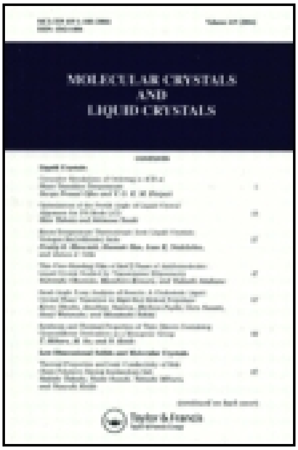

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Behaviour of Nematik Layer Oriented by Electric Field and Pressure Gradient in the Striped Liquid Crystal Cell

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The results of an optical investigation of a nematic layer acted by a pressure gradient and an electric field in a sandwich-like liquid crystal cell with striped electrodes are presented. The time-dependent harmonic pressure gradient changed an initially homeotropic orientation of layer of the nematic mixture with a positive permitivity anisotropy. The stabilizing electric voltage was applied to the each stripe. As a value of the voltage could be varied for different stripes independently they showed an individual reaction on the pressure gradient.

Keywords: pressure gradient; electric field; nematic mixture

INTRODUTION

It is well known that liquid crystals can be used for a registration of mechanical vibrations of different types[1]. The main reason which makes such applications rather perspective is the possibility of a nematic layer to change it's orientation and optical properties under extremely low mechanical stresses. It's very important for an elaboration of high sensitive liquid crystal devices, particularly of differential manometer. In the last case a pressure difference Δp induces a flow of liquid crystal through a capillary which reorients a director and changes birefringence of a laser light.

Unfortunately, a simple sandwich-like liquid crystal cell shows a rather narrow diapason of registered amplitudes of mechanical stresses in which the optical response increases monotonically with increasing of stresses due to interference of usual and unusual light beams.

The use of stabilizing electric field can improve the situation[2], but it leads simultaneously to the decreasing of the sensitivity of a liquid crystal cell.

In this work we present the results of experimental investigations of an oplital response of the striped liquid crystal cell on the action of a low frequency pressure difference :

$$\Delta p = \Delta p_m \sin(2\pi t / T) \tag{1}$$

(T=5.2 s - the period of vibrations) .

The liquid crystal cell (figure 1) consists of two glass plates coated by transparent electrodes (one of them is divided by 5 stripes).

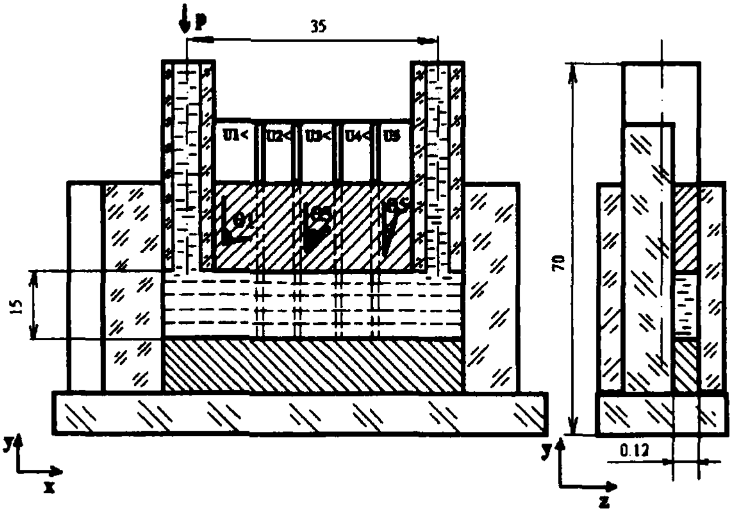

FIGURE 1 The stripe liquid crystal cell.

