Fast LC Devices with Lowest Control Voltage

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ABSTRACT

Novel FLC cells were developed with the response time of about 30÷70 μs under the electric field 1.0÷2.0 V/μm for 1.0 μm layer thickness (reflectance mode) and 1.3 μm (transparent mode). Stereo glasses with shutters modulating the light with the frequency till 600 Hz at ±1.5 V and 1500 Hz at ±3.0 V were manufactured.

1. INTRODUCTION

It is known that ferroelectric LC (FLC) materials are much faster than nematic LC ones but some drawbacks did not allow considering them as promising materials. To date, main problems are solved successfully. Besides, FLC cell technology is closed to NLC one.

In this work the results of studying the novel electro-optical mode in FLC cell and testing stereo glasses manufactured for IDW exhibition are presented.

2. FAST AND LOW-VOLTAGE LIGHT MODULATION

The electro-optical response time and intensity in dependence on electric field parameters, boundary conditions and FLC properties have been studied recently [1,2] for the case when portion unwinding of the helix structure arises from the interaction of FLC molecules with substrates at the electric field E=0, and domain walls motion results in the director reorientation at $E > 0$. In such a case the novel fast and low voltage electro-optical mode is observed in thin FLC layers if the following energy condition is satisfied:

$$W_{el} = K_\varphi q^2 \approx W_Q/d \quad (1),$$

where W_{el} is the elastic energy, K_φ – elastic module, q – deformation vector of FLC helix structure ($q \neq$ wave vector $q_0=2\pi/p_0$ that is valid for the undeformed helix structure with a pitch p_0), W_Q – dispersion coefficient of the anchoring energy, and d – FLC layer thickness. For example, the partial unwinding of FLC helix structure with p_0 = 0.45 μm and W_Q = 0.05 Erg/cm^2 is observed in FLC cell of 0.9÷1.4 μm thickness.

In contrast to DHF-effect [3], which is observed at

$$W_{el} = K_\varphi q_0^2 >> W_Q/d \text{ and } p_0 << d \quad (2),$$

and to Clark-Lagerwall effect [4], which is realized at

$$W_{el} = K_\varphi q^2 << W_Q/d \text{ and } d << p_0 \quad (3),$$

fulfilling the condition (1) provides not only fast on/off switching (30-50 μs) and high frequency of light modulation (a few kHz) with gray scale hysteresis-free modulation characteristics (like in NLC) but allows doing this at very low control voltage. Really, the experimental FLC cell of 1 cm^2 aperture modulates the light transmittance on λ=0.65 μm with the frequency up to 3 kHz at ±1.5 V, 5 kHz at ±2.0 V and 8 kHz at ±3.0 V (!!!). Figure 1 illustrates dynamic possibilities of developed FLC-materials and electro-optical cells.

Thus, very fast electro-optical response time is achieved in FLC cell in weak electric fields (1÷2 V/μm only). This electro-optical mode can be used for creating the fast shutters of stereo glasses and 2D-3D displays.

3. ACTIVE STEREO GLASSES BASED ON FLC SHUTTERS

Two different versions of stereo glasses for modern and future 3D television were manufactured and planned to be presented on IDW exhibition by company “MEGAVISION” (Moscow) which supports our research work on FLC materials and devices. The size of each FLC shutter is 50x35 mm, the aperture is about 17 cm^2. They were inserted into an original frame, which allows user to observe 3D images both through his (her) own spectacles (not taking off them) or without them. The frame contains a small 3V lithium battery CR2032 (that is usually used for watches) and a controller converting DC to bipolar pulses (rectangular wave) of ±1.5 V or ±3.0 V amplitude. FLC material with average (not the best) parameters was used.

A controller used in the first version of stereo glasses provides output ±1.5 V. The refresh rate of FLC shutters in these spectacles is 200 Hz, optical response time does not exceed 60 μs, and cross-talk is negligible. It should be noted, these shutters could provide up to 600 Hz of light modulation frequency with a contrast 200:1 (is determined by polarizers) at the control voltage ±1.5 V as experiment measurements showed.

