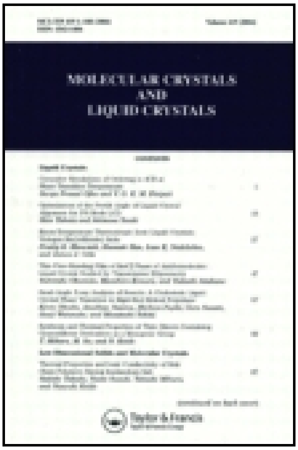

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Liquid Crystal in Rectangular Channels: New Possibilities for Three Dimensional Studies

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The new construction of LC cell useful for a study both simple twist deformation and 3D structures in liquid crystals induced by boundaries and electric fields is proposed. One of the main advantages of the cell is a very high sensitivity of optical response to the small variations of the twist angle. It is possible to create homogeneous "in plane" electric field under special choice of dimensions of a rectangular channel filled with a liquid crystal. The new LC cell provides good perspectives for measurements of practically important viscous and elastic properties of liquid crystals including a rotational viscosity coefficient. The cell can be also used for a study of static and dynamic properties of liquid crystals at weak anchoring.

Keywords: 3D geometry; electric field; rotational viscosity

INTRODUCTION

Liquid crystals (LC) play a fundamental role in a modern display industry [1]. Most of the existing LC displays are based on the number of electrooptical effects related to a rotation of the local optical axis (director **n**) under the action of applied electric field. These effects are strongly influenced both by electrical properties of liquid crystal media (e.g. the sign of dielectric permittivity anisotropy $\Delta\varepsilon$) and by

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boundary orientation of liquid crystals at the surface of the substrate. Most of the traditional LC displays use twisted nematic (TN) or supertwisted nematic (STN) modes, when the initially twisted nematic layer is transformed into homeotropic like orientation via application of strong electric field to the thin layer of LC with $\Delta\varepsilon > 0$. Such transformations include a combination of the three principal types of deformations of LC structure, namely twist (T), splay (S) and bend (B) types. It is well known, that in a general case back flow arises due to the intrinsic interaction between rotational and translation motions of LC molecules. For TN and STN modes this effect is of a minor importance as it changes the characteristic times only slightly. It means, that only one rotational viscosity coefficient γ_1 can be used for proper estimations of dynamical properties of LC displays of such types. The situation is quite different for some new types of displays using vertical aligned nematic (VAN) mode, when B type deformation results in drastic changes of operating times. The maximal shear viscosity coefficient η_1, that can be called as "back flow viscosity" plays the most essential role in decreasing the characteristic times. The optimization of both γ_1 and η_1 at a chemical synthesis of new LC materials can considerably improve the response time of VAN displays. The most reliable data on the viscosity coefficients of LC can be obtained via direct methods [2]. Most of them require bulk samples of LC oriented by relatively strong magnetic fields. It prevents their usage for a control of restricted amount of newly synthesized LC. Optic methods can be considered as mostly useful for such problem. In particular, recently we proposed the new optic method for the measurements of anisotropic shear viscosities where LC surface induced orientation [3].

Electric field can be considered as the most convenient factor to induce a relaxation of LC structure, describing by rotational viscosity coefficient. Nevertheless contrary to the case of magnetic fields electric fields are distorted by orientational changes of LC structure due to a relatively high values of $\Delta\varepsilon$. It makes description of LC behavior in electrooptical effects rather complicated. Direct measurements of γ_1 can be made using a simple LC twist deformation, which seems to be mostly convenient. Such type of an electrooptical mode can be realized via "in-plane" switching of an electric field. Unfortunately, the pure twist deformation is hard for the observation in traditional LC cell geometry due to Mauguin waveguide regime, so some complicated modifications were proposed [4].

In this article we describe the principally new geometry of the experiment, which provides a simple and effective way for a study of simple twist LC deformations under the action of a homogeneous electric field. We also consider the advantages of such geometry for a study of weak surface anchoring, which is also used in modern displays, e.g. bistable ones [5–7]. Such phenomena is of a great scientific interest as there is no detailed understanding of physical processes in the vicinity of weakly anchoring surfaces. We hope that proposed geometry will be also useful for a study of 3D LC structures induced by electric (magnetic) fields and shear flows at different types of boundary conditions.

LC Cell for 3D Study of Liquid Crystals

We have tried to realize new types of 3D geometry by application of LC cell of a special construction, shown in Figure 1.

The channel of a rectangular cross section is formed by two pairs of glass plates. The upper plate and the bottom one of a thickness 1.1 mm are coated with ITO transparent electrodes to provide the electric field inside the channel. Two others plates of relatively small thickness ($d = 270\,\mu m$) and with polished edge surfaces are pressed between the first pair of the plates. So the wedge like channel of a rectangular cross section with a width b linearly dependent on the Y-coordinate can be obtained in such manner. The small angle of the wedge (about 0.5 deg) makes it possible to consider the opposite polished edge surfaces as locally parallel to simplify the description of the phenomena under consideration. The described construction provides a slow variation

