodes consist of two longitudinal sound waves, nonpropagating (overdumped) thermal mode and 2 pairs of nonpropagating modes connected with the flow and director reorientation [13]. Two of them with damping constants $\tau_{slow}^{-1} \approx Kq^2 / \mu$ (dispersion low) are slow. They correspond to slow relaxation of curved director with the torque due to Frank elasticity of LC. The other two are fast modes with damping constants $\tau_{fast}^{-1} \approx \mu q^2 / \rho$. The relaxation rate of fast modes is a characteristic of a shear waves in LC. They are analogues to the shear waves in a fluid. In the experiments the short pulse laser action onto liquid crystals conditions of small deviations of hydrodynamic variables from equilibrium values are fulfilled. Most of such experiments deal with the excitation of sound waves, thermal and slow modes. The time-resolved grating experiments made by Khoo [11] and Eichler [12] with co-workers showed that maximum of diffracted beam intensity was achieved with some delay after the pulse was over. Qualitatively this is a manifestation of the fast mode and hence the demonstration of the importance of the flow-reorientation coupling effect. This effect is not simple for quantitative analysis because one should solve a full set of nematodynamic equations taking into account cross terms.

In this paper we present the detail calculations of flow-reorientation coupling effect in relaxation of refractive index grating caused by short laser pulse in nematic LC. The calculations are based on the approached which we had developed earlier [14,15] for the common case without making usual one-constant approximation. We have calculated the angular dependence of diffracted beam amplitude for planar and homeotropic cells. We have estimated the role and contribution of different forces, responsible for the effect as well.

CONSTITUTIVE EQUATIONS

The main set of nematodynamic equations consist of four laws: conservation of mass, linear momentum, energy and total angular momentum [16]

$$\begin{aligned} &\dot{\rho} + \rho v_{i,j} = 0 \\ &\rho \dot{v}_i = t_{ji,j} + F_i \\ &\rho \dot{u} = Q - q_{i,i} + t_{ji} d_{ij} + \pi_{ji} N_{ij} - g_i N_i \\ &\rho_1 \ddot{n}_i = G_i + g_i + \pi_{ji,j} \end{aligned} \tag{1}$$

where ρ is mass density, v_i - is i-th component of flow velocity, $t_{ji} = t^0{}_{ji} + t'_{ji}$ is stress tensor associated with the medium, F_i is i-th component of any applied body force per unit volume. n_i is i-th component of the director, u is internal energy per unit mass, Q-is the heat supply function, q_i - i-th component of heat flow, $d_{ij} = (v_{i,j} + v_{j,i})/2$, $N_{ij} = n_{i,j} - \omega_{ik} n_{k,j}$; $N_i = \dot{n}_i - \omega_{ij} n_j$; $\omega_{ij} = (v_{i,j} - v_{j,i})/2$. π_{ji} - is the torque stress tensor, G_i, g_i are external and intrinsic forces acting onto the director, ρ_1 is inertial moment. $\rho_1 \approx 10^{-16} kg/m$ and usually is not taken into account. Dissipative (viscous) part of stress tensor is $t'_{ji} = \mu_1 n_k n_p d_{kp} n_i n_j + \mu_2 n_j N_i + \mu_3 n_i N_j + \mu_4 d_{ij} + {}$ ${} + \mu_5 n_k n_j d_{ki} + \mu_6 n_k n_i d_{kj}$, μ_{1-6} - Leslie's viscosities. In a linear approximation only hydrostatic pressure P contribute to the static part of stress tensor $t^0{}_{ji} \approx -P\delta_{ij} \approx -((\partial P/\partial T)_\rho \delta T + (\partial P/\partial \rho)_T \delta\rho)\delta_{ij} = -(\chi_0 \rho_0 V_T{}^2 \delta T + V_T{}^2 \delta\rho)\delta_{ij}$; $\pi_{ji} = \partial F/\partial n_{j,i}$; $F = ((K_{11} - K_{22}) n_{k,k} n_{m,m} + K_{22} n_{k,m} n_{k,m} + (K_{33} - K_{22}) n_k n_n \cdot$ $\cdot n_{m,k} n_{m,n})/2$ is elastic Frank energy. K_{ii} are elastic constants, $g_i = g^0{}_i + g'_i$; $g^0{}_i = -\partial F/\partial n_i$; Dissipative part of intrinsic force $g'_i = \lambda_1 N_i + \lambda_2 d_{ij} n_j$ is a flow coupling term. It ensure that viscous flow may cause the reorientation of the director. Part of the viscous stress tensor $\mu_2 n_j N_i + \mu_3 n_i N_j$ entering to the second equation also ensure a flow-reorientation coupling because of $\dot{n}$. Thus reorientation of the director cause the flow.