The second version of stereo glasses was prepared to show the maximal modulation frequency that FLC shutters are able to provide at output ±3.0 V. Experiment measurements showed that this frequency reaches 1500 Hz at the same contrast 200:1, and optical response time also does not exceed 50 μs. Because there are no displays capable to reproduce images with such high refresh rate, this light modulation frequency is indicated with use of a special detector and visual device in the exhibition booth.

Usage of stereo glasses with such rectangular-wave optical response has the following sense. At first, during viewing stereo image the optical decay time t_{decay} of each LC shutter corresponds to the time t_{dark} of dark area in upper part of display screen (Figure 2):

$$t_{dark} = t_{decay} - t_{retrace} \quad (4)$$

where $t_{retrace}$ is the time between adjacent frames. The closing control voltage applied to the right shutter is taken off at the end of each odd frame. So during the time t_{dark} the right eye of the observer will see through this shutter the dark area in the upper part of the screen.

Let us evaluate the square of the dark area in the upper part of the screen in the case of 144 Hz frame rate (3D cinema with Christie video projectors) and of modern stereo glasses with nematic LC (π-cell LC shutters in XPAND X101, X102 and RealD CrystalEyes 3 glasses, STN LC shutters in Real D CrystalEyes 4, nVidia 3D Vision, Samsung SSG-2100AB, Sony TDG-BR100, Panasonic TY-EW3D10U glasses), where real t_{decay} is about 2-2,5 ms. As standard displays have $t_{retrace}$≈1 ms so t_{dark} is about 1-1,5 ms according with (4). The time duration of one frame at 144 Hz frame rate is about 7 ms, so the square of the dark area will be 14-21% of the frame. Using our FLC shutters in stereo glasses leads to absence of the dark area because of t_{decay} = 60 μs, and $t_{retrace}$ = 1 ms.

Such FLC glasses are capable to meet any possible frame rate of future realizations of 3D frame sequential method. Today's 120-144 Hz frame rate for 3D image means only 60-75 Hz per eye whereas the flicker is completely disappeared at least 120 Hz or more per eye. Several methods are suggested by Sony, Samsung, Toshiba [5] to depress flicker by introducing virtual 240-480 Hz frequency in 3D TV and computer monitors with help of light interruption by accordingly controlled backlight while saving the real frame rate former 120 Hz. Our glasses allows to work with possible future super high frame rate consumer 3D TV and professional 3D monitors developed with real 240-480 Hz frame rate obtaining by that 120-240 Hz per eye to eliminate flicker completely.

4. CONCLUSION

The results of experimental studying the novel electro-optical low-voltage mode and testing stereo glasses show that FLC material is very promising for use in displays (including projection displays based on FLCOS-structure), especially in 3D displays. Essential increasing their refresh rate will extend functional possibilities of displays and information systems.

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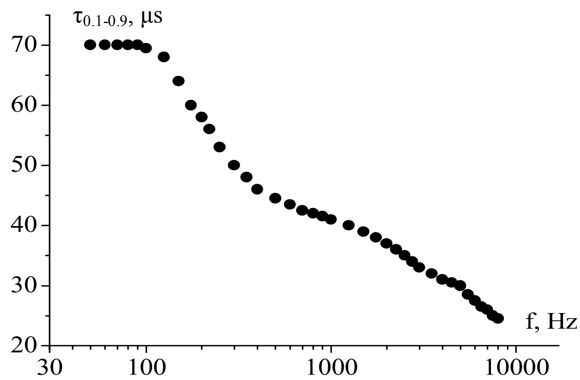

Figure 1. Frequency dependence of the electrooptical response time (reflectance mode) for FLC cells at electric field intensity of 2 V/μm. Cell aperture = 1.5 cm^2, FLC layer thickness d = 1.0 μm, helix pitch p_0 = 0.45 μm.

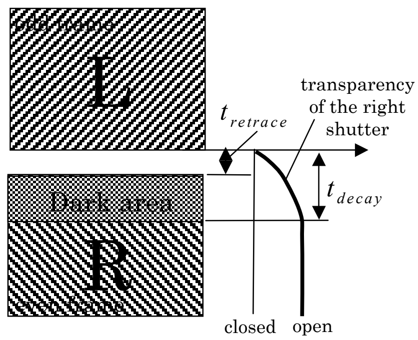

Figure 2. Dark area owing to finite time of the optical decay time t_{decay} of the shutter.