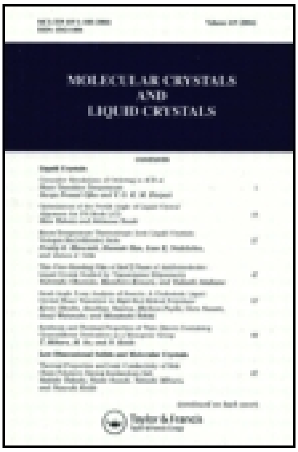

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

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Version of record first published: 04 Oct 2006.

Mol. Cryst. Liq. Cryst. 1995, Vol. 265, pp. 631–636
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SPATIAL MODULATION OF MATRIX NEMATIC LCD'S A FIBEROPTIC COMPONENTS

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Abstract The effectiveness of matrix-type spatial-temporal LC modulators used in information-array formation circuits depends not only on the electrooptic parameters of the modulating layer but also on the modulator design.

New possibilities for using multichannel modulation of radiation in optical circuits intended for formation and retrieval of information arrays are opened up by the development of matrix liquid crystal displays (LCD) based on fiber-optic components. The work is concerned with the results of development and investigation of liquid-crystal matrix modulators on fibre-optic faceplates. The light transmission of the substrates employed was 0.75-0.80 in the visible spectral range, and the resolution was not worse than $60mm^{-1}$. The modulator samples utilized the twist-effect and the effect of dynamic light scattering in nematic liquid crystals, the LC layer width was $10\mu m$. The modulation characteristics were investigated on samples featuring different sizes and shapes of electrodes. It is demostrated that the contrast provided by the spatial-temporal modulators on fibre-optic faceplate is enhanced owing to a reduced noise level in the output faceplate plane.

EXPERIMENTAL CASES

Investigations were conducted on pilot versions of matrix nematic LCD's having different layouts and integration densities of light valves defined by the sizes and shapes of electrodes. The widht of transparent electrodes was varied within 20 to 500 μm. To obtain oriented nematic LC layers, polyvinyl alcohol and SiO films were deposited onto LCD's electrodes. LC layer thickness was set by the height of support elements deposited onto the LCD's electrodes. In the LCD's investigated, fiber-optic substrates with optical transmission coefficients of 0.8 in the working spectral range (λ = 0.632 μm) were employed. The contrast-transfer coefficient at the spatial frequency of 60 mm^{-1} for the substrates chosen was 0.75-0.80.

Fiber-optic substrates have an intricate hexagonal structure[1] Nonuniform- ity of the surface of such structure can reach 0.1 to 0.3 μm. Therefore, the transparent electrodes formed have a surface exhibiting a nonuniform micro mosaic pattern , with no discontinuities observed in the conductive layer (oxide In_2O_3+ SnO_2 films). The orienting coating maintains the spatial nonuniformity of the substrate and electrodes. Besides, the electrodes extend above the substrate surface by the height defined by the conductive layer thickness. It is known that the substrate surface plays an important role because of its interaction with LC molecules which affects the properties of both near-surface layers and the entire LC volume.[2] When LC contacts fiber-optic substrates, there occurs initial misorientation of LC molecules in which regular and "random" components can be distinguished.

Let us consider the process of reorientation of LC molecules in electric field in the presence of initial orientation distortion (regular component) arising because of noncoincidence in the directions of planar orientation of molecules and electrodes. The results of analysis are given for the S-effect. In the coordinate system under consideration, the upper LC-valve electrode is directed along the X-axis, and the lower along the Y-axis, respectively. If it is assumed that at the valve's edge LC molecules deviate from the planar orientation by an angle θ_0 , then the periodic deformation of the LC-layer director arisingin this case can be described as follows:

$$n_x = 0 \quad n_y = \cos\theta \qquad n_z = \sin\theta \tag{1}$$

The deformation period is determined by electrode structure spacing and the angle between the LC molecule orientation direction and the direction of LCD electrodes.

The equation describing reorientation of LC molecules in electric field can be obtained by taking Frank's equation for the free energy density of LC layer and considering its linear one-constant approximation with regard for eqn.(1)[3]:

$$\frac{\partial\theta}{\partial y^2} + \frac{\partial\theta}{\partial z^2} + \frac{\Delta\varepsilon\ E}{4\pi K}\theta = 0 \tag{2}$$

In our case, the boundary conditions take the form:

for $z = 0$ $\qquad \theta = 0$

for $z = d$ $\qquad \theta = f(y)$

where f(y) gives a linear description of a change in the molecules inclination angle from $+\theta_0$ at one electrode edge ($y = 0$) to $-\theta_0$ at the other edge ($y = m$).

Taking into account the boundary conditions given, the solution of eqn.(2) will take the form:

$$\theta = \sum \frac{8\ \theta_0}{j^2\pi^2}\ \frac{\sin \frac{\pi z}{d}\sqrt{\left(\frac{E}{E_{th}}\right)^2 - j^2\left(\frac{d}{m}\right)^2}}{\sin\pi\sqrt{\left(\frac{E}{E_{th}}\right)^2 - j^2\left(\frac{d}{m}\right)^2}}\ \cos j\frac{\pi y}{m}$$

where E_{th} is the Frederiks threshold in electric field.

