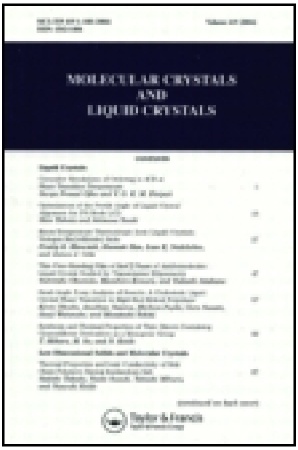

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Friedericksz Threshold in Bipolar Nematic Droplets with Rigidly Fixed Poles

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Friedericksz Threshold in Bipolar Nematic Droplets with Rigidly Fixed Poles

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We have studied experimentally a problem of the threshold behavior of Friedericksz transition in bipolar nematic droplets with rigidly fixed poles. The dependence of the light transmission of the PDLC film on the applied voltage has obviously revealed a threshold for the straightforward passing beam, confirming the threshold behavior of reorientation process in a central part of the droplet, which was theoretically predicted in [5]. In agreement with a simulation [5] the dependencies of scattering light intensity versus voltage have showed the non-threshold behavior. We have checked-up also the interference origin of the oscillations of volt-contrast curves for these PDLC films. A number of oscillations and their amplitude depend on wavelength and films thickness.

Keywords: polymer dispersed liquid crystals; nematic droplets

INTRODUCTION

Experimental study of volt-contrast curves in polymer dispersed liquid crystals (PDLC) with rigidly fixed poles in a bipolar nematic droplets have been carried out in [1,2]. It has been found that the transmittance of the light passing straightforward through the film on applied voltage reveals threshold behavior with the oscillations above the critical field. Oscillations are observed only for droplets with a diameter of large than 4 μm. The greater droplets the large number of oscillations.

These specific features have been explained by the theoretical simulation [3,4,5] of a transformation of the director configuration in the droplets that allowed to calculate a volt-contrast curve (VCC). The interference of light beams passing trough the LC droplets and polymer is a cause of the oscillations. Reorientation process of bipolar nematic droplet with rigidly fixed poles [3,4,5] differs significantly from one in droplets with moving poles [6,7,8]. In the case of fixed poles the threshold reorientation occurs only in that part of a droplet, where the LC director is orthogonal to the applied field. In the rest of the droplet volume, the director reorientation is nonthreshold.

We study experimentally here the complex behavior (threshold-nonthreshold) of the director reorientation in bipolar nematic droplets with rigidly fixed poles. We analyze also the dependencies of VCC dependencies both on the wavelength and the thickness of PDLC cell.

SAMPLES AND ELECTO-OPTIC MEASUREMENTS

PDLC films were prepared by a method of solvent-induced phase separation (SIPS) [9]. Polyvinylbutyral dissolved in ethanol are mixed with the LC 5CB in ratio 1:1 to form a homogeneous solution. The solution was poured on glass substrate with transparent electrodes and the solvent evaporated resulting in formation of the composite film. A second substrate has been placed on the top of film heating to create the optical contact between PDLC and substrates. To vary the droplet size we controlled the rate of evaporation.

Electro-optic response of PDLC cells was measured using a helium neon laser, generator of sinusoidal electric signals, photodiode and XY recorder. The output of the photodiode was linear with light intensity over all range of measurements. To study the spectral dependencies of volt-contrast curves we used argon laser generating a different wavelength.

VOLT-CONTRAST CURVES OF THE PASSING STRAIGHTFORFARD AND SCATTERING LIGHT

As it follows from the simulation [3,4,5], the reorientation of LC director depends strongly on the coordinates inside nematic droplets. Director in the central point O (Fig.1), XOY plane and at the Z-axis isn't reoriented up to critical field

