OPTICAL RESPONSE OF HOMEOTROPICALLY ALIGNED FERROELECTRIC LIQUID CRYSTAL

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Abstract: A stability of homeotropically aligned C*FLC layer and the optical response 20 μs in electric field 2.4 V/μm at room temperature are advantages for fast FLC devices.

In the present work the linear electrooptic effect in the homeotropically aligned cell with ferroelectric liquid crystal (FLC) was investigated to design fast spatial light modulators. An easy preparation of experimental samples and their stability are the advantages of such alignment. In this case the smectic C* layers are parallel to the surfaces of the substrates, and the director makes a constant angle with the normal to the layer and can reorientate only by preserving the dipole moments in the plane which is parallel to the substrates (Fig. 1).

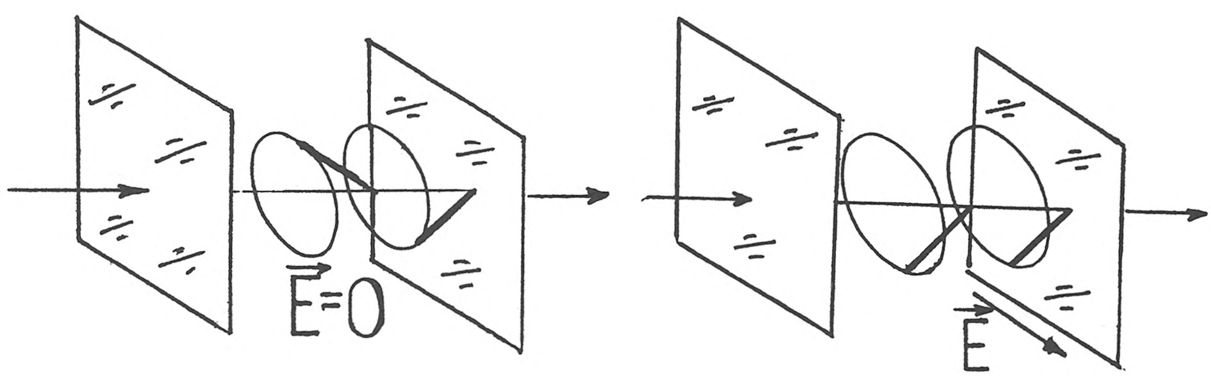

Fig. 1. The geometry of electrooptical effect observation.

When the potential of the boundaries of the FLC is spatially nonhomogeneous, there appears a component of electric field E that lies in the plane of the FLC layer (transverse component), which forces a molecule to rotate. The space change of initially homogeneous orientation of the FLC caused by nonhomogeneous distribution of the potential leads to the space modulation of polarized light transmitted through the FLC.

The thickness of FLC was varied from 5 to 10 μm. Chiral mixture based on the nonchiral smectic matrix and optically active esther additive [1] was used. The helix pitch of the mixture at room temperature was 0.4 μm, the birefringence was 0.2, the value of spontaneous polarization, P_c, was about $0.75 \cdot 10^{-7}$ C/cm^2, and the temperature range of C*phase was +8...56°C.

The FLC was situated between two glass substrates. Onto one of the substrates an interdigital electrode structure was deposited, and the gap between the electrodes was 17 μm. For the normally incident light with respect to smectic layer a homeotropically oriented FLC is optically active (1 deg/mm). Internal field deforms the helix and there appears optical anisotropy to FLC layer for the same direction of incident light.

In this paper the dynamics of the electrooptical response was mainly studied. Changing of the modulation depth with wavelength of the induced light in the spectral range 400-700 nm had also been observed. As it turned out, the modulation depth was the highest in the interval 400-440 nm, when the thickness of the cell was 5 μm.

There is the dependence of the optical response contrast on the tilt angle of the incident light. Also anisotropy was observed in two planes, which are parallel and transverse to the electrodes of system. But contrast is changed slowly inside intervals of tilted angle ±5° and ±10°, respectively. The observed angle anisotropy in the switched-on state reflects the role of changing of the phase delay between ordinary and extraordinary beams with the angle of the incident light.

Change of the modulation depth with voltage is shown in Fig.2. The voltage range of the elastic unwinding of the helix is shown. When the voltage was about 1 V/μm and higher the helix could not be deformed elastically because of the defects of dechiralization [2].

For the whole unwinding it was necessary to get rid of the defects. And with increasing of the voltage of external field the defects moved along the axis of the helix to the boundary substrates. The mechanism of the defects moving is rather slow and by the time it is equal to 100 μs-1 ms, that is why on the leading edge of the response there appears a flat part except of the steep one, responsible for the elastic unwinding. With rising of the voltage there increases the steepness of both the first and second parts. Also the trailing edge of the response depends on the voltage of the applied field. At low voltage there occurs fast restoration of the response (Fig.3), which is due to the elastic unwinding of the helix. With rising of the voltage the unwinding process gets slower.

