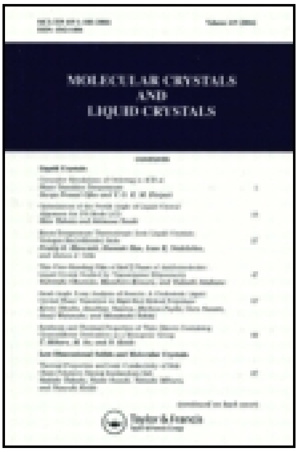

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THE ONE-POLAROID REFLECTIVE MODE IN LC DEVICES

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Abstract We discuss a method to investigate electrooptical effects in liquid-crystalline devices. Taking the one-polaroid reflective mode as an example it is shown that with this approach one can find all possible variants of the transitions with the light modulation in it. The electrooptical parameters of this mode are compared with those for the ordinary two-polaroid STN effect and suggestions for practical applications are outlined.

Keywords: displays, liquid-crystalline devices, reflection

INTRODUCTION

In order to reduce power consumption portable computers are equiped with LC displays of reflective type.
The most widely used are the full-page passive matrix displays, based on super-twist, double supertwist and neutralized supertwist effects[1-2]. These displays have high contrast and reaction time as well. The main drawback of STN effect is the deeply coloured background. Although two other types of displays are uncoloured, the refractivity of neutralized STN displays does not exceed 25% and for double STN is even lower than 15%. This is the reason they are used only in the transmission regime with built-in sources of light, which increase power consumption. Besides this, if these displays are used in the reflective regime and the real polarizer and reflector are outside the gap, the viewing angle is decreased drastically as the thickness of the glass plates increased. According to this the development of the reflective LCD's with high brightness is very timely.

The authors of[1] dealing with STN effect mentioned that it is possible to construct reflective LCD using only the front polaroid. It was reported that while the brightness is increased, the contrast is decreased by about 75% compared to the double-polaroid effect. A more detailed study of the one polaroid mode was published in[3], where after the optimization of liquid crystalline parameters (twist angle 200°, Δnd=0.56 μm) it was shown that with the polaroid parallel to the optical axis of the liquid crystal it is possible to reach contrast ratios as high as 10:1 in passive matrix displays. Our purpose was to find the way to increase the contrast of the reflective mode keeping the brightness as high as possible.

COMPUTATION METHOD

The propagation of light through deformed helical liquid crystalline structure has been computed with the help of propagation functions. The equations describing liquid crystalline structure in the external electric field were solved by the Euler method. In all computation we used the following values of the dielectric and elastic constants: $\Delta\varepsilon$ =7, $\varepsilon_{\perp}$ =3, K_{11}=6.5x10^{-7} din, K_{22}=4.0x10^{-7} din, K_{33}=10.0x10^{-7} din. These values are not optimized, but they are convenient for graphical demonstration of the liquid crystalline layer parameters effect on the electrooptical properties of the displays. Equilibrium pitch P of the helix was taken depending on the twist angle-using the relation:

$$\frac{d}{P} = \frac{\varphi}{2\pi} - 0.2 \qquad (1)$$

where d is the thickness of the liquid crystalline layer. Such choice does not allow us to take into consideration texture transformations in chiral nematics[4].

For computational purposes the liquid crystalline cell has been divided into elementary twisted layers with constant value of the refractive index anisotropy, which was taken equal to the average one. In such approximation the light propagation through the elementary layer can be calculated analytically. On the other hand this permits to decrease the number of auxiliary layers compared to the case of untwisted ones. In the computations we neglected the following effects:

- the pretilt of the LC director on the surfaces,
- the dispersion of the refractive indices,
- the anisotropy of the glassplates,
- the reflection of light on the borders of the media.

The polaroids were considered to be ideal.

RESULTS AND DISCUSSION

Considering optical properties of the reflective display we can represent it as two LC layers with opposite twist placed between two polaroids. In contrast to double STN display the directions of the optical axes at the surfaces coincide and the polaroids are parallel.

During the propagation of light through the cell to the reflector the polarization vector does not strictly follow the structure. This leads to the appearance of the phase difference between the ordinary and extraordinary waves. In the twisted structure, in contrast to ordinary birefringent layers, the phase difference appears even in the case when the polaroid is parallel to the optical axis. The reflective mode has the peculiarity that due to the twist the phase difference between the ordinary and extraordinary waves varies non monotonically. This leads to the shift of the reflection maxima, as compared to the reflection spectra of the ordinary birefringent layer, and to the appearance of rather wide ranges of high reflection as well as to the narrowing of the absorption bands.