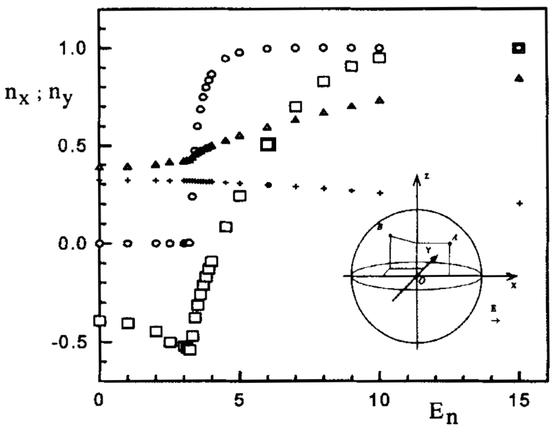

FIGURE 1 The director reorientation inside bipolar nematic droplet with rigidly fixed poles versus the relative value of applied electric field E_n [5] for three points showed on an insert. n_x (○, □, Δ for points *O*, *A*, *B* accordingly); n_y (+ for point *B*) are the X and Y projections of LC director. n_y=0 for points *O*, *A* in the whole of range E_n.
$n_z^2 = 1 - n_x^2 - n_y^2$.

E_n=3.3. In other coordinates, for example in the point A and B, director orientation begin to change from E_n=0.

The light passed straightforward through the PDLC film is a superposition of light beams passed through the polymer matrix and one passed through the LC droplets along the X-axes. Threshold reorientation of LC director at the X-axes (Fig.1) must results in threshold behavior of the dependencies of light the transmission on the applied voltage. On the other hand, the scattering light is a sum of light beams passed through the noncentral points inside the droplets, in which initial orientation of director isn't orthogonal to the electric field. Therefore volt-contrast curve of the light scattered at the angle α>0 (Fig.2) will not reveal the threshold behavior. As can see in Fig.2, the experimental data confirm the results of above analysis.

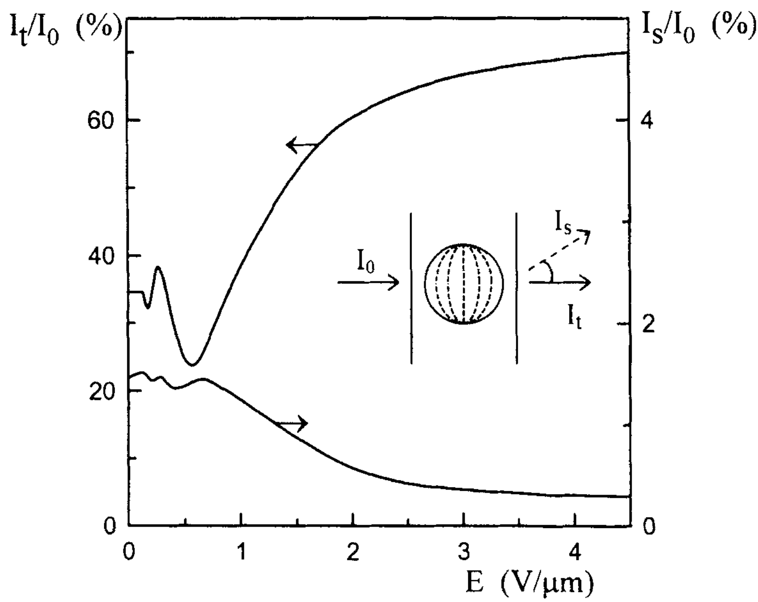

FIGURE 2 Volt-contrast curve for the light beams I_t passed straightforward through the PDLC films and I_s scattered at the angle $\alpha=7^0$.

SPECTRAL DEPENDENCIES OF OSCILLATION PARAMETERS

Light transmission of PDLC film can be described approximately in framework of an anomalous diffraction approach by the formulas [10,11,3,5]:

$$J = J_0 \exp(-N\sigma d) \ , \qquad (1)$$

$$\sigma = 2\sigma_0 \left[1 - \frac{2}{\nu} \sin\nu + \frac{2}{\nu^2} (1 - \cos\nu) \right] \ , \qquad (2)$$

$$\nu = 2kR\left(\frac{n_{lc}}{n_p} - 1 \right). \qquad (3)$$

where N is number of spherical particles in unit volume; $\sigma_0 = \pi R^2$; R is the radius of a droplet; n_{lc}, n_p - refractive indexes of the liquid crystals and polymer, respectively.

It is clear from (1)-(3), scattering cross-section σ depends on the wavelength because of the spectral dependence of parameter ν. Consequently the parameters of volt-contrast curve (position of maximums and minimums, a number of oscillations) must be dependent on the wavelength. Fig.3 shows the experimentally measured curves of light transmission of PDLC under study on the applied voltage for different wavelength of argon laser (λ = 515, 488, 477, 458 nm). There is only one maximum for λ=515 nm. For another wavelengths (especially for λ=458 nm) we observe two maximums: one is about 4 V and other is near of threshold field. It should be noted that the positions of the extremes are also dependent on wavelength.

