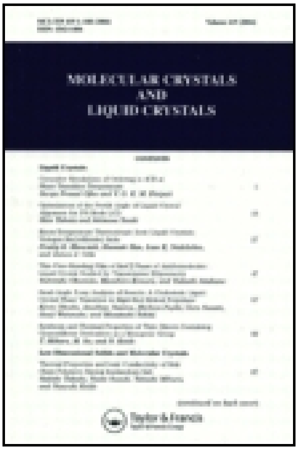


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Optical Modulation by Surface Droplets of Ferroelectric Liquid Crystal

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

[a] Institute of Physics, National Academy of Sciences, Minsk, Belarus

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 351, pp. 371-377
Reprints available directly from the publisher
Photocopying permitted by license only

Optical Modulation by Surface Droplets of Ferroelectric Liquid Crystal

VALERY A. LOIKO and ALEXANDER V. KONKOLOVICH

Institute of Physics, National Academy of Sciences, Minsk, Belarus

The influence of polydispersion and disorientation of droplet axes in surface liquid crystal droplets (SLCD) films on the conditions for the realization of the interference effect of coherent scattered light quenching has been investigated.

Keywords: ferroelectric; transmittance; contrast ratio; modulation depth

INTRODUCTION

One way to increase the modulation depth and the contrast ratio of polymer-dispersed liquid crystal films (PDLC) films is to create a PDLC monolayer in which the interference effect of quenching of coherent scattered light is realized.[1]

The realization of the quenching effect depends on the internal structure, size of droplets, the refractive indexes of the binding polymer[2] and liquid crystal (LC). The present paper considers the so-called surface liquid crystal droplets (SLCD) films in which the hemi-sphere-shaped droplets are applied on a flat substrate and are embedded in the polymer. As to its structure, the SLCD film represents a PDLC monolayer. The droplets are formed from a bistable ferroelectric LC with a uniformly oriented configuration of the LC directors.

Earlier[3] the conditions were found for quenching the coherent transmission coefficient of SLCD film in the case of monodisperse droplets oriented with their axes in one direction (by "droplet axis" we mean the direction of the normal to the smectic layers). The real SLCD film has some spread in sizes of droplets and their axes are mainly oriented in one direction. It is therefore necessary to investigate the influence of polydispersion and disorientation of droplet axes on the conditions for coherent transmittance quenching.

QUENCHING CONDITIONS IN THE ANOMALOUS DIFFRACTION APPROACH. GAMMA-SIZE-DISTRIBUTION OF DROPLETS AND UNIFORM DISTRIBUTION OF THEIR ORIENTATIONS

The equation for the coherent transmittance of SLCD film T_c was obtained in Reference.[3]

Let us here assume that there is statistical independence between the droplet sizes c (c is the radius of the droplet) and the angle of orientation of their axes φ (φ is the angle between droplet axis and the direction of average orientation of droplet axes) and the distribution function of droplet sizes is described by the gamma-distribution:

$$P(c) = \frac{\mu^{\mu+1}}{\Gamma(\mu+1)} \frac{c^{\mu}}{c_m^{\mu+1}} \exp(-\mu c / c_m), \qquad (1)$$

and the orientation of the droplet axes is described by the uniform distribution:

$$P(\varphi) = \begin{cases} 1/2\varphi_o, \varphi \le \varphi_o \\ 0, \varphi > \varphi_o \end{cases} . \qquad (2)$$

In Equations (1), (2), c_m is the modal (most probable) size of droplets; φ_o is the maximum deviation angle of the droplet axis from the direction of average orientation; Γ is the gamma-function with parameter μ. As a result, we find that to make the coherent transmission coefficient vanish in the $\underline{d^+}$ - state[2,3] (to realize the quenching effect), the following conditions should be met:

(i) the angle of polarization α (α is the angle between the incident wave polarization vector and the direction of prevailing orientation of droplet axes) should be equal to the tilt angle φ_d ($\alpha = \varphi_d$);

(ii) the refractive index of the polymer n_p should be equal to the ordinary refractive index of LC n_o ($n_p = n_o$);

(iii) the modal size of droplets c_m should satisfy the relation:

$$kc_m = \frac{v'_m}{n_e / n_p - 1}, \qquad (3)$$

where n_e is the extraordinary refractive index of LC and v'_m is the solution to the equation:

$$(\mu+2)arctg\frac{v'_m}{\mu} - arctg\frac{v'_m}{\mu}(\mu+2) = \pi s, \tag{4}$$

$s = 1,3,5,\ldots$;

(iv) the filling coefficient $\eta^{2,3}$ should be equal to η_0, where η_0 is defined by the expression:

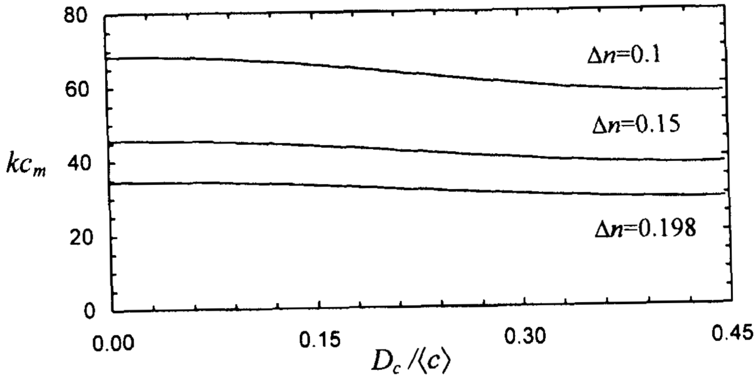
$$\eta_0 = 2\left\{\left(1+\frac{\sin 2\varphi_o}{2\varphi_o}\right)\times \left[1+\frac{2\mu^2}{v'^2_m(\mu+1)(\mu+2)}\left(1+\sqrt{1+\frac{v'^2_m(\mu+2)^2}{\mu^2}}\Bigg/\left(\sqrt{1+\frac{v'^2_m}{\mu^2}}\right)^{\mu+2}\right)\right]\right\}^{-1}. \tag{5}$$