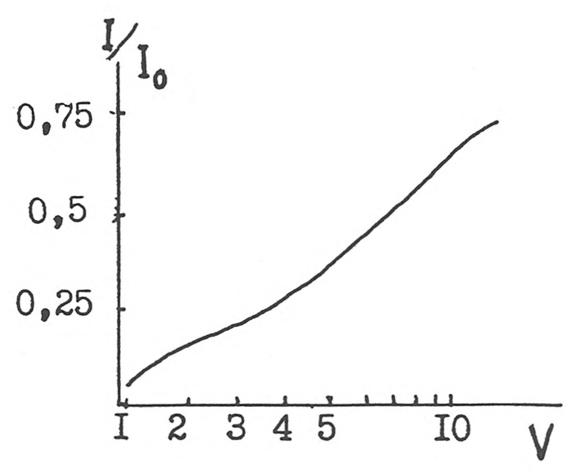

Fig.2. The depth of modulation, $m=I/I_0$ vs applied voltage V.

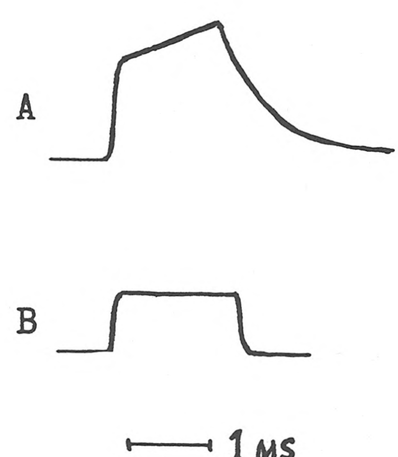

Fig.3. Oscillograms of FLC optical response: a)full deformation, b)elastic one.

The response time depends nonlinearly on the energy of the applied electric pulse. So it was interesting to study the growth of the pulse amplitude to achieve the given optical contrast with decreasing of the pulsewidth. These dependences are represented in Fig.4 , where the shortest time of the whole cycle of the switching had been achieved, 60 μs, with contrast 2:1. When the width and the amplitude of the pulse were 2 μs and 40 V - 2.4 V/μm with contrast 9:1 the whole cycle was 100 μs.

In Fig.5 one can see that the modulation depth, m , vs temperature, T, changes mainly between 53-56°C, that is, near transition point.

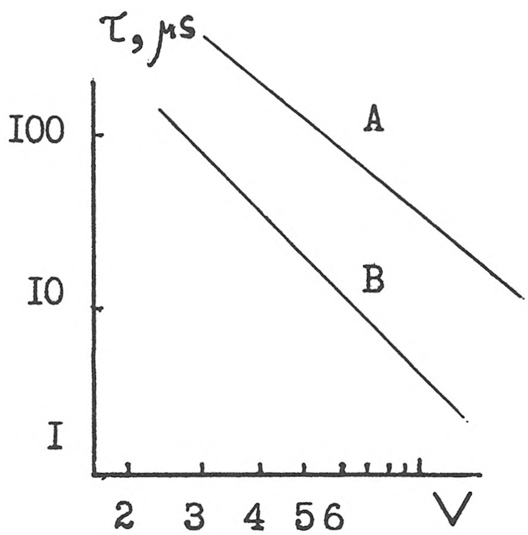

Fig.4. The dependence of applied pulse duration τ(μs) on the amplitude V (Volts) under constant contrast of FLC response:
a) contrast is 9:1
b) contrast is 2:1.

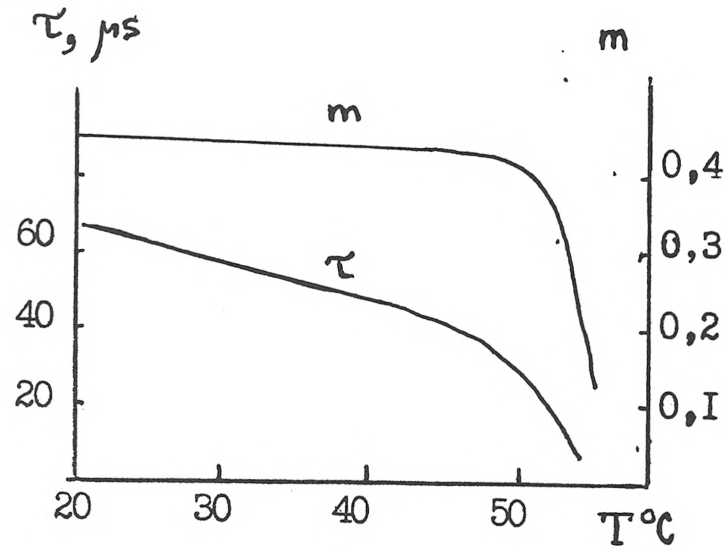

Fig.5. The elastic deformation relaxation time τ(μs) and modulation depth, m, versus temperature.

From Fig.5 it follows that switching time (elastic part) of the cell is faster when temperature is 49-50°C, while the contrast changes slightly.

With increase in temperature the value of spontaneous P_c decreases, but under the same condition, the viscosity decreases as well [3,4], and the decrease in the viscosity is faster than that in the polarization, which leads to the decrease in time with temperature increasing.

In studying the FLC fast response, the problem of the delay time, in respect to the driving electric pulse, is rather important. The samples used have no delay time, in contrast to the homogeneously aligned cell, which has the delay time of 100 μs [5]. The absence of the delay time is connected with much lower anchoring forces of FLC with surfaces of substrates than those for homogeneously aligned cells.

Thus, in this work the possibility was shown of designing the fast switching electrooptical devices of the large apeture based on the homeotropically oriented C^*FLC. The switching time of the response was 20 μs when contrast was 2:1, and driving field was 2.4 V/μ.

References

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