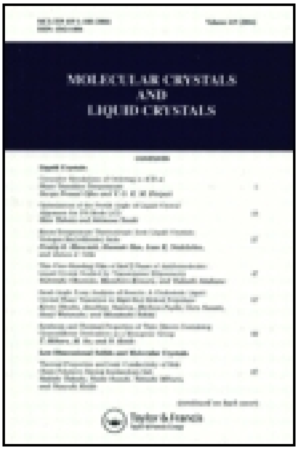

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Electrooptical Response of Surface Droplets of Liquid Crystal

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Electrooptical Response of Surface Droplets of Liquid Crystal

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The peculiarities of the electrooptical response for nematic surface droplets of liquid crystal are considered. The possibility of a dramatic increase for the contrast ratio on the base of the coherent transmittance quenching effect is shown.

Keywords: liquid crystal dispersion; nematic; transmittance

INTRODUCTION

In the last years, much consideration has been given to the new liquid crystal (LC) electrooptical materials - surface droplets of liquid crystal (SDLC) [1-3] - in which LCs droplets are arranged in one layer (monolayer) and embedded in the binding polymer. The flexibility of these materials, their high luminance, the comparatively large format, the simple production process, reliability in use, etc., make them promising for various practical applications (light modulators, optical shutters, TV projection system, displays, colour filters, etc.).

One of the most important tasks concerning SDLC materials is to seek methods for increasing their contrast. It is possible to increase the contrast ratio by creating the SDLC film, in which the interference quenching effect is realized [3-5].

The realization of the quenching effect in the SDLC films depends on many parameters: optical constants of the liquid crystal and the polymer binder; the size, shape, concentration and the degree of ordering of droplets; polydispersity of droplets; the director field structure in the droplet and orientation of the droplets' optical axes.

In this work theoretical consideration of electrooptical response for nematic SDLC film has been made.

TRANSMITTANCE OF SDLC

Let a SDLC be normally illuminated by a plane linearly polarized wave. Determine the transmittance T of the SDLC as the ratio of scattered flux Φ_s to the incident flux, Φ_o.

Taking into account that scattered light is the sum of coherently (regularly) scattered light and incoherently (diffusely) scattered light [6], we write:

$$T = \frac{\Phi_s}{\Phi_o} = T_c + T_{inc}, \tag{1}$$

where the coherent transmittance, T_c, is [3-6]

$$T_c = 1 - Q\eta + \frac{Q^2 L}{2}\eta^2, \tag{2}$$

and the incoherent transmittance T_{inc}, is

$$T_{inc} = \frac{R^2}{I_o A}\int_{\Omega}(I_{inc}^{VV} + I_{inc}^{VH})d\Omega. \tag{3}$$

In the Eqs.(2), (3), Ω is the solid angle of field of view (FOV); Q is the extinction efficiency factor [7,8]; η is the filling coefficient of SDLC and is equal to the ratio of the area of projections of all droplets on the substrate plane to the area in which they are distributed; R is the distance from the SDLC to the detector; I_o is the incident light intensity; $I_{inc}^{VV}, I_{inc}^{VH}$ are the *VV*- and *VH*- components of incoherently scattered light [9]; the parameter L is given by the formula:

$$L = \frac{1}{2}\left(1 + \frac{\mathrm{Im}^2\,\overline{f_{VV}(0)}}{\mathrm{Re}^2\,\overline{f_{VV}(0)}}\right)\left(1 + \frac{\left|\overline{f_{VH}(0)}\right|^2}{\left|\overline{f_{VV}(0)}\right|^2}\right), \tag{4}$$

where $\overline{f_{VV}(0)}$ and $\overline{f_{VH}(0)}$ are the average values (in terms of sizes and orientations of droplets directors) of the components of the vector amplitude of scattering.

Attention is drawn to the fact that for droplets with $L = 0.5$ and $Q = 2/\eta$ the coherent transmittance coefficient can be equal to zero (see Eq. 2). This effect takes place as a results of the interference of the incident and the scattered wave when their amplitudes are equal and the phases are opposite.

It is impossible to obtained "zero transmittance" of the SDLC by experiment, since transmittance measurements are carried out , as a rule, by angular apertures larger than the angle of diffraction divergence of the beam (within this angle the coherent component of scattered light is formed) and in practice a certain portion of incoherent scattered light is always registered. Therefore, detailed analysis of the possibilities of increasing the contrast ratio of the SDLC film at the cost of the interference effect of coherent intensity quenching should also include the influence of incoherent intensity on the film transmittance.