In figure 1 we presented the dependence of the one-polaroid mode transmittance on the twist angle and on $x=\Delta nd/L$ parameter, taken at different orientations of the polarizer.

The position of a range in which the absorption is observed is determined by

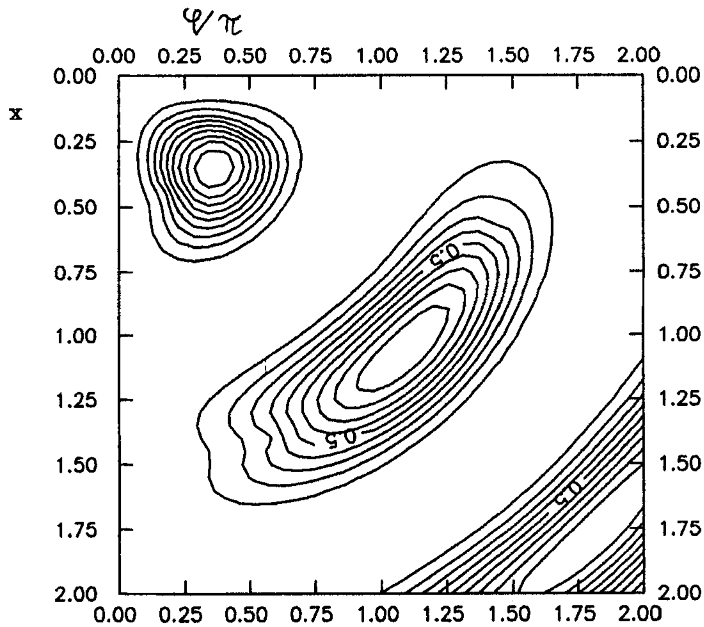

FIGURE 1 The intensity isolines for the reflective mode.

$$\frac{\Delta nd}{L} = (0.5 + \frac{\Phi}{\pi} + k)\cos(\frac{\pi}{4} - \frac{4}{\pi}\Phi^2) \quad (2)$$

$$\frac{\varphi}{\pi} = (0.5 + \frac{\Phi}{\pi} + k)\sin(\frac{\pi}{4} - \frac{4}{\pi}\Phi^2) \quad (3)$$

where Φ is the polarizer orientation, k stands for the peak number. These expressions describe the optimal conditions for the black-white (B) mode realization. We studied the ranges between the absorption regions. Here, one can realize the white-to-black transition (W).

The reflection spectra were computed for various values of the twist angle and Δnd as a function of the applied voltage. The orientation of the polaroid was chosen from the condition of the maximum achievable contrast. The results are presented in figure 2 as the curves of constant contrast.

As it can be seen from figure 2, the normally white mode W that we found here has a nuch higher contrast than the normally black mode B reported in[3]. At the same time, the B mode (as well as the yellow STN mode) under the conditions of maximum contrast has poor brightness (see figure 3).

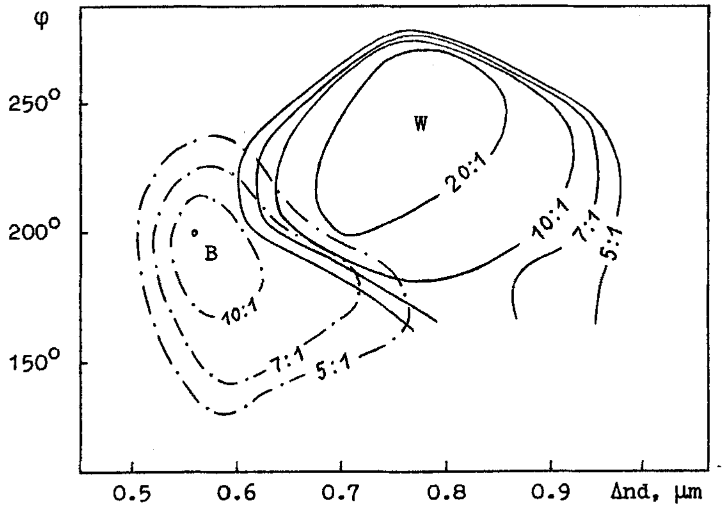

FIGURE 2 The contrast dependence on the LC layer parameters for the reflective modes: B - normally black, W - normally white. The point shows the result of the authors of (3).

