New Low Power Liquid Crystal Shutter Based on OMI-cell

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Abstract

The electrooptical characteristics of OMI (optical mode interference) cell were investigated as the application for LC shutters. The optical responses under dynamic driving were simulated by solving the Ericksen-Leslie hydrodynamic equations numerically. The prototypes were made accordingly for verification. The experimental data show good coincidence with the simulation results.

1. Introduction

Liquid crystal (LC) shutters have been studied and been applied to various applications such as stereoscopic systems, color field-sequential CRT displays. [1] It has shown many advantages in these areas like high contrast, fast response, low power consumption and low cost.

In trying to achieve LC shutters with high contrast, fast response and low power consumption, we suggest a LC cell of p twist with optically self-compensated structure. Boundary surfaces of such cells both favor a uniformly tilted alignment, and the pretilt angles at the substrates are equal in magnitude but opposite in sign. The polarizers are crossed and are along or perpendicular to the rubbing direction of LC molecules at boundary substrates to minimize the interference phenomena. [2-4] Under this structure, LC cell is kept in on-state with maximal contrast for approximate half of relaxation times, thus the frame response is absent. Based on this pseudo memory effect, it is possible to obtain long term optical delay using high-voltage pulses with the period equal to memory time. This can greatly reduce the power consumption to keep the LC cell in on-state, shorten the reaction time, and decrease the relaxation time to memory time.

In this report, the dynamics of OMI mode LC are studied by simulation based on the Ericksen-Leslie hydrodynamic equations.[6,7] The experimental scheme is described. The results of simulation and experiment together with the discussions are presented.

2. Theory

The backflow effect induces the well known optical bounce phenomenon of the nematic LCD after the voltage across the LC cell is switched off. [7,8] This shear flow greatly impacts on the optical delay during the relaxation process. The "off" times of the optical response of the LC shutters are found numerically to be strongly dependent on the LC twist angle.[2] If the combination of various parameters of LC cell is appropriately selected, the LC can be kept in on-state without damping off under appropriate driving scheme. This pseudo memory effect could afford relatively long optical delay without holding the voltage on the LC cell all the time, which could significantly reduce the power consumed by LC shutter and decrease the reaction time in the mean time due to the high-voltage pulse. This phenomenon can be simulated by solving the Ericksen-leslie hydrodynamic equations numerically.

The Ericksen-leslie hydrodynamic equations are:

$$\begin{gathered} \partial t(r u_i) + \partial_j (r u_i u_j + p d_{i,j} - s^{d}_{ji} - s^{f}_{ji} - s'_{ji}) = 0 \\ I d^2 n_i / dt^2 = h_i + h'_i + g n_i \end{gathered} \qquad (1)$$

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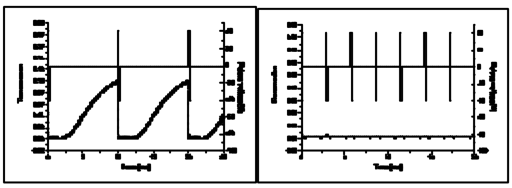
where i and j denote x, y, or z components, ρ is the fluid density, u is the fluid velocity, p is the hydrostatic pressure, σ^{d} is the stress tensor due to elastic distortion, σ^{f} is the stress tensor induced by electric or magnetic field, σ' is the viscous stress tensor, h is the molecular field from elastic and field-induced free energy, h' is the viscous molecular field, I is the rotational inertial density of the fluid, and γ is a Lagrangian multiplier; n is the unit vector of liquid crystal director. Here all the quantities depend on z and t only. The boundary conditions are assumed that the director at the substrates is fixed and time-independent.

Here, we used the parameter values for MLC-6080 (E.Merck). Since very few measured viscosity coefficients are available, we took Leslie viscosity coefficients for 5CB in our computation except simply keeping the rotational viscosity $\gamma_1 = \alpha_3 - \alpha_2$ same to that of MLC-6080. Fig.1 shows the simulation results under pulses of different frequency. We can see that from Fig. 1a, the contrast does not apparently decrease when the voltage is shut off, and the delay time holds nearly half of the relaxation time. If we apply higher frequency pulses, the transmission can remain maximal forming the pseudo memory effect.



(a) (b)

Figure 1. Calculated pulse responses of OMI cell under different pulse interval.

3. Experiments

To verify our thoughts experimentally, we prepared a prototype of liquid crystal at OMI mode. To compare with the effects of TN and STN modes, we also provided two cells operated at TN and STN modes respectively. We used MLC-6080 (E.Merck) as the material for all three liquid crystal modes. The parameter values used in experiment are set the same with those used in simulation as much as possible except the Leslie coefficients. The thickness of the LC-layer (3.5 µm) was selected to provide a maximal transmission for a given LC birefringence value. The polarizers were crossed with their transmission axes parallel (or perpendicular) to director at the surfaces. To get data more similar to real application, the non-polarized incandescent lamp was used in both simulation and experiment.

Fig. 2 shows the responses of OMI cell obtained in the experiment, which exhibit a very good coincidence with the simulation results. While the pseudo memory effect got, the contrast was achieved as high as 520:1 in the mean time.

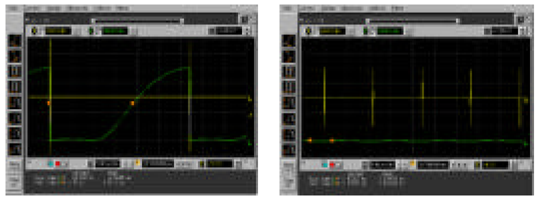
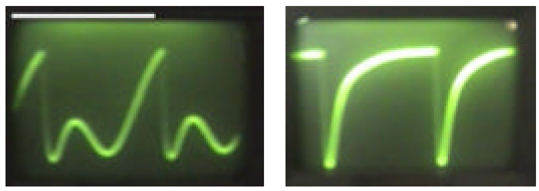


Figure 2. Measured dynamic responses of OMI cell under different pulse interval.

For comparison, the dynamic responses of the prototypes of TN and STN were also examined. From fig. 3a, we can find that the contrast fluctuates greatly in TN cell when the voltage is switched off. While in STN cell (fig. 3b), the optical delay is minimal since the backflow effect is not that significant for large twist angles.



(a) (b)

Figure 3. Measured dynamic responses of (a) TN; (b) STN cells.

4. Conclusion

In this report, the OMI mode of liquid crystal is investigated. Theoretical analysis and dynamics of optical response of LC under the specific driving scheme are presented. A new application of 180° OMI cell for liquid crystal shutters is predicted in theory. The 180° OMI cell exhibits high contrast ratio and fast response with low power consumption under dynamic driving, which are favorable in the liquid crystal shutters applications. Based on the simulation, the prototype of LC has been made for verification.

The experimental results show good agreement with the simulation outcome. The prototype of OMI confirms the merits shown in the simulation. The OMI cell can potentially be applied for various electrophotograhic devices such as stereoscopic systems, color field-sequential CRT displays and others.

5. Acknowledgement

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6. References

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