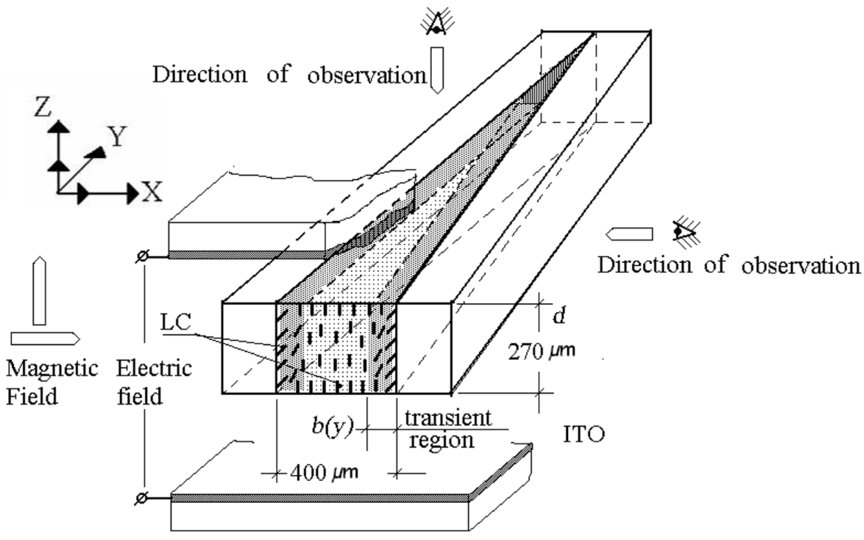

FIGURE 1 General scheme of the LC cell.

of the ratio r = b/d of the channel, which plays a key role in our experiments. Moreover the values of b and d were small enough to make liquid crystal media inside the channel to be transparent both in Z and X directions. It is of importance for better understanding of 3D orientational structures of LC, which can be formed inside the channel under the action of surfaces, fields and flows. Up to our knowledge such observation were previously fulfilled only for the tube like capillaries [4].

It is quite obvious that in our case there are a number of possibilities to use different kinds of a surface treatment to realize 3D boundary conditions of different types. Also one can propose some new experimental geometries by using proper combinations of electric field, magnetic field and shear flows. Such work is in progress now.

In this article we focus our attention on some particular cases which definitely show the advantages of the proposed experimental approach for a study of viscous and elastic properties of liquid crystals including those connected with interaction between LC and surfaces of a finite anchoring. Firstly we would like to explain the difference in a space structure of electric field for essentially different values of the ratio r = d/b (Fig. 1).

It is clear, that the most simple configurations of an applied electric field can be realized for the two limiting cases.

1. $r \ll 1$. This case corresponds to the traditional geometry mostly used at study of electrooptical effects in LC. It is well known that at initially homogeneous alignment provided by a surface treatment the electric field can be considered as a homogeneous field in Z direction at least for small deviations of an orientation from the initial state. So such phenomena as Freedericksz transitions are described in a similar manner for electric and magnetic fields [4]. Nevertheless the situation is drastically different in case of strong deformations due to a strong dependence of the dielectric permittivity of LC ε on LC orientation. It is easy to understand from Figure 2b, where liquid crystal inside the channel is replaced by a number of isotropic layers oriented *normally* to the field direction with different values of $\varepsilon = \varepsilon^{(i)}$.

   The well known boundary conditions (at the boundary between i and i + 1 layers) for the normal (n) projections of electric flux density $\mathbf{D} = \varepsilon_0\,\varepsilon\mathbf{E}$ are written down as [8]:

$$\mathbf{D}_n^{(i)} = \mathbf{D}_n^{(i+1)} \text{ or } \varepsilon^{(i)}\mathbf{E}_n^{(i)} = \varepsilon^{(i+1)}\mathbf{E}_n^{(i+1)} \tag{1}$$

   So the electric field **E** becomes *inhomogeneous* due to a dependence on Z coordinate.

   It makes the description of non linear electrooptical effects in the traditional geometry rather complicated.

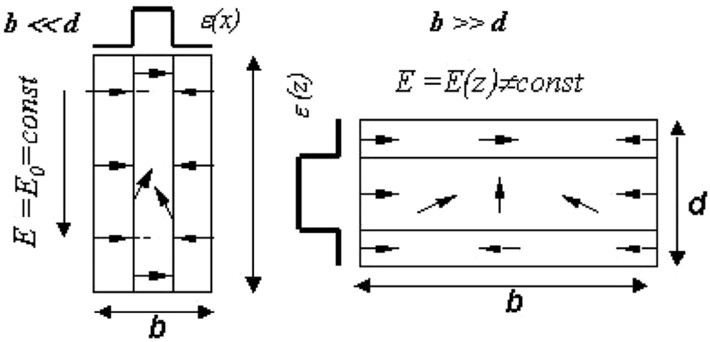

FIGURE 2 Electric field in a gap. a) case where r >> 1, b) case where r << 1.

2. r >> 1. This case experimentally not realized up to now seems to be very interesting. Indeed, the conventional model applicable for this situation and shown in Figure 2a includes a number of layers, oriented *parallel* to the field direction as orienting action of surfaces in X direction has to be essentially higher than in Z direction at comparable anchoring forces, except for regions close to the upper and the bottom plates, shown in Figure 1. The boundary conditions for tangential (τ) projections of **E** corresponding to this conventional model are written as:

$$\mathbf{E}_\tau^{(i)} = \mathbf{E}_\tau^{(i+1)} \tag{2}$$

For the situation shown in Figure 2a electric field **E** far from the channel has to be homogeneous and is determined as usual field in a plane capacitor:

$$\mathbf{E} = -U/d \tag{3}$$

where U - is the applied voltage.

It means that one can consider electric field inside the narrow channel as homogeneous too with a strength described by expression (3) and *independent* on the local orientation of LC. Of course such arguments fail at the distances from upper and lower plates comparable with the thickness of the cell d. To some extent such field is similar to that used for "in- plane" switching, where electric voltage is applied between two electrodes placed into the cell [1]. But in the latter case the dipole like configuration of field has to take place. It obviously results in more essential deviations from the ideal homogeneous field than in the geometry described above.

The existence of both the homogeneous electric field and the two (Z and X) directions of observation provides an elaboration of simple and effective methods for a study of material characteristics of liquid crystals. In particular, one can realize the most simple type of LC deformation namely twist deformation in the case $r >> 1$ mentioned above. The simple theoretical description of the orientational changes and optical effects in the geometry under consideration will be further presented in the article. Of course the intermediate case $r \sim 1$ is of a great interest too, as a competition of normally oriented surfaces can be easily obtained by a proper surface treatment. It can be of importance for a study of disclinations, for example. Such experiments are beyond this paper and now in progress.

Liquid Crystal in Narrow Channel with Strong Anchoring Under Homogeneous Electric Field ($r >> 1$)

Theoretical Description

Below we describe one of the most simple case of a pure twist deformation which takes place when a homogeneous electric field is applied in the plane of LC layer in the narrow channel (Fig. 3). In this case we can neglect the back flow effects, which essentially simplifies the solution of the problem.

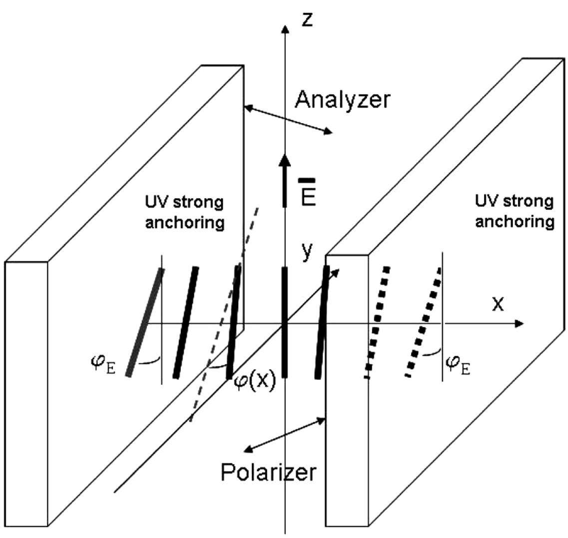

FIGURE 3 LC layer in the narrow channel.

We consider the initially homogeneous planar orientation and will chose the additional axis Z^* directed along the initial direction of LC media. We will introduce two angles: φ – the angle between the director in distorted state ($\mathbf{n}$(z,t)) and that ($\mathbf{n}_0$) in the initial homogeneous state and φ_E – the angle between field direction and $\mathbf{n}_0$. In this case we can define the next torques acting on the director:

Electric field torque:

$$M_E = -(\varepsilon_0 \Delta\varepsilon/2)E^2 \sin 2(\varphi - \varphi_E) \quad (4)$$

Elastic curvature torque:

$$M_K = K_{22}(\partial^2\varphi/\partial x^2) \quad (5)$$

Viscous torque:

$$M_v = -\gamma_1(\partial\varphi/\partial t) \quad (6)$$

where K_{22} and γ_1 are the Frank's elastic module and the rotational viscosity coefficient. The instant orientation of a director can be extracted from the moment balance equation:

$$M_E + M_K + M_v = 0 \quad (7)$$

To simplify the problem we will consider both φ and φ_E to be small enough, so (7) is written in the linear approximation as:

$$\xi^2(\partial^2\varphi/\partial x^2) - \tau_E(\partial\varphi/\partial t) - (\varphi - \varphi_E) = 0 \quad (8)$$

where

$$\xi = (K_{22}/\varepsilon_0\Delta\varepsilon)^{1/2}E^{-1} \quad (9)$$

electric coherence length;

$$\tau_E = \gamma_1/(\varepsilon_0\Delta\varepsilon_a E^2) \quad (10)$$

a characteristic time of a director reorientation under strong electric field.

Stationary Solution for Field Induced Distortions

Firstly we will consider the stationary case. By introducing $\varphi^* = (\varphi\text{-}\varphi_E)$, we will obtain from (8) the following standard equation:

$$\xi^2(\partial^2\varphi^*/\partial x^2) - \varphi^* = 0 \quad (11)$$

with a general solution:

$$\varphi^*(x) = C_1 \exp(+\xi^{-1}x) + C_2 \exp(-\xi^{-1}x) \tag{12}$$

The constants C_i can be found from boundary conditions. For a strong surface anchoring they have the usual case:

$$\varphi^*(x = \pm b/2) = -\varphi_E \tag{13}$$

From (12)–(13) one can easily obtain the next solution for the angle $\varphi(x)$:

$$\varphi(x) = \varphi_E[1 - ch(x/\xi)/ch(b/2\xi)] \tag{14}$$

It is easy to show that φ (x)→0 for weak fields ($\xi\rightarrow\infty$) and

– φ (x)→φ_E for strong fields ($\xi\rightarrow 0$) except for boundary layers of the thickness equal to ξ. In general case the maximal distortion, which takes place in the center of the channel can be expressed as:

$$\varphi(x = 0) = \varphi_E[1 - 1/ch(b/2\xi)] \tag{15}$$

In the traditional optical geometry (light passes through the sandwich like cell in the direction *normal to the director*) a simple twist deformation results in the rotation of the polarization plane so it hardly can be detected at least for Mauguin waveguide regime [4]. In our case the optical geometry is quite different – light passes through the cell *in the plane of the director rotation*. One has to wait for an essential birefringence and strong optical effects due to a relatively long optical way even in the case of small deformations of the initial orientational structure.

The intensity of light passing in Z-direction through the channel, oriented at 45° relatively to the crossed polars can be expressed as:

$$I = I_0 \sin^2(\delta/2) \tag{16}$$

where I_0 – the input light intensity, and δ-is the phase delay between the extraordinary ray and the ordinary one. For the geometry, shown in Figure 3 it can be written as:

$$\delta \approx (2\pi d\Delta n/\lambda)\sin^2[\varphi(x) - \varphi_E] \approx (2\pi d\Delta n/\lambda)[\varphi(x) - \varphi_E]^2 \tag{17}$$

Using (14) one can obtain:

$$\delta \approx (2\pi d\Delta n/\lambda)\varphi_E^2[ch(x/\xi)/ch(b/2\xi)]^2 \tag{18}$$

So we can conclude, that the space distribution of pure twist deformation can be directly and simply detected and studied in the proposed geometry via light intensity changes. The ratio $K_{22}/\Delta\varepsilon$ in expression (9) for electric coherence length can be found by analyzing the experimental results. It is difficult to perform such study in traditional geometry. One has to use conoscopic images in Mauguin regime [4]. Moreover, a homogeneous "in-plane" electric field can hardly be realized in standard LC cells.

Linear Dynamic Solution for Switching off Field

It is well known that only pure twist deformation does not involve a motion of molecular centers of mass. So it provides the direct way for a determination of a rotational viscosity coefficient. The main problem in previous experiments of such types was related to a proper registration of a twist like director motion in the plane of the cell [2]. The new geometry described above reveals certain advantages from the point view of rotational viscosity measurements. They relate to a high sensitivity of optical response on twist LC deformation and with a possibility to obtain a homogeneous electric field to realize a pure twist deformation. Below we will consider briefly the relaxation of a director after turning off electric field and a reciprocal dynamical optical response in the proposed geometry. As usual for the problems of such type [9] we will use the Fourier expansion for the dynamical deviation angle φ (x,t):

$$\varphi(\mathrm{x}, \mathrm{t}) = \Sigma \varphi_{\mathrm{n}}(\mathrm{t}) \cos(\mathrm{q_n x}) \tag{19}$$

where

$$\mathrm{q_n} = (\pi + 2\mathrm{n}\pi)/\mathrm{b} \tag{20}$$

is a wave vector.

In case under consideration the electric field torque (4) is equal to zero, so the dynamical equation of motion becomes rather simple:

$$\mathrm{K}_{22}(\partial^2 \varphi/\partial \mathrm{x}^2) - \gamma_1(\partial \varphi/\partial \mathrm{t}) = 0 \tag{21}$$

The initial condition can be written as:

$$\varphi(\mathrm{x}, \mathrm{t} = 0) = \varphi(\mathrm{x}) \tag{22}$$

where φ (x) corresponds to the electrically induced stationary deformation defined by (14) So the solution of the Eq. (21) has a well known form:

$$\varphi_{\mathrm{n}}(\mathrm{t}) = \varphi_{\mathrm{n}}(0) \exp(-\mathrm{t}/\tau_{\mathrm{n}}) \tag{23}$$

where $\varphi_{\mathrm{n}}(0)$ are defined by Fourier transformation of (22) and the relaxation time τ_{n} depends on the number of a harmonic:

$$\tau_n = \gamma_1/(\mathrm{K}_{22}\mathrm{q_n^2}) \tag{24}$$

For the slowest harmonic

$$\tau_0 = \gamma_1 b^2/(K_{22}\pi^2) \tag{25}$$

and this time defines the changes of the director orientation at the final stage of a relaxation process

$$\varphi(x, t > \tau_0) = \varphi_0(0)\exp(-t/t_0) \tag{26}$$

It is quite clear that a high resolution of the optical technique is needed to register small time variations of the azimuthal angle to get a reliable information about rotational viscosity coefficient. Our geometry provides such a possibility as mentioned above.

For extremely small angles $\varphi(x)$ and φ_E one can obtain from (17):

$$\delta \approx (2\pi d\Delta n/\lambda)[\varphi(x) - \varphi_E]^2 \approx (2\pi d\Delta n/\lambda)[\varphi_E^2 - 2\varphi_E\varphi(x)] \tag{27}$$

So the time dependence of the light intensity at the end of a director motion is expressed as:

$$I \approx I_0(\delta/2)^2 = I_0((2\pi d\Delta n/\lambda)^2[\varphi_E^4 - 4\varphi_E^3\varphi(x)] \approx I(\infty) - \Delta I\exp(-t/\tau_0) \tag{28}$$

where

$$I(\infty) = I_0(2\pi d\Delta n/\lambda)^2\varphi_E^4 \tag{29}$$

and,

$$\Delta I = I_0(2\pi d\Delta n/\lambda)^2(4\varphi_E^3\varphi_0(0)) \tag{30}$$

Accordingly to (27) for large enough values of d (as it was in our experiments) there is a possibility to get relatively high values of δ. In this case (28) has to be replaced by the next expression:

$$I = I_0\sin^2\{[\delta_\infty - \Delta\delta\exp(-t/\tau_0)]/2\} \tag{31}$$

with

$$\delta_\infty = (2\pi d\Delta n/\lambda)\varphi_E^2 \tag{32}$$

$$\Delta\delta = 2(2\pi d\Delta n/\lambda)\varphi_E\varphi_0(0) \tag{33}$$

For $t > \tau_0$ it results in the next time dependence for intensity changes:

$$I = I_\infty - \Delta I\exp(-t/\tau_0) \tag{34}$$

where

$$I_\infty = I_0 \sin^2(\delta_\infty/2) \tag{35}$$

$$\Delta I = I_0(\Delta\delta/2)\sin(\delta_\infty) \tag{36}$$

One can take into account that the sign of ΔI depends on the value of δ_∞.

So we conclude that the light intensity at long enough time has to vary accordingly to a simple exponential law with the same time as the relaxation time τ_0 of slowest director harmonic. As there is no back flow effects γ_1/K_{33} directly can be determined from I(t) dependences.

EXPERIMENTAL RESULTS AND DISCUSSION

In this part we present the first experimental results, which confirm some theoretical estimates considered above. To be sure in a linear regime of a director motion we have treated the thin edges of the inner glass plates by photoalignment technique [1] to get homogeneous planar orientation at a small angle (about 10 deg) relatively Z axes. The upper and bottom plates were coated by thin layers of chromolan for homeotropic surface orientation needed to avoid possible disclination lines. So we believe that maximal variations of an azimuthal angle did not exceed 10 degrees in the experiments under consideration. The channel was filled with a nematic mixture ZhK654 (NIOPIK production) with a high positive value (10.7) of $\Delta\varepsilon$. It consists of the well studied [10] binary mixture ZhK440 (nematic matrix) mixed with some amount (about 30%) of the polar material. Electric voltage U of a high enough frequency $f = 3\,\text{kHz}$ was applied to avoid possible hydrodynamic instabilities. We used digital photos of the gap obtained via a polarizing microscope as the primary experimental data. The images were obtained when the channel was oriented at 45° respectively to the crossed polarizers. It was possible to realize the observation of the cell from both Z and X directions. In the latter case we did not observe any essential changes in images of the channel under field application, as it shown in the Figure 4. It is a typical behavior for a twist like deformation in usual LC cells under Mauguin regime [4].

The situation was drastically different at observation of the channel from Z direction. The set of experimental images of the cell for different values of a voltage U and local width of the channel b is shown in Figure 5.

In the absence of electric field the gap looks as non-homogeneous, at least at the width of the channel higher than $20\,\mu\text{m}$. It reflects a competition between orientational action of the two pairs of orthogonal surfaces with different boundary conditions.

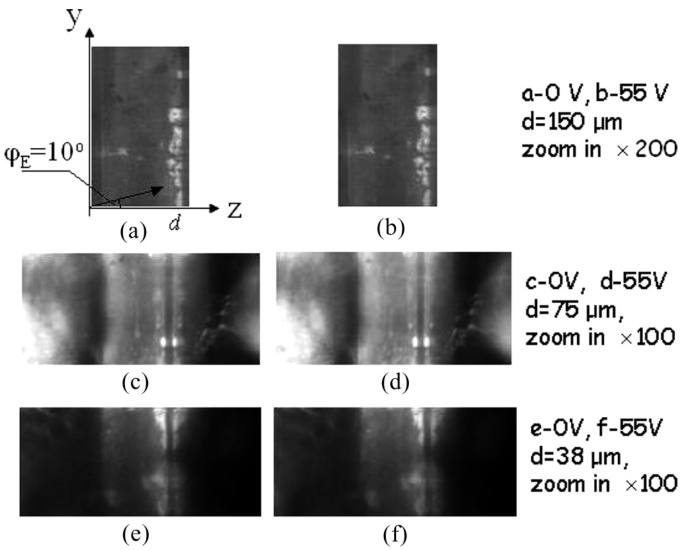

FIGURE 4 Microscopic images of the cell in X-direction before and after turning on the electric field, polarizers are crossed.

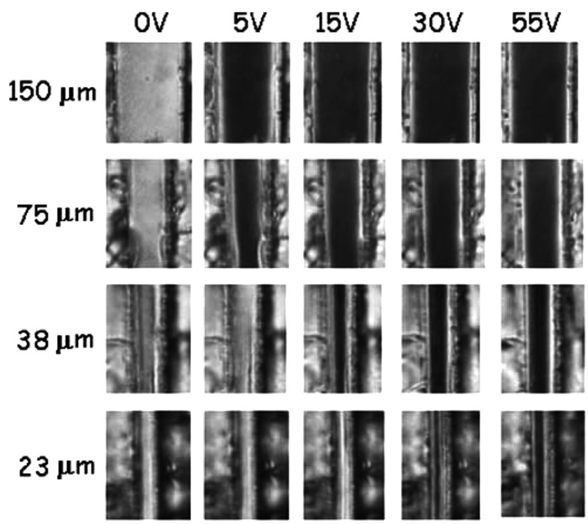

FIGURE 5 Microscopic images of the gap in Z-direction before and after turning on the electric field.

One can see a high sensitivity of the cell to the electric field at relatively large values of b. In this case the central part of the gap becomes dark at a voltage lower than 5 V. It corresponds to the electrically induced homogeneous homeotropic (respectively the upper and bottom plates) orientation of LC (a director **n** is oriented along Z axis) and to zero birefringence in Z direction. Narrow bright stripes along the edges of the channel can be considered as the regions with an intermediate orientation (the director has to adopt to the planar boundary orientation on the edge surfaces of the channel). The characteristic size of this region has to be comparable with the electric coherence length, defined by the expression (9). Indeed, one can see the decrease of this region at voltage increasing, which is in correspondence with the ξ (E) predicted by a theory. At small values of the channel gap ($b \leq 40\mu$) when the channel can be considered as narrow one ($r \gg 1$) one can try to compare the electric coherence length and the size of a boundary stripe. By assuming $K_{22} \approx 7.2 * 10^{-12}$N (which is the value, corresponding to ZhK440) we will obtain ξ ($V = 15V$)$\approx$4 µm µm which is approximately two times smaller then the linear size of the boundary stripe at such voltage. One can wait for a difference of this type so the presented estimate shows the possibility for a determination of K_{22} module by a proper processing of the images. The transformations of the space distribution of the local light brightness extracted from digital images at variation of the voltage and the width of the channel are shown in Figure 6.

One can see the boundary regions with the thickness decreasing with a voltage. This is the first step for a reconstruction of the entire 3D-picture of the orientational structure inside the channel, which is under consideration now for boundary conditions of different types. The experimental dependences of a light brightness on the x-coordinate are shown in Figure 7 at different voltages.

The character of these dependences is similar to the theoretical one for light intensity defined by the expression (18) and shown in Figure 8 (in our calculation we used $\Delta n \cong 0.2$ and $\lambda = 0.63$ µm). The agreement between the theory and the experiment seems to be satisfactory, taking into account possible corrections in the values of material coefficients. In particular, experiments were done in white light which results in some effective value of Δn.

We also used the value of K_{22} measured for the matrix mixture ZhK 440 [10] though the polar compound may increase the value of this parameter. For example, adding of 20% of the same polar compound in the similar system results in changing of Frank's module K_{11} from $6.86 * 10^{-12}$ N to $8.31 * 10^{-12}$ N and in increasing of K_{33} from $10.5 * 10^{-12}$ N to $17.5 * 10^{-12}$ N [11]. The example of calculations of

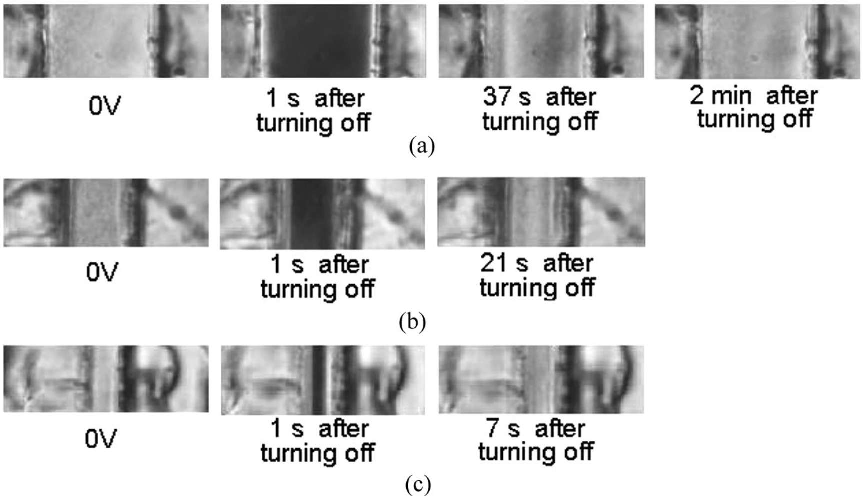

FIGURE 6 Microscopic images of the gap in Z-direction after turning off the electric field in crossed polarizes. U = 55 V text = 80 min, f = 3 kHz. (a) b = 150 μm; (b) b = 75 μm; (c) b = 38 μm.

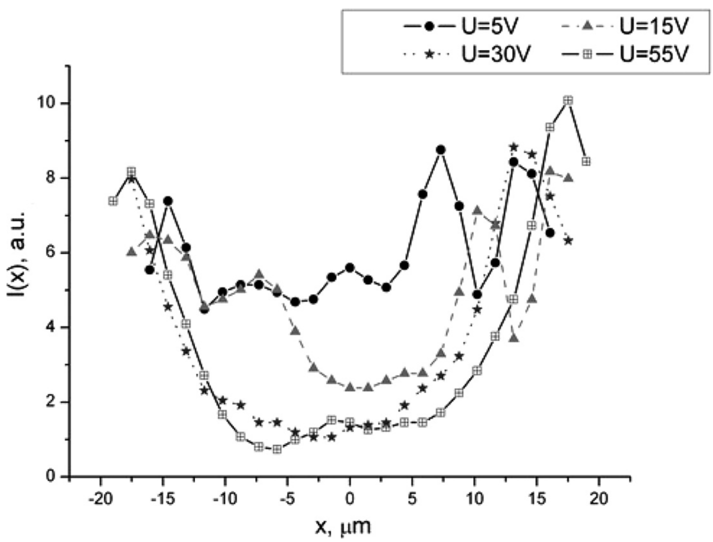

FIGURE 7 Experimental distribution of light brightness along x axis at different voltages: b = 38 μm, f = 3 kHz, U = 5–55 V.

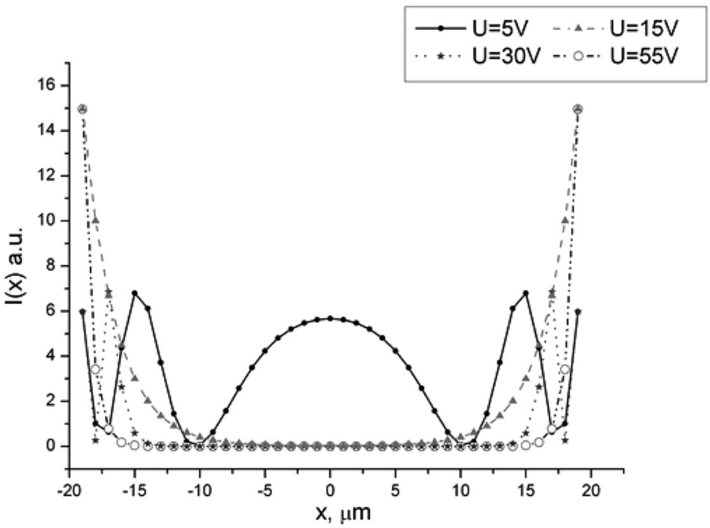

FIGURE 8 Theoretical distribution of light brightness along x axis at different voltages: b = 38 μm, f = 3 kHz, U = 5–55 V $K_{22} = 7.2 * 10^{-12}$ N.

the light intensity distribution using the higher value of K_{22} ($10 * 10^{-12}$ N) shown in Figure 9 confirms the assumption made above.

Distribution of light brightness inside the channel is shown in Figure 10. It was obtained at different voltages and thicknesses b along X-axis.

The existence of non-monotonic optical response reflects the essential changes of the phase delay δ at slight variations of the azimuthal angle, which in an accordance with the analysis presented above. It provides an extremely high sensitivity of the proposed method to the simple twist deformation of LC. So the processing of such images can be used to extract information about a rotational viscosity coefficient γ_1. The obtained time dependences of the light intensity at the final stage of the director relaxation are shown in Figure 11.

They can be approximated by the simple exponential law (34) predicted by the linear theory to extract the value of the relaxation time. For small enough values of the channel width experimentally determined times are proportional to the b^2, which is in accordance with the theoretical dependence (23). The comparison between experimental values of τ_0 at b = 38 μ (3 s) and that calculated value (2.8 s.) by using material parameters of ZhK 440 ($K_{22} = 7.2 * 10^{-12}$ N, $\gamma_1 = 0.13$ Pa.s [12] shows that proposed geometry can be properly used for a determination of the rotational viscosity coefficient of liquid

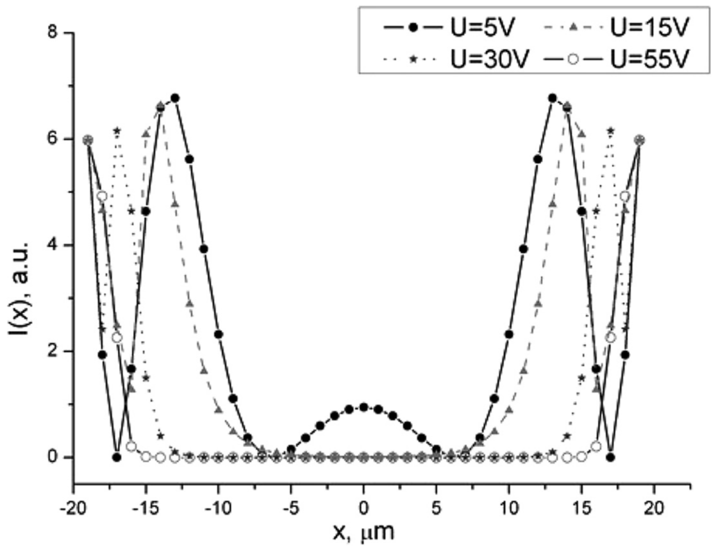

FIGURE 9 Theoretical distribution of light brightness along x axis at different voltages: b = 38 μm, f = 3 kHz, U = 5–55 V, $K_{22} = 10 * 10^{-12}$ N.

crystals. Obviously the influence of the polar compound on the ratio K_{22}/γ_1 plays a minor role as the both parameters may depend on the concentration approximately in the same manner.

At last we would like to say some words about application of this experimental LC cell geometry to study interaction of liquid crystal with surfaces of relatively weak anchoring. Two main advantages, namely high sensitivity to the small azimuthal variations and a possibility to provide pure twist-like deformation promise interesting results for weak anchoring.

In a static regime deviations from simple solutions presented above can be obtained. So anchoring energies can be found from simple experiments.

In s quasy static regime under strong electric field- azimuthal gliding of an easy axis can be detected with high resolution (about 0.1°) via slow changes of light intensity. It is of importance for relatively strong surfaces where slight gliding was observed recently [12,13]. The experiments of such types are under process now.

In dynamic regime one can try to get information about surface viscosity as this parameter defines the phase shift between the bulk director and the surface one.

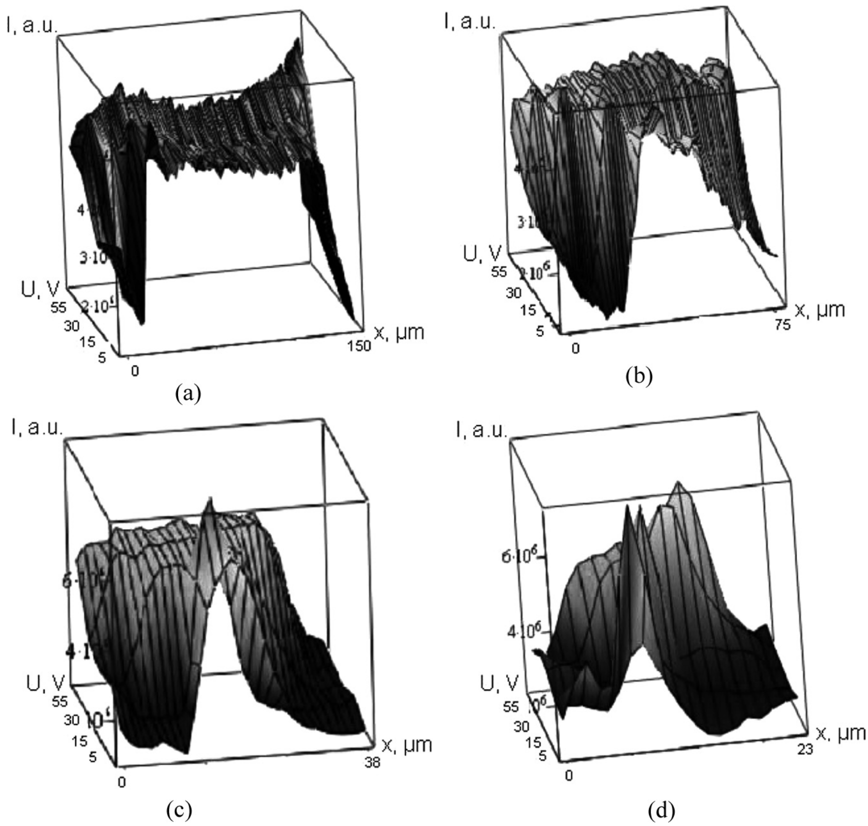

FIGURE 10 Distribution of light brightness along X axis at different voltage; (a) b = 150 μm, (b) b = 75 μm, (c) b = 38 μm, (d) b = 23 μm. U = 0–55 V, f = 3 kHz.

Photoalignment technique is very promising for such experiments as it allows to control anchoring strength [15]. Azimuthal anchoring strength can be done low enough, which is important for extracting of the surface viscosity contribution in dynamic response of LC layer on electric fields and oscillating flows [16–18].

CONCLUSION

New type of the experimental geometry useful for 3D investigations of LC structure is proposed and realized experimentally. The liquid crystal wedge-like cell is elaborated to provide the observation of an orientational structure of LC from two orthogonal directions. Electric

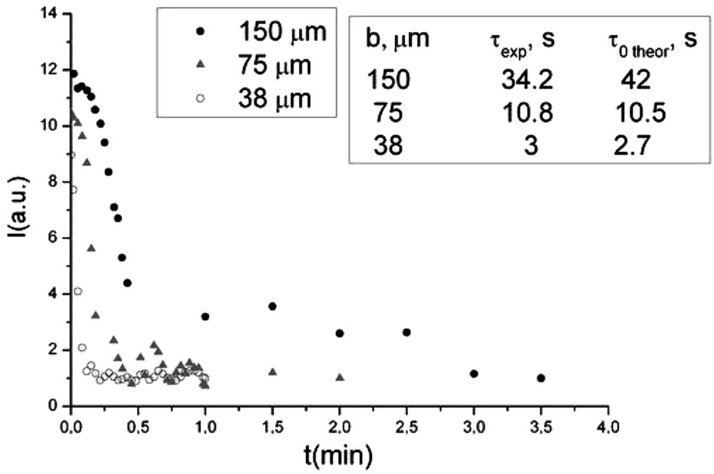

FIGURE 11 Time dependence of light intensity after turning off the electric field text = 80 min, U = 55 V, f = 3 kHz, b = 38, 75, 150 μm.

field close to the homogeneous is used to obtain a pure twist like deformation of LC layer. Extremely high sensitivity of optical response to azimuthal motion of LC director is established in the framework of the linear hydrodynamic model and confirmed experimentally. It is shown, that the proposed geometry can be used to determine the Frank's elastic module K_{22} and the rotational viscosity coefficient. The possibility of applying of such geometry for a study of a surface anchoring is discussed.

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