It is known that the calculation of ponderomotive forces arising due to the interaction of electromagnetic field with liquid crystals can be made on the base of Maxwell stress tensor [17-19]. The expression of Maxwell stress tensor given by Landau and Lifshitz [17] for a fluid was extended to anisotropic linear system, in particular to liquid crystals, by P.A.Penz and G.W. Ford [18]:

$$T_{ij} = \frac{E_i D_j}{4\pi} - \frac{\delta_{ij}}{8\pi} E_k \left(D_k - \rho E_l \frac{\partial \varepsilon_{kl}}{\partial \rho} \right) + \frac{H_i B_j}{4\pi} - \frac{\delta_{ij}}{8\pi} H_k \left(B_k - \rho H_l \frac{\partial \mu_{kl}}{\partial \rho} \right) \quad (2)$$

It has been assumed the linear constitutive relations between the electric field $\vec{E}$ and displacement field $\vec{D}$ as well as between the magnetic field $\vec{H}$ and the induction $\vec{B}$: $\vec{D} = \hat{\varepsilon}\vec{E}$, $\vec{B} = \hat{\mu}\vec{H}$. The electromagnetic forces can be expressed as operations on tensor T_{ij}:

$$F_i = \frac{\partial T_{ij}}{\partial x_j}, \quad \tau_i = -\varepsilon_{ijk} T_{jk} \quad (3)$$

τ_i is applied body torque. ε_{ijk} is completely antisymmetric (Levi-Civita) tensor. The connection between τ_i and external force G_i acting onto the director is $\tau_i = (\vec{n} \times \vec{G})_i = \varepsilon_{ijk} n_j G_k$. As it is stressed in [18] T_{ij} for anisotropic systems is not necessarily symmetric. That is why a dielectric with an anisotropic dielectric tensor can experience a body torque $(\vec{P} \times \vec{E})_i = -\varepsilon_{ijk} T_{jk}$, where $\vec{P}$ is the dipole moment per unit volume. Calculating applied body torque by means of (2) and (3) under condition that magnetic part of T_{ij} can be omitted in case of optical field because $|E| \approx |H|$, $\chi_a / \varepsilon_a << 1$, gives:

$$\tau_i = \frac{\varepsilon_a}{4\pi} (\vec{n} \times \vec{E})(\vec{n}\vec{E}) \quad (4)$$

This expression completely coincide with the expression of optical torque which has been derived from variation principles by B.Ya. Zel'dovich and N.V.Tabiryan [1]. The validity of it has been verified in different experiments concerning nonlinear optical effects [1,6,8]. Electromagnetic body force $\vec{F}$ causes the flow which through the coupling term may lead to the reorientation of the director and thus contribute to the refractive index changes.

The expression (2) and (3) was used to treat the electrohydrodynamic instability in nematic LC (known as the Williams domain mode) [18,19] and for the description of Poiseuille and torsional shear flow with application of a.c. electric field [20]. To our knowledge the quantitative verification of (3) has not been made yet with respect to the optical field.