The pressure difference Δp is applied to the nematic layer by the tubes and induces an oscillating flow of a nematic through the rectangular cappillar (the thickness of the layer - l =120 μ). The cell is filled by a nematic mixture with high positive value of an anisotropy of a dielectric permitivity ($\Delta\varepsilon \approx 8.2$). The initial homeotropic orientation of nematic layer is created by proper surface treatment. The individual electric voltage Un (f=50 MHz) can be supplied to each stripe (n=1...5) to provide a different stabilizing action of electric field. The laser light beam (λ=0.63 μ) passes through the cell and the analyzer, so the pressure induced orientational changes (θ) of the layer lead to the simultaneous oscillations $\Delta I(t)$ of light intensity which are registered by a photodiode and a recorder. The cell can be moved in the direction of flow to provide an investigation of an optical response of different stripes.

The typical time dependencies of light intensity changes ($\Delta I(t)$) for different stripes are shown in figure 2.

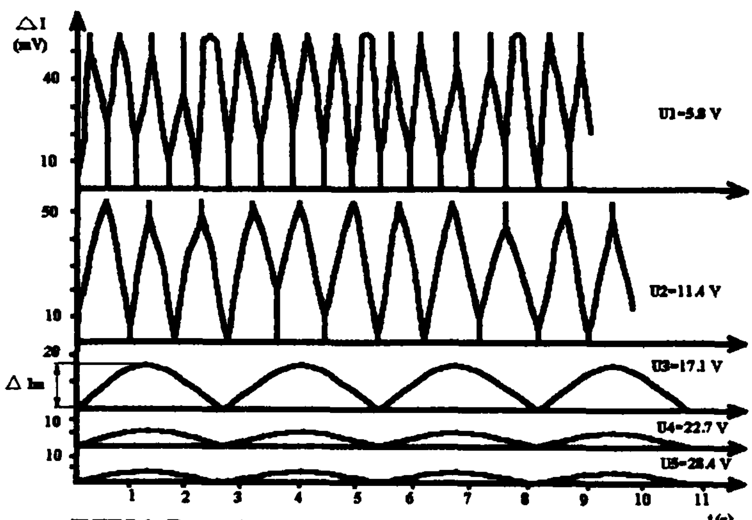

FIGURE 2 The time depedencies of light intensity chenges for different stripes.

These dependencies differ sufficiently and can be effectively changed by varying the electric field voltage. The optical intensity varies quasi-harmonically with amplitude ΔI_m at a relative high voltage applied to the stripe. The dependencies of ΔI_m on the pressure difference amplitude Δp_m for different stripes are shown in figure 3.

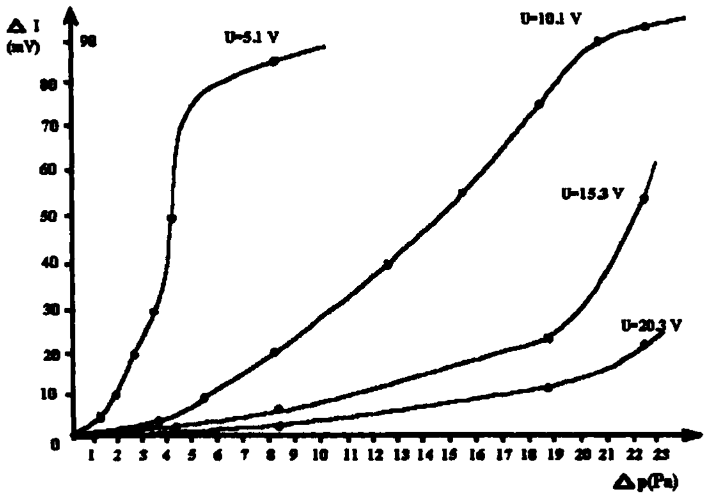

FIGURE 3 The dependecies of ΔI_m on pressure difference amplitude Δp_m.

They show the possibility of an elaboration of liquid crystal element of a high sensitivity and of a wide range for registration of mechanical vibrations due to a proper choice of voltages applied to different stripes.

