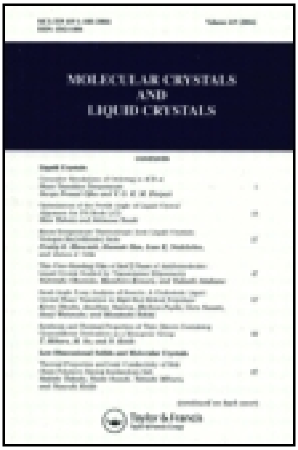

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Valery A. Loiko [a] & Alexander V. Konkolovich [a]

[a] Institute of Physics, National Academy of Sciences of Belarus, 68 F. Skaryna Ave., 220072, Minsk, Belarus

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Polymer-Dispersed Ferroelectric Liquid Crystal Films: Propagation of Polarized Light in the Birefringence Mode

VALERY A. LOIKO and ALEXANDER V. KONKOLOVICH

Institute of Physics, National Academy of Sciences of Belarus, 68 F. Skaryna Ave., 220072 Minsk, Belarus

On the basis of the amplitude-phase screen model, coherent transmittance for a thin layer of liquid crystal droplets is considered. It is shown that for the polymer dispersed ferroelectric liquid crystal (PDFLC) film produced on the basis of bistable smectic liquid crystals it is possible to provide coherent transmittance close to zero and unity for two stable states of droplet director in the applied field.

Keywords: ferroelectric; transmittance; contrast ratio

INTRODUCTION

One of the problems in developing liquid crystal (LC) devices on the basis of LCs dispersed into a polymer is the search for ways of increasing their contrast ratio. In the present paper a simple model is proposed for describing the passage of polarized light through a thin polymer dispersed liquid crystal (PDLC) film. It takes into account interference of incident and forward-scattering waves and gives an analytical expression for the coherent transmission coefficient of a thin PDLC layer. The results have been analyzed for a layer of ellipsoidal ferroelectric droplets. The effect of coherent transmission quenching has been studied theoretically and the conditions have been determined under which it is possible to switch the values of the coherent transmission coefficient from zero to unity for two stable states of the droplet director. The result obtained can be used in developing PDLC devices with a high contrast ratio in the transmission mode.

COHERENT TRANSMITTANCE OF A THIN PDLC LAYER.

Let a thin polymer dispersed liquid crystal (PDLC) film, whose thickness is equal to several sizes of the droplets forming it, is illuminated along the normal by a polarized plane wave. We consider two components of the radiation passed through the layer: the VV- and the VH-component with polarizations, respectively, parallel and perpendicular to the plane of polarization of the incident wave. We shall further use indices VV and VH (as a superscript or a subscript) to denote these components.

Based on the model of an amplitude-phase screen (APS) [1-3], for the local amplitude transmission coefficients of the layer we write

$$T_a^{VV} = \begin{cases} 1, \underline{x} \in A_1, \\ \prod_{j=1}^{N} V_j^{VV}, \underline{x} \in A_2 = \bigcup \sigma_j, \end{cases} \tag{1a}$$

$$T_a^{VH} = \begin{cases} 0, \underline{x} \in A_1, \\ \prod_{j=1}^{N} V_j^{VH}, \underline{x} \in A_2 = \bigcup \sigma_j, \end{cases} \tag{1b}$$

where A_1 and A_2 are, respectively, the unshaded and shaded regions in the layer plane; $A_1 + A_2 = A$ is the layer area; σ_j is the j-th droplet projection on the layer plane; V_j^{VV} and V_j^{VH} are the transmission functions of equivalent screens identified with the j-th droplet; N-is the number of droplets on the path of the ray through the layer.

Coherent transmission coefficient [4]

$$T_c = \left|\left\langle T_a^{VV} \right\rangle\right|^2 + \left|\left\langle T_a^{VH} \right\rangle\right|^2, \tag{2}$$

where the angular brackets denote the statistical averaging (in the general case, averaging over sizes, shapes and orientation of droplets in the layer is required).

Assume that the layer consists of oriented droplets identical in shape and equal in size. Then, on averaging, it is sufficient to introduce into consideration the one-dimensional probability distribution function $P_N(L)$ for droplets number N in the layer of thickness L. If we also restrict ourselves to the single scattering approximation in the layer, then from Equation (1) we obtain

$$\left\langle T_a^{VV} \right\rangle = P_o(L) + \sum_{j=1}^{N_{max}} V_{VV}^N P_N(L), \tag{3a}$$

$$\left\langle T_a^{VH} \right\rangle = \sum_{j=1}^{N_{max}} V_{VH}^N P_N(L), \tag{3b}$$

where N_{max} is the maximum number of droplets which can meet the ray passing through the layer; V_{VV} and V_{VH} are related to the corresponding components of the vector amplitude of scattering at a zero angle of scattering $f_{VV}(0)$ and $f_{VH}(0)$ by the relations [1]:

$$V_{VV} = 1 - \frac{2\pi}{k^2\sigma} f_{VV}(0), \tag{4a}$$

$$V_{VH} = \frac{2\pi}{k^2\sigma} f_{VH}(0), \tag{4b}$$

where $k = 2\pi/\lambda$, λ - is the wavelength in the polymer; σ is the droplet section by the layer plane.