Let us consider the interference field of laser beams intersecting in the LC medium in the plane-wave approximation

$$\vec{E} = 0.5\left(\vec{e}_1 E_1 \exp(i\vec{k}_1\vec{r}) + \vec{e}_2 E_2 \exp(i\vec{k}_2\vec{r}) + c.c\right) \tag{5}$$

$\vec{q} = \vec{k}_1 - \vec{k}_2$ is the grating vector. We assume that nematic is an optical uniaxial crystal with the tensor of dielectric permittivity $\varepsilon_{ij} = \varepsilon_\perp \delta_{ij} + \varepsilon_a n_i n_j$, $\varepsilon_a = \varepsilon_{II} - \varepsilon_\perp$ is the permittivity anisotropy, $\varepsilon_\perp$ is the permittivity of ordinary wave. Substituting (5) into (3) and retaining only interference term in the excitation field $\sim \exp(i\vec{q}\vec{r})$ applied body force is given by

$$\begin{aligned}\vec{F} = (i/16\pi)\{&-\varepsilon_\perp[\vec{e}_1(\vec{e}_2\vec{q}) + \vec{e}_2(\vec{e}_1\vec{q})] - \varepsilon_a[\vec{e}_1(\vec{e}_2\vec{n}) + \vec{e}_2(\vec{e}_1\vec{n})](\vec{n}\vec{q}) + \\ &+ \vec{q}[\varepsilon_\perp(\vec{e}_1\vec{e}_2) + \varepsilon_a(\vec{e}_1\vec{n})(\vec{e}_2\vec{n})] - \rho\vec{q}[(\partial\varepsilon_\perp/\partial\rho)(\vec{e}_1\vec{e}_2) + \\ &+ (\partial\varepsilon_a/\partial\rho)(\vec{e}_1\vec{n})(\vec{e}_2\vec{n})]\}E_1E_2\exp(-i\vec{q}\vec{r}) + c.c\end{aligned} \tag{6}$$

As it was shown earlier [14] in the linear approximation the set of hydrodynamic equations (1) can be divided into two independent part. The coupled set of five equations describes the small deviations from equilibrium values in mass density $\delta\rho$, temperature δT, two components of the flow taking place in the plane $(\vec{n},\vec{q})$ and the reorientation of the director $\delta\vec{n}$, which take place in the same plane perpendicular to the unperturbed $\vec{n}$. Another coupled set of two equations describes flow velocity $v_\perp$ and reorientation $\delta n_\perp$ in the direction perpendicular to the plane $(\vec{n},\vec{q})$. Let call them transverse modes. We focused our attention on the transverse motion because it allows to see the shear flow effect in the refractive index grating in a simplest form and without contribution of other modes. The terms in the force (6) involving ρ, which are responsible for electrostriction, does not influence to the transverse motion. The other terms cause shear flow .

TRANSVERSE REORIENTATIONAL MODE

We assume that the oriented nematic layer is placed between two plane glasses. (Figure 1). But in the case $q^2 \gg (\pi/d)^2$, a^{-2} (d is a cell thickness, $2a$ - is laser beam diameter) it is correct to consider liquid crystal in the cell as unbounded medium.

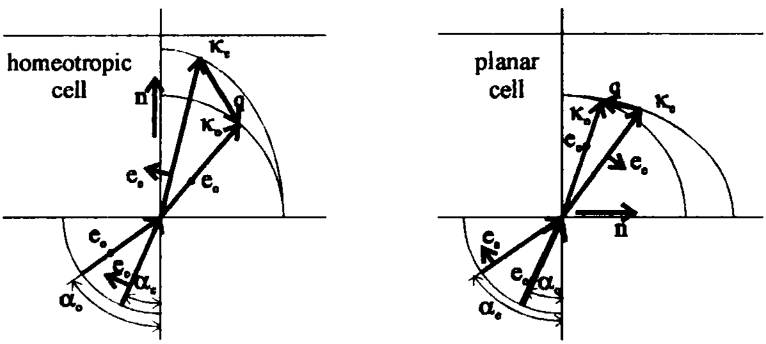

FIGURE 1. The geometry of light beams interaction.