It is possible to explain the presented results in the framework of linear hydrodynamic equations of incompressible nematics written as follows:

$$\rho \frac{\partial \vartheta_x}{\partial t} = -\frac{\partial p}{\partial X} + \eta_2 \frac{\partial^2 \vartheta_x}{\partial Z^2} + \alpha_2 \frac{\partial^2 \theta}{\partial Z \partial t} \qquad (2)$$

$$k_{33}\frac{\partial^2\theta}{\partial Z^2}=\alpha_2\frac{\partial \vartheta_X}{\partial Z}+\gamma_1\frac{\partial\theta}{\partial t}+\frac{\Delta\varepsilon E^2}{4\pi}\theta \tag{3}$$

where η_2 - the shear viscosity coefficient, ρ - the density, ϑ_X - the flow velocity, E - the electric field strength, α_2 - the Leslie's coefficient which provides a coupling between the velocity $[\vartheta_X(z)]$ and the orientation $\theta(z)$, γ_1 - the rotational viscosity coefficient, k_{33} - the Frank's module.

The solution of the system of the equations (2,3) can be easy found in the case of slow varying flow ($\omega_0 << \omega_\vartheta, \omega_L$; $\omega_\vartheta, \omega_L$ - characteristic frequencies of flow and orientation motions) which is true for this experiment. For hard anchoring at the boundaries of velocity of the flow and of the orientation: $[\vartheta(Z=+h,t)=0,\ \theta(Z=+h,t)=0]$, it has the following form :

$$\vartheta(Z,t)=\frac{G_0(t)}{2\eta_2}\left(Z^2-h^2\right) \tag{4}$$

$$\theta(Z,t)=G_0(t)\cdot\frac{8\pi h^2}{\Delta\varepsilon U^2\eta_2}\cdot\left[\frac{Z\cdot sh\left(\sqrt{\frac{\Delta\varepsilon}{4\pi k_{33}}}\cdot\frac{UZ}{2h}\right)}{sh\sqrt{\frac{\Delta\varepsilon}{4\pi k_{33}}}\cdot\frac{U}{2}}-Z\right] \tag{5}$$

where $G_0(t)=\frac{\Delta p}{L}$, $2h=1$.

The intensity variations of light intensity are determined by the mean value of $\theta^2(Z,t)$:

$$\Delta I(t) = \Delta I_m \sin^2 \frac{\delta}{2} = \Delta I_m \sin^2 \left\{ \frac{\pi h}{\lambda} \cdot \Delta n \cdot \theta^2(t) \right\} \tag{6}$$

where :

$$\theta^2(t) = \frac{1}{h} \int_0^h \theta^2(Z,t) dZ = \left[\frac{G_0(t)}{2\eta_2 k_{33}} \right]^2 \cdot h^6 F(ph) \tag{7}$$

$$F(ph) = \frac{1}{(ph)^6} \left\{ \frac{ph}{4sh^2(ph)} \left[sh(2ph) - 2ph \right] + 2\left[1 - ph \frac{ch(ph)}{sh(ph)} \right] + \frac{1}{3}(ph)^2 \right\} \tag{8}$$

where $p = \sqrt{\frac{\Delta\varepsilon E^2}{4\pi k_{33}}}$. So the amplitude changes of the phase difference δ can be described by the equation :

$$\frac{\delta}{2} = A \cdot \Delta p_0^2 \cdot F(ph) \tag{9}$$

where A is a parameter, which depends on material coefficients of a nematic liquid crystal.

The last equation explains a strong dependence of the optical response on the amplitude of a pressure difference Δp_0 which is shown in figure 3 . The dependence of ΔI_m on U is determined by a function F(ph) which is presented in the Table.

TABLE The dependence of F on the parameter (ph)

ph	0	1	2	3	4	5	6	8	10
$\frac{F(ph)}{F(ph=0)}$	1	0.84	0.51	0.28	0.15	0.09	0.05	0.02	0.01

The dates of the table and the equations (6), (7) show that the electric field must suppress effectively the optical response of the layer and this behavior was observed experimentally (figure 3).

It is worthwhile to notice that by a proper choice of stabilizing voltages one can see sharp boundaries between neighbor stripes. So a visual estimate of a pressure difference can be obtained with the help of this cell.

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