Presuming that the droplets do not penetrate into one another [5], we can obtain the following expression [6] for $P_N(L)$:

$$P_N(L) = \frac{b^N C_{N_{max}}^N}{(1+b)^{N_{max}}}, \tag{5}$$

where $C_{N_{max}}^N$ is the number of combinations from N_{max} to N, $N_{max} = [L/l]$, l is the linear size of droplets in the direction of the normal to the layer, the square brackets mean that the integer part of the ratio is taken. The dimensionless quantity b in the Eq. (5) depends on the relative volume concentration of droplets C_3 and their shape. For spherical [6] and, as can be shown, ellipsoidal droplets

$$b = 1.5C_3 \exp(1.5C_3). \tag{6}$$

As a result, from Eqs (2), (3), (5),

$$T_c = \left\{1 - \frac{b}{b+1} 2\,\mathrm{Re}(1 - V_{VV}) + \left(\frac{b}{b+1}\right)^2 |1 - V_{VV}|^2\right\}^{L/l} +$$
$$+ \frac{1}{(1+b)^{2L/l}} \left\{1 + \left\{1 + 2b\,\mathrm{Re}\,V_{VH} + b^2 |V_{VH}|^2\right\}^{L/l} - \right. \qquad (7)$$
$$\left. 2\left\{1 + 2b\,\mathrm{Re}\,V_{VH} + b^2 |V_{VH}|^2\right\}^{2L/l} \cos\left(\frac{L}{l} arctg \frac{b\,\mathrm{Im}\,V_{VH}}{1 + b\,\mathrm{Re}\,V_{VH}}\right)\right\}$$

ELLIPSOIDAL FERROELECTRIC DROPLETS

Let us consider a layer of ellipsoidal ferroelectric droplets within the framework of the anomalous diffraction approximation [4,7,8]. We determine the following quantities needed for our consideration: the angle of polarization α, the tilt angle φ_d, the refractive indices of the ordinary ray n_o, the extraordinary ray n_e and polymer n_p. The expressions for the component of the vector amplitude of scattering $f_{VV}(0)$ and $f_{VH}(0)$, are given in [4].

We shall investigate the coherent transmission coefficient of a thin PDFLC layer for two stable states of the director: the d^+- and d^--states characterized, respectively, by the angles of polarization $\alpha^+ = 0$ and $\alpha^- = 2\varphi_d$ [4]. We analyze the possibilities of coherent transmission quenching in a thin PDFLC layer and the switching of its values from zero to unity. Figure 1 shows the dependence of the coherent transmission coefficient in the d^+- state on the diffraction parameter kc ($l = 2c$). For the values of $kc \approx 34$ and $c_3 \approx 0.54$ the coherent transmission coefficient T_c^+ tends to zero, i. e. there occurs quenching of the coherent component in the radiation passed through the PDFLC film. The volume concentration of droplets at which $T_c^+ \to 0$ does not depend on the layer thickness.

The value of kc at which $T_c^+ = 0$ is determined by the equation:

$$kc \approx \frac{4.49}{2\left|\frac{n_e}{n_p} - 1\right|}. \tag{8}$$

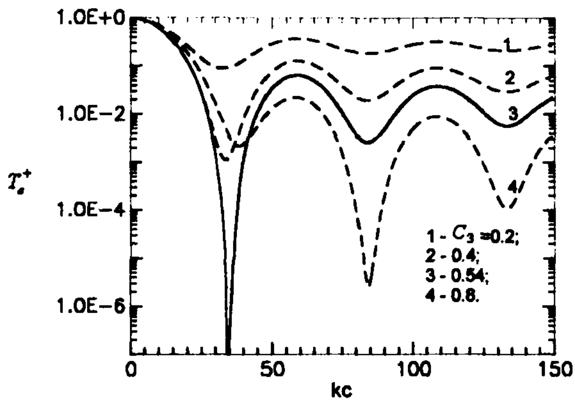

FIGURE 1. Coherent transmittance in $\underline{d}^+$ - state versus the size parameter ($\alpha^+ = 0; n_e = 1.65; n_p = 1.55. \forall n_o; L/2c = 2$).

Note that in the d^+ -state the coherent transmission of the layer does not depend on the ordinary refractive index n_o. This is due to the incident wave polarization in the principal plane. For calculations we chose the ordinary refractive index of the droplet equal to the refractive index of the polymer, since this condition together with the condition $\varphi_d = 45^{\circ}$ gives ordinary refractive index of the droplet equal to the refractive index of the polymer, since this condition together with the condition $\varphi_d = 45^\circ$ gives the value of T_c^- equal to unity independent of the diffraction parameter, the droplet concentration and the layer thickness. And if the size of droplets satisfies expression (8) and their concentration corresponds to the condition of coherent transmission quenching in the d^+-state ($c_3 \approx 0.54$), then coherent transmission values equal to zero and unity are thereby attained by switching the director from the d^- - to the d^+ - -state.

For tilt angle $\varphi_d < 45^\circ$ coherent transmission in the d^--state decreases with increasing thickness of the layer (see Figure 2) at equal values of φ_d.

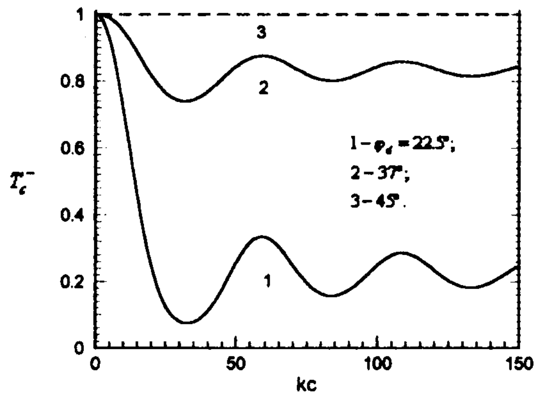

FIGURE 2. Coherent transmittance in d^- - state versus the size parameter $n_e = 1.65; n_o = n_p = 1.55 . C_3 = 0.54 ; L/2c = 2$).

Attention is drawn to the fact that it is possible to reach the values of $T_c^+ = 1$ and $T_c^- = 0$. To this end, we have to choose the refractive index of

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