By substituting $\dot{\delta n}$ from director equation into the flow equation the linearized set of equations for $v_\perp$ and $\delta n_\perp$ can be transformed to the next form:

$$\dot{v}_\perp + \tau_{fast}^{-1} v_\perp + \frac{i\mu_2(\vec{n}\vec{q})R_\perp}{\rho}\delta n_\perp = \frac{1}{\rho}\left(F_\perp - \frac{i\mu_2(\vec{n}\vec{q})}{\lambda_1}G_\perp\right) \qquad (7a)$$

$$\dot{\delta n}_{\perp} - R_{\perp}\delta n_{\perp} + i\frac{\lambda_1 - \lambda_2}{2\lambda_1}(\vec{n}\vec{q})v_{\perp} = \frac{G_{\perp}}{\lambda_1} \tag{7b}$$

where $\tau_{fast} = 2\rho / \left(\mu_4 q^2 + (\mu_5 - \mu_2\lambda_2 / \lambda_1)(\vec{n}\vec{q})^2\right)$; $R_{\perp} = \left[K_{22}q^2 + (K_{33} - K_{22})(\vec{n}\vec{q})^2\right] / \lambda_1$; $F_{\perp}$ and $G_{\perp}$ are the generalised forces acting in the direction perpendicular to the plane $(\vec{n},\vec{q})$. Practically one can get forces acting purely in such direction in the geometry with ordinary $\vec{e}_o$ and extraordinary $\vec{e}_e$ polarization of pump waves if wave vectors of two beams together with unperturbed director $\vec{n}$ belong to the same plane. In this case

$$\vec{F} = (i/16\pi)\{-\varepsilon_{\perp}\vec{e}_o(\vec{e}_e\vec{q}) - \varepsilon_a\vec{e}_o(\vec{e}_e\vec{n})(\vec{n}\vec{q})\}E_o^{*}E_e\exp(-i\vec{q}\vec{r}) + c.c \tag{8}$$

$$\vec{G}_{\perp} = -\frac{\varepsilon_a}{16\pi}\vec{e}_o(\vec{n}\vec{e}_e)E_o^{*}E_e\exp(-i\vec{q}\vec{r}) + c.c \tag{9}$$

The set (7) has the form: $\dot{\vec{X}} + \hat{L}\vec{X} = \vec{f}$ where $\vec{X} = \{v_{\perp}, \delta n_{\perp}\}$, $\hat{L}$ is a linear operator, $\vec{f}$ - external disturbance vector. Common solution of it for zero initial conditions is a sum of eigenmodes:

$$\vec{X} = \sum_{i=1}^{2}\exp(-t/\tau_i)\int_0^t \vec{X}_i(\vec{f}\vec{Y}_i^{*})\exp(t'/\tau_i)dt'$$

where $\vec{X}_i$ and $\vec{Y}_i$ are normal eigenvectors of operator $\hat{L}$ and conjugate operator $\hat{L}^{+}$ corresponding to eigenvalue τ_i^{-1}. In the set (7) $\tau_1 \equiv \tau_{fast}$, $\tau_2 \equiv \tau_{slow} = -1/R_{\perp}(1 - \mu_2^2(\vec{n}\vec{q})^2\tau_{fast}/\rho\lambda_1)$. The eigenvectors of full system have been calculated [14] in the main order with respect to small parameters: the ratios of characteristic times (or eigenvalues). In our case $\tau_{slow} << \tau_{fast}$ for typical LC parameters ($K_{ii} \approx 5\cdot10^{-12}N, \rho \approx 10^3 kg/m^3, \mu_i \approx 0.1\,Pa\cdot s$). Thus the solution of (7) reads:

$$\delta n \approx \frac{E_o E_e}{16\pi\lambda_1}\Bigg[B\exp(-t/\tau_{fast})\int_0^t A(t')\exp(t/\tau_{fast})dt' - -\left(B+\varepsilon_a(\vec{n}\vec{e}_e)\right)\exp(-t/\tau_{slow})\int_0^t A(t')\exp(t/\tau_{slow})dt'\Bigg]\exp(-i\vec{q}\vec{r}) \tag{10}$$

where $B=\varepsilon_\perp\mu_2(\vec{n}\vec{q})(\vec{e}_e\vec{q})\tau_{fast}/\rho$; $A(t)$ is the pulse envelope. In this expression the terms proportional to $\varepsilon_\perp$ arise because of the electromagnetic force F, which cause the shear flow. It turns out in this geometry that only the term proportional to ε_a in (10) contain direct contribution of optical torque. The build-up of the reorientation process in planar cell for different exitation pulse duration is shown on Figure 2.

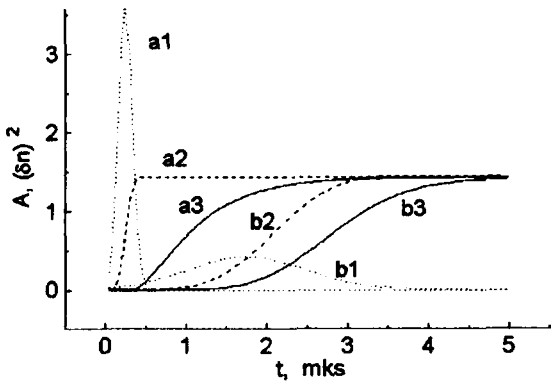

FIGURE 2. The build-up of the director reorientation process (a3, b3) for the different excitation pulse duration: (a1) tpulse=0.2 mks; (b1) tpulse=1.7 mks; (a2, b2) - reorientation without flow-coupling effect. tfast = 0.6 mks.

The pulse envelope is taken Gaussian. $\alpha_e = 20^o$, $\alpha_o = 19^o$, relaxation time of the fast mode is 0.6 mks. There are the two cases: in the first one (a) pulse duration $\tau_{pulse} = 0.2$mks is less then relaxation time of the fast mode τ_{fast}, in the second case (b) $\tau_{pulse} = 1.7$mks $> \tau_{fast}$. On the same figure it is shown the build-up process if fast mode is not taken into account and solution contain only slow mode. It is clear that due to the fast mode excitation maximum amplitude of the director reorientation is achieved with the delay $\tau \approx \tau_{fast}$ after the pulse is over. When the fast mode become zero the angle of the director reorientation achieves maximum amplitude. After that director relax to zero with slow mode relaxation time τ_{slow}. If $(\vec{n}\vec{q}) = 0$ there is no any contribution of the flow to reorientation of the director. But because $\varepsilon_a / \varepsilon_\perp \approx 10^{-1}$, $\mu_2 q^2 \tau_{fast} / \rho \approx 1$, for oblique incidence the reorientation connected with shear flow can be bigger then the one due to the optical torque.

ANGULAR DEPENDENCE OF REORIENTATION

The amplitudes and relaxation times in (10) contain the scalar products $(\vec{e}_e\vec{q})$, $(\vec{e}_e\vec{n})$, $(\vec{n}\vec{q})$. They involves three angles which are the characteristic of mutual arrangement of $\vec{n}$, $\vec{q}$, $\vec{e}_e$ vectors in the medium and depend on the angles of incidence of two waves onto the cell . Let α_e ,α_o be the angles of incidence of extraordinary and ordinary waves. Then $|\vec{q}|$ and angles between $\vec{n}$, $\vec{q}$, $\vec{e}_e$ can be easy calculated for homeotropic and planar cells. For the homeotropic cell they are:

$$q^2 = \left[\frac{\sqrt{\mu}\omega}{c}\right]^2 \left\{ \left[\sqrt{\varepsilon_o}(Sin\alpha_o - Sin\alpha_e)\right]^2 + \left[\sqrt{\varepsilon_\perp - \varepsilon_o Sin^2\alpha_o} - \sqrt{\varepsilon_\perp - \frac{\varepsilon_\perp}{\varepsilon_{II}}\varepsilon_o Sin^2\alpha_e}\right]^2 \right\}$$