In common, for FOV values of the order of the beam diffraction divergence angle the incoherent transmittance, T_{inc}, in Eq. (3) can be neglected and we can restrict ourselves to the coherent transmittance coefficient, T_c, alone. If the interference effect of coherent transmittance quenching is realized thereby, this makes it possible to increase dramatically the contrast ratio, which is determined as the ratio of transmittances under applied field and without it. In the case where the effect of coherent light quenching has been attained in the SDLC film and the FOV is considerably larger than the diffraction divergence angle, the incoherent intensity cannot be neglected and analysis of the contrast ratio as a function of FOV is required.

PECULIARITIES OF THE SDLC ELECTROOPTICAL RESPONSE

In given section we consider the electrooptical response peculiarities for the SDLC with bipolar nematic droplets at conditions when the quenching effect of the coherent component scattered light is realized. There are two kinds of electrooptical response for bipolar nematic droplets: S-formed response, and oscillation ("anomalous") response (see Figures 1,2). Figure 1 shows the SDLC film transmittance with bipolar nematic droplets versus the polar orientation angle θ between the droplets director and SDLC film plane. The quenching effect is achieved at planar structure of droplets director ($\theta = 0$). At switching directors structure from planar to homeotropic ($\theta = 90^\circ$) in certain conditions it is possible to obtain the maximum value of transmittance equal to unit [3]. The angle θ depends on applied electric field [10].

Figure 2 illustrates the quenching effect at values $0^\circ < \theta < 90^\circ$. Oscillation character of electrooptical response is defined by oscillation of efficiency extinction factor.

The given results on Figures 1,2 points to possibilities of electrooptical response optimization with wide linear part and interference contrast ratio enhancement. Today, the contrast enhancement in four time has been reached [11,12].

The results has been obtained in single-scattering approximation and anomalous diffraction approach. The calculation of angular structure for scattering light carried out using the Percus-Yewick approximation in the framework of "hard" dicks model [6].

Conclusion

Obtained results gives new possibilities for creating high contrast laser modulators on the base of SDLC film with interference contrast enhancement.

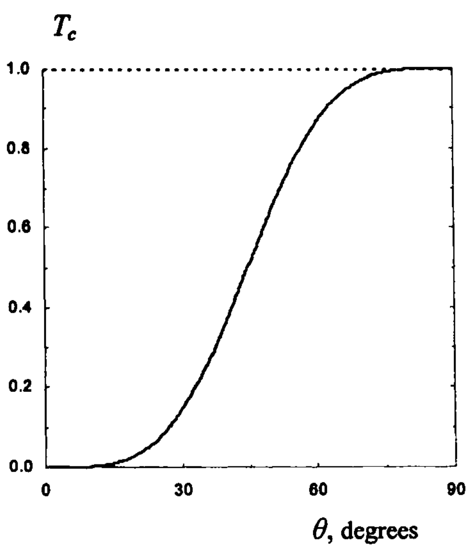

FIGURE 1. Coherent transmittance T_c versus polar orientation angle θ of droplets director at transition from the planar configuration ($\theta = 0$)

to the gomeotropic one ($\theta = 90°$). The effect of coherent transmittance quenching is achieved at planar orientation of droplets directors ($\theta = 0$). The ordinary refractive index $n_o = 1.53$; the optical anisotropy $\Delta n = 0.187$; the polymer refractive index $n_p = 1.546$; the droplet order parameter $s_d = 0.7$; the filling coefficient $\eta = 0.643$; the size parameter $sp = 27$.

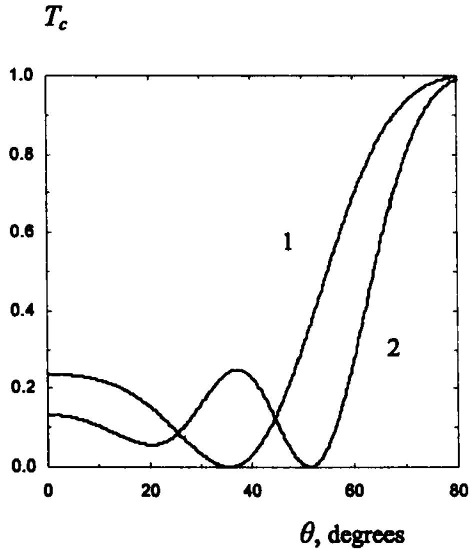

FIGURE 2. The coherent transmittance versus polar orientation angle of droplets directors. The effect of coherent transmittance quenching is achieved at $\theta \neq 0$. The ordinary refractive index $n_o = 1.53$; the optical anisotropy $\Delta n = 0.187$; the polymer refractive index $n_p = 1.546$; the droplet order parameter $s_d = 0.7$; the filling coefficient $\eta = 0.643$.

1. Size parameter $sp = 42.5$;
2. $sp = 75$.

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