Analysis of the solution obtained shows that reorientation of LC molecules is not uniform over the valve aperture. Reorientation of LC molecules under the action of external field begins at the edges of the light valve where there is initial pre-tilting of molecules. For instance, if in an external electric field molecules disposed in the pre-tilting region $+\theta_0$ at one valve edge tend to rotate anti-clockwise, those disposed at the other edge (θ_0) will rotate in the clockwise direction. As the driving field amplitude is further increased, the neighboring LC molecules having smaller pre-tilting also become involved in this process and so on. As a result, two domains with opposite twisting separated by a wall are formed within the valve aperture. The reorientation regime studied experimentally is realized in the case of formation of sufficiently thick orienting layer ($\leq$ 0.3 μm) on substrates. The experimental results obtained are in a good agreement with the calculated data. Fig. 1 gives microphotographic pictures illustrating nonuniform switching of the LCD light valves over the aperture. The wall thickness decreases with increasing driving voltage, and for high U_{dr} the wall is broken up into two disclination lines. Generally, formation of domains reduces the contrast of switched-on LCD valve.

The switching behavior of the LCD valves is considerably differentif the "random" component of initial pre-tilting of LC molecules caused by LC's contact with micromosaic structure of the fiber-optic substrate surface is taken into account. Eqn. (2) has new boundary conditions. To a good approximation the function f(∂) can be represented as a set of sinusoidal dependences with different periods.Experimentally,this condition corresponds to formation of a thin orienting layer on fiber-optic substrates. Owing to an intricate nature of the initial pre-tilting, additional stabilizing moment will be created to prevent reorientation of LC molecules in external field. The microphotographs shown in Fig. 1 illustrate switching of the LCD light valves which is uniform over the aperture. Comparison of the contrast-voltage characteristics of the LCD valves' switching modes investigated indicates that in the latter case the LC molecule reorientation threshold becomes higher and the slope of the contrast-voltage characteristics increases (Fig. 2). Note that the light valve switching contrast also increases. For the

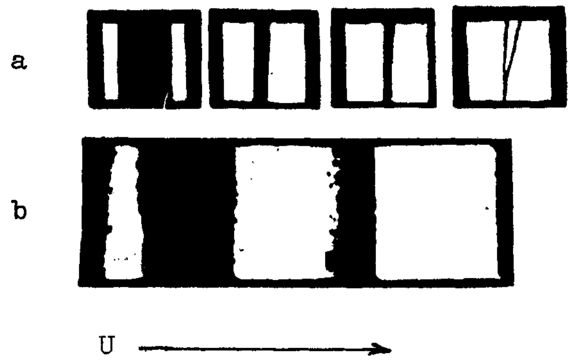

FIGURE 1. Microphotographs of the switched-on LC valve for different regimes of molecules-LCD substrate interaction (the valves size is 50 x 50 μm): a - formation of domain structure; b - uniform switching.

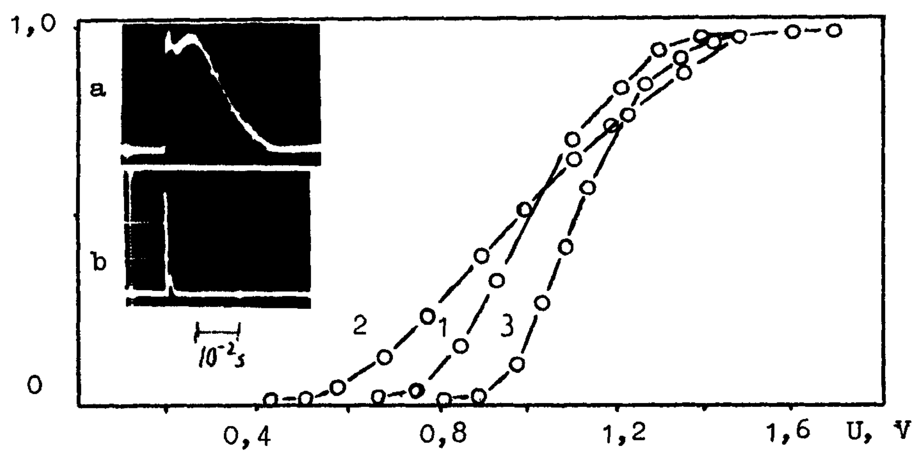

FIGURE 2 Contrast-voltage characteristics and oscillogram of the LC-valve switching: 1 - a continuous LC cell; 2 - switching regime allowing for distortions of the LC-layer on periodic electrode structure; 3 - switching regime allowing for distortions of the LC-layer on micromosaic surface structure of the fiber-optic substrate.

given initial conditions, fast light valve switching regime is realized in a more stable fashion and at lower levels of driving signals[4] The oscillograms given in the figure illustrate switching behavior of the light valves: the oscillogram (a) corresponds to ordinary switching; (b) to fast switching regime. In both cases, the driving pulse duration is the same and equals about 5 x 10^{-5}s. The amplitude U_{dr} (oscillogram (b)) is about 50 V, which is considerably lower (by 3 or 4 times) than analogous parameter obtained in ref. 4 for the LCD's on ordinary glass substrates.

In conclusion, interaction of the LC-layer with an intricate surface structure of the LCD's fiber-optic substrate results in thechangingof the electrooptic switching parameters of the light-valves as compared with conventional LCD's. An increase in the threshold characteristics and the slope of the contrast-voltage characteristic make it possible to optimize contrast-temporal parameters of LCD's.

REFERENCES

1. S.D. Fantone, Appl.Optics, 30, 5220-5222 (1991)
2. L.G. Grechko, L.N. Zasedka, I.P. Pinkevich and V.Yu. Reshetnyak, Poverkhnost, N 3, 72-84, (1993) (in Russian).
3. P.G. de Gennes, The Physics of Liquid Crystals,(Oxford, University Press, 1974)
4. A.A. Kovalev, Yu.V. Razvin and V.A. Potachitz, Zh.Tech. Fis., 57, 548-550 (1987) (in Russian).