P-26: Double Cells Achromatic Ferroelectric Liquid Crystal Displays

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Abstract

An achromatic Ferroelectric Liquid Crystal (FLC) display based on the configuration of double parallel-aligned cells with crossed directors has been demonstrated. With the help of the compensating cell, a FLC display with high black-to-white contrast ratio and wide viewing angle was obtained.

1. Introduction

Recently, there is much work has been done on bistable liquid crystal displays for their potential in all low power applications and e-paper. Several bistable technologies have attracted many interests such as the cholesteric display [1], zenithal bistability [2], bistable twisted nematic displays [3], bistable bend-splay displays [4] and ferroelectric liquid crystal displays [5]. Among them, ferroelectric liquid crystal has the advantage of fast response times at μs order, superior to all the other competitors.

Our group has proposed and demonstrated a ferroelectric liquid crystal display prepared by photo-alignment technique [5]. It shows remarkable bistability, wide viewing angle and very high contrast ratio CR > 500:1 at the wavelength λ = 630 nm. However, serious spectra dispersion occurs on bright state so that the cell appears like black character on slight cyan background. Such slight chromatic switching is not desirable in real applications.

In this report, we propose a new configuration using two parallel-aligned FLC cells with crossed directors to cancel the chromatic dispersion. The principal cell and the compensating one both work in surface stabilized FLC electrooptical mode, and are nearly identical except the cell gap. The two cells have same voltage control, thus they switch in the same time so that the directors of the two cells are always perpendicular.

Using this configuration, we have obtained a FLC display in transmissive mode with black-to-white contrast ratio CR > 300:1 in simulation. We have also made and tested a FLC display prototype to verify it experimentally. In experiment, contrast ratio lager than 46:1 has been achieved, which means black-to-white switching in ordinary FLC is possible.

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2. Results and discussions

The configuration of our experiment for the double cell is shown in figure 1: the director of the first cell serving as the principal cell is parallel to the optic axis of the polarizer. The compensating FLC cell and the principal cell are aligned parallel to each other, but the directors of both FLC cell is crossed. The analyzer is perpendicular to the polarizer.

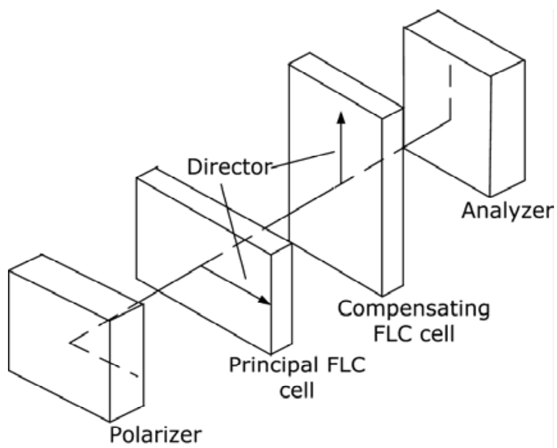


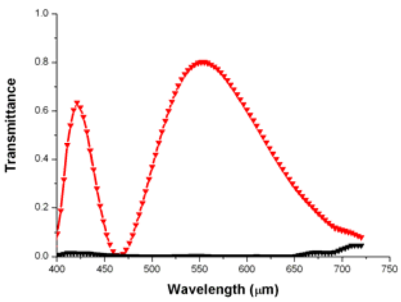
Figure. 1. Schematic diagram of the experimental configuration.

In this case of configuration, the total phase retardation of the double parallel-aligned cells FLC display is :

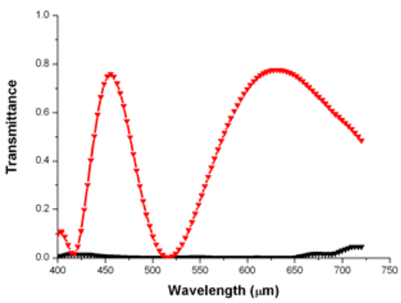
$$\delta = \frac{2\pi(d_1\Delta n_1(\lambda) - d_2\Delta n_2(\lambda))}{\lambda} \quad (1)$$

where the subscript 1, 2 denote the parameters of the principal and compensating cell respectively. The optical anisotropy Δn as a function of wavelength λ is a physical characteristic of the liquid crystal material, which can be measured in experiment. The subtractive sign in equation (1) originates from the crossed situation of the two FLC cells. It means that the extraordinary part of the incident polarization light in principal cell becomes ordinary in compensating cell, and vice versa [6]. Equation (1) shows that the total phase retardation δ only depends on the cell gap difference if we use the same liquid crystal material. It is known that FLC display can achieve black-to-white switching only for small cell gap near 1.5 µm. Nevertheless, small cell gap means worse uniformity and stability. Small spacer is not desirable in mass production as well. The configuration of double FLC cell can help achieve black-to-white achromatic switching similar to single thin FLC as well as good cell uniformity and stability.

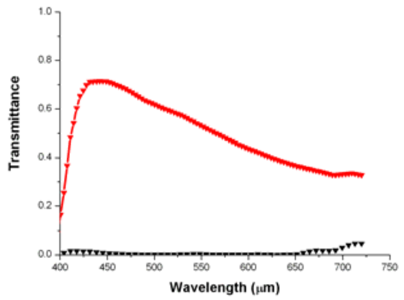
This idea was first realized in simulation. The ferroelectric liquid crystal used in our experiment is FLC 497A (from Physical Institute of Russian Academy of Sciences), whose optical anisotropy Δn at wavelength λ = 550 nm is around 0.17. According to equation (1), the optimal cell gap difference should be 1.5 µm. However, we currently have no spacers satisfying this condition in hand. So, we use 5 µm and 6 µm instead to verify the structure. Similarly, the cell gaps used in simulation adopt the same values as in experiment although the result is a little worse than the most optimal cell gap difference. Figure 2 shows the simulated transmission spectra using MOUSE-LCD [7]. Figure 2(a) and (b) exhibit the chromatic switching in single FLC cell configuration although their contrasts are pretty high. The transmission spectra after combining the compensating cell are shown in figure 2(c). Although the bright state is slightly chromatic, the black-to-white contrast is still very high, reaching at over 200:1.



(a)



(b)



(c)

Figure 2 Simulated transmission spectra of FLC display: (a) 5 µm; (b) 6 µm; (c) double cells.

To confirm the theoretical and the simulated results, two FLC cells with 5 µm and 6 µm thickness were fabricated using FLC 497A [5]. The cells were treated under asymmetric boundary conditions, where only one ITO surface of FLC cells was prepared with the SD-1 layer, while another ITO surface was simply washed in DMF solution and covered with spacers. The good surface alignment was obtained after the photoaligning process. The appearance of the bright and dark states of the double cell FLC display is shown in figure 3. It exhibits a remarkable contrast ratio and good uniformity.