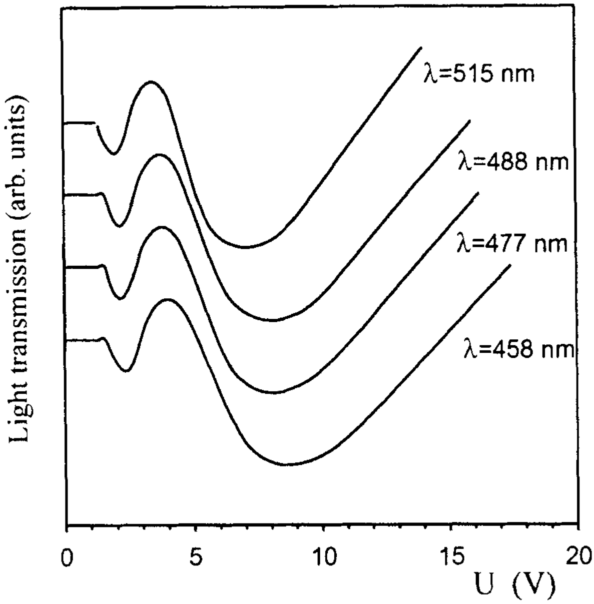

FIGURE 3 Light transmissions of PDLC film versus an applied electric field for the argon laser beam with different wavelength.

VOLT-CONTRAST CURVES OF PDLC CELL WITH MULTIPLE LIGHT SCATTERING

This topic is an attempt to answer the question why researches didn't observed earlier the oscillations of volt-contrast curve. As was discussed in [1,2], it is necessary to meet simultaneously two requirements to obtain the oscillation behavior: the size of LC droplets must be greater than 4 μm and the ensemble of droplets must be arranged in one layer in the polymer film plane.

For the illustration of this conclusion, we prepared three monolayer PDLC cells with different size of LC droplets. The dependencies of the light transmission of these films on the applied voltage (see Fig.4) very distinguish

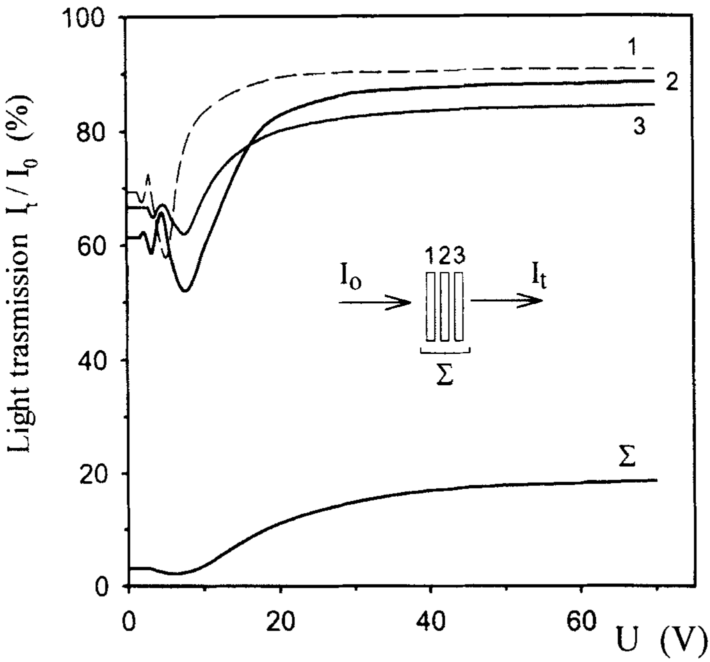

FIGURE 4 Volt-contrast curves for the three separate PDLC cells (1, 2, 3) and common one for all cells arranged in series (Σ).

from each other. Then we arranged the cells in series and measured the common light transmission through all PDLC films. A curve Σ (see Fig.4) demonstrates obviously, that all extremes disappear and only first minimum remains with smaller amplitude. It should be noted, that similar behavior of VCC was observed earlier [12], but explained by the appearance of additional defects inside the LC droplets.

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