The least value of the filling coefficient η_0 as a function of the variation coefficient of the size distribution of droplets $D_c/\langle c\rangle$ (D_c is r.m.s. deviation; $\langle c\rangle$ is the mean value of droplet sizes; for the gamma-distribution: $\langle c\rangle = (\mu+1)c_m/\mu$; $D_c/\langle c\rangle = 1/\sqrt{\mu+1}$) is realized for the solution v'_m corresponding to $s = 1$ in Equation (4).

To the asymptotic transition to the monodisperse case of oriented droplets ($\mu \to \infty, \varphi_o \to 0$) at $s = 1$ correspond the values of $v'_m = 4.4934$ and $\eta_0 = 0.6431$. The quenching conditions for monodisperse oriented droplets, which follow from Equations (3)-(5) obtained here, are specified in the previous paper.[3] Note that in the case of oriented droplets ($\varphi_o = 0$), to attain the effect of coherent transmittance quenching, the conditions of equality of the refractive indices n_p and n_o is not needed unlike the case of partially disoriented directors of droplets under consideration. The condition $n_p = n_o$ at a title angle $\varphi_d = 45^\circ$ for monodisperse oriented droplets provides, along with the fulfillment of the conditions for quenching,[2,3] a change in the value of T_c from zero by unity when the director goes from the $\underline{d}^+$ - state to the $\underline{d}^-$ - state.[2,3] At disoriented droplet axes, it is not possible to attain the value of T_c equal to unity (total transparency of SLCD film) for illumination by linearly polarized light.

Figure 1 shows the modal size parameter kc_m as a function of the variation coefficient $D_c / \langle c \rangle$ for various values of optical anisotropy of droplets $\Delta n = n_e - n_o$ ($n_p = n_o$). It is seen that with increasing variation coefficient $D_c / \langle c \rangle$ the modal size parameter at which the quenching effect is realized decreases. To larger values of optical anisotropy of droplets there correspond lesser values of the modal size parameter for the same value of the variation coefficient of the size distribution of droplets.

The filling coefficient η_0 as a function of the variation coefficient $D_c / \langle c \rangle$ for various values of the maximum deviation angle of droplet axes φ_o is given in Figure 2. From Figure 2 it is seen that to an increase in both the variation coefficient and the deviation angle of droplet axes φ_o there corresponds an increase in the filling coefficient η_0 for the realization of the quenching effect (the minimum value of $\eta_0 = 0.6431$ is attained in the case of monodisperse oriented droplets



FUGURE 1 The modal size parameter kc_m versus the variation coefficient $D_c/\langle c\rangle$ for realization of coherent transmittance quenching. $n_o = 1.524$.

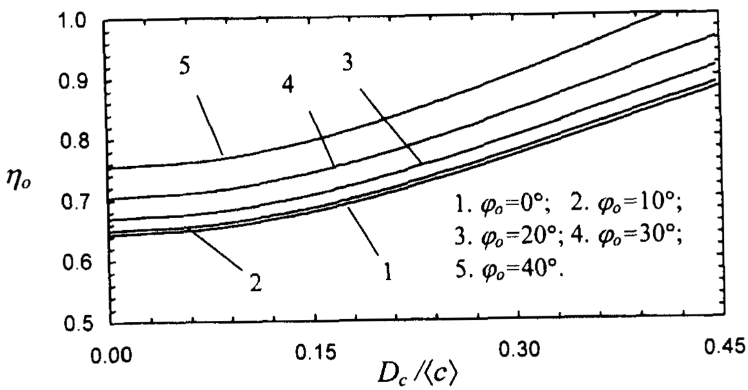


FIGURE 2 The filling coefficient η_0 versus the variation coefficient $D_c/\langle c\rangle$ for realization of coherent transmittance quenching.

($D_c/\langle c\rangle = 0, \varphi_o = 0$). As calculations show, at $\varphi_o < 5^\circ$ the curves of $\eta_0 = \eta_0(D_c/\langle c\rangle)$ practically merge.

CONCLUSION

The results obtained show that the interference effect of coherent scattered light quenching in SLCD films can also be observed in the case of polydispersion of droplets and disorientation of their axes. Polydispersion and disorientation of axes of droplets lead to a change in the conditions (compared to monodispersed oriented droplets) for realization of this effect.

Acknowledgments

The research described in this publication was made possible in part by Award No. BE1-113 of the U. S. Civilian Research & Development Foundation for the Independent States of the Former Soviet Union (CRDF) and European Commission in the frame of INCO-Copernicus program (contract No. ERB IC15-CT98-0806).

References

[1] A. P. Ivanov, V. A. Loiko, V. P. Dick, *Light scattering in closely packed dispersion media* (Nauka i thechnika, Minsk), Chap.2, pp.34–73 (1988 Rus.).
[2] V. A. Loiko, A. V. Konkolovich, *Mol. Cryst. Liq. Cryst.*, **320,** 337 (1998).
[3] V. A. Loiko, A. V. Konkolovich, V. Vorflusef, S. Kumar, *Proc. SID.* 7^{th} International Symposium "Advanced Display Technologies", Minsk, Belarus, pp. 71–74 (1998).