$$(\vec{n}\vec{q}) = \frac{\sqrt{\mu}\omega}{c}\left[\sqrt{\varepsilon_\perp - \varepsilon_o Sin^2\alpha_o} - \sqrt{\varepsilon_\perp - \frac{\varepsilon_\perp}{\varepsilon_{II}}\varepsilon_o Sin^2\alpha_e}\right]$$

$$(\vec{n}\vec{e}_e) = \frac{\sqrt{\varepsilon_\perp}}{\sqrt{\varepsilon_{II}}} \frac{Sin\alpha_e}{\sqrt{\varepsilon_{II} - \varepsilon_a Sin^2\alpha_e / \varepsilon_{II}}} \qquad (11)$$

$$(\vec{e}_e\vec{q}) = \frac{\sqrt{\mu}\omega}{c}\frac{\sqrt{\frac{\varepsilon_\perp}{\varepsilon_\Pi}}Sin\alpha_e\sqrt{\varepsilon_\perp - Sin^2\alpha_o} - \sqrt{\varepsilon_\Pi - Sin^2\alpha_e}(Sin\alpha_o - \frac{\varepsilon_a}{\varepsilon_\Pi}Sin\alpha_e)}{\sqrt{\varepsilon_\Pi - \varepsilon_a Sin^2\alpha_e / \varepsilon_\Pi}}$$

For the planar cell scalar products reads:

$$q^2 = \left[\frac{\sqrt{\mu}\omega}{c}\right]^2\left\{\left[\sqrt{\varepsilon_o}(Sin\alpha_o - Sin\alpha_e)\right]^2 + \left[\sqrt{\varepsilon_\perp - \varepsilon_o Sin^2\alpha_o} - \sqrt{\varepsilon_\Pi - \frac{\varepsilon_\Pi}{\varepsilon_\perp}\varepsilon_o Sin^2\alpha_e}\right]^2\right\}$$

$$(\vec{n}\vec{q}) = \frac{\sqrt{\mu}\omega}{c}\left[\sqrt{\varepsilon_o}(Sin\alpha_o - Sin\alpha_e)\right]$$

$$(\vec{n}\vec{e}_e) = \frac{\sqrt{\varepsilon_\perp - Sin^2\alpha_e}}{\sqrt{\varepsilon_\perp + \varepsilon_a Sin^2\alpha_e / \varepsilon_\perp}} \qquad (12)$$

$$(\vec{e}_e\vec{q}) = \frac{\sqrt{\mu}\omega}{c}\frac{\sqrt{\varepsilon_\perp - Sin^2\alpha_e}(Sin\alpha_o + \frac{\varepsilon_a}{\varepsilon_\perp}Sin\alpha_e) - \sqrt{\frac{\varepsilon_\Pi}{\varepsilon_\perp}}Sin\alpha_e\sqrt{\varepsilon_\perp - Sin^2\alpha_o}}{\sqrt{\varepsilon_\perp + \varepsilon_a Sin^2\alpha_e / \varepsilon_\perp}}$$

Using (11), (12) we calculated maximum amplitude of the director reorientation as a function of two angles. On Figure 3(a) it is shown the amplitude of reorientation for planar and homeotropic cells as a function of α_e, when $\alpha_e - \alpha_o$ is fixed. The dot curve correspond to the amplitude of the reorientation caused by the optical torque, which depend on the α_e angle only. The other curves give the amplitudes with the shear flow contribution. In the case of planar cell amplitudes are of the same order. But in the case of homeotropic cell there is a rather big range of angles where the contribution of the shear flow is much bigger than that of optical torque. Figure 3(b) shows that maximum of the reorientation amplitude is achieved in homeotropic cell when $\alpha_e > 25^0$, $\alpha_o > \alpha_e$. The refractive index grating is usually investigated by the diffraction of the weak probe beam. In the thin-phase grating limit the intensity of the beam I_d diffracted to the first order is

$$I_d(d)/I_p(0) = \left(\pi d e_i^p \delta\varepsilon_{ij} e_j^d / \lambda_d \sqrt{\varepsilon_d}\right)^2$$

(index s refer to the diffracted beam, p - to the probe beam). In our case the

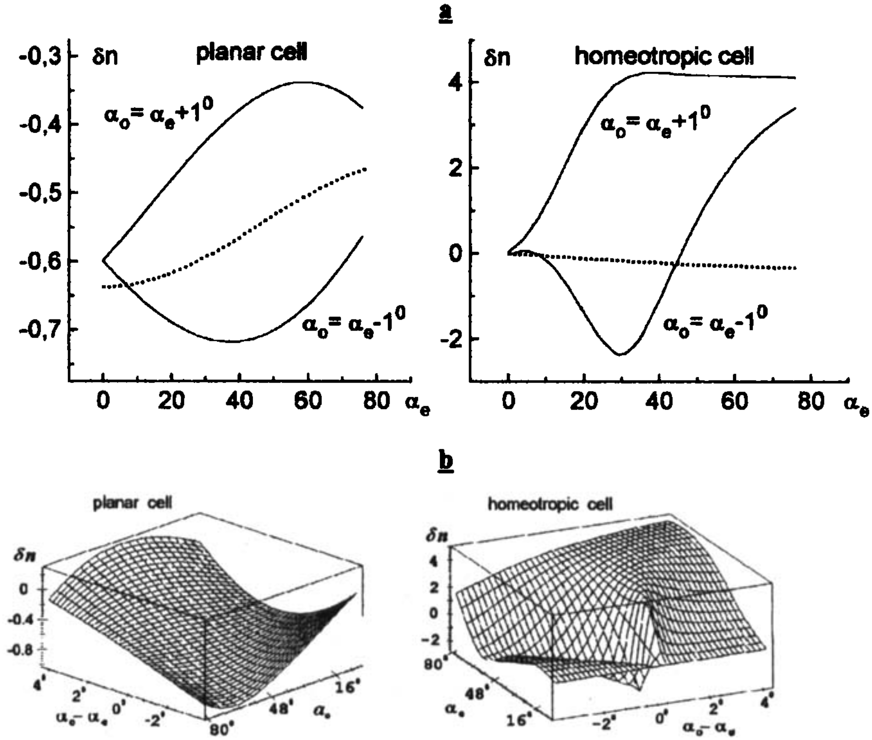

FIGURE 3. Angular dependence of the reorientation amplitude. (a): Dot line is the reorientation due to the optical torque.

refractive index grating arise due to the director reorientation, hence modulation in dielectric permittivity is $\delta\varepsilon_{ij} = n_i \delta n_j + n_j \delta n_i$. The estimation of the diffraction efficiency of the grating for nematic 5CB ($\rho \approx 10^3 kg/m^3$, $\mu_1 \approx 0.1\, Pa \cdot s$, $\lambda = 0.53 mkm$, $\varepsilon_\perp = 2.1$, $\varepsilon_a = 0.64$, $d = 100 mkm$) is $I_s / I_p \approx 1.4 \cdot 10^{-4} \cdot W^2$, W[mJ/mm^2] - energy density.

CONCLUSION

In this paper we have shown that flow reorientation coupling effect causes the retardation between excitation pulse and maximum amplitude of the director reorientation. The angular dependence of the director reorientation which was calculated taking into account shear flow induced by the electromagnetic field of pump waves qualitatively differ from the reorientation due to optical torque. This fact can be used in experimental verification of the description of shear flow induced by short electromagnetic pulse based on Maxwell stress tensor. We have calculated also that for oblique incidence of the two beams onto the homeotropic cell the reorientation due to shear flow induced by the electromagnetic field should be about ten times bigger then reorientation due to optical torque.

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