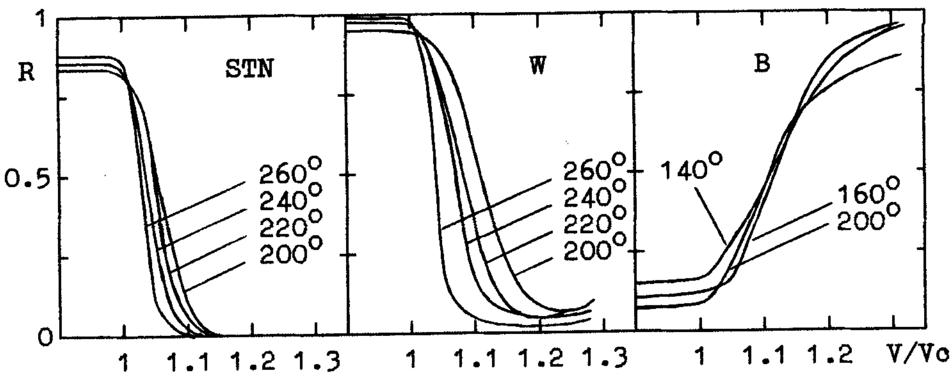

FIGURE 3 Reflectivity - voltage characteristics for yellow STN mode (STN), one polaroid mode studied in this paper (W) and one polaroid mode found in[3] (B). Twist angle is 240° (for B mode 200°).

It is interesting to compare reflectivity - voltage characteristics of these modes, because of possibilities of their employment in passive matrix displays. Yellow and blue STN modes have approximately the same slope, as they are realized under the same conditions. For reflective modes we have found that the W mode has much higher twist angles and consequently higher slope than the B mode. Optimal twist angles, for example, are 200° for B mode and near 250° for W mode respectively. Besides this, as it is seen from figure 3, the slope of reflectivity - voltage characteristic for B mode remains low at all twist angles.

One of the drawbacks of the STN effect is the presence of deeply coloured background and the change of the colour while the applied voltage is changed. From figure 4 one can see that W mode is not only much less coloured, but this colour is varies less with voltage.

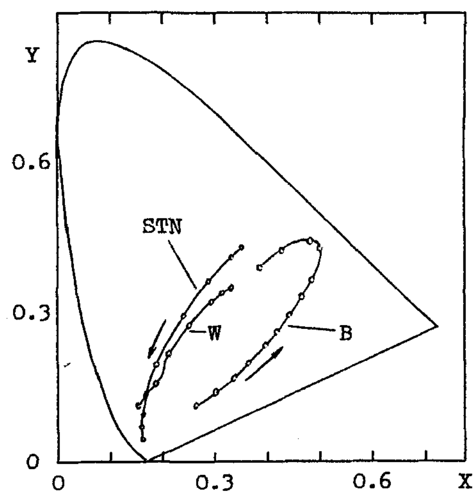

FIGURE 4 The voltage dependence of the colour coordinates for yellow (STN), B and W modes. Points stand for the change of voltage by 0.02 Vc. Arrows show the direction of the rise. Twist angle is 240° (for B mode 200°).

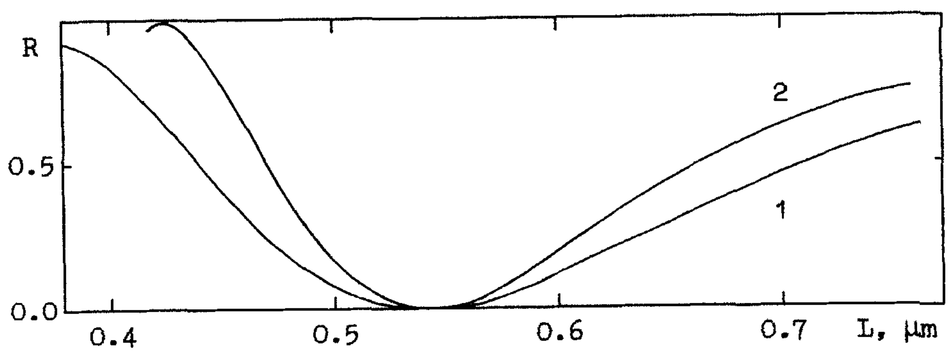

FIGURE 5 The transmittance spectrum changes after taking into account the refractive indices dispersion.

Nevertheless, during the construction of the liquid-crystalline devices the following peculiarities of these modes should be taken into account. First of all, any reflective mode requires specular reflection (in other cases the contrast is reduced) and that is why it is preferable to use them in the projection systems (black-white as well as coloured). Secondly, the liquid crystalline mixtures with high birefringence dispersion are not desirable because it leads to the narrowing of the absorption bands (figure 5) and consequently to the reduction of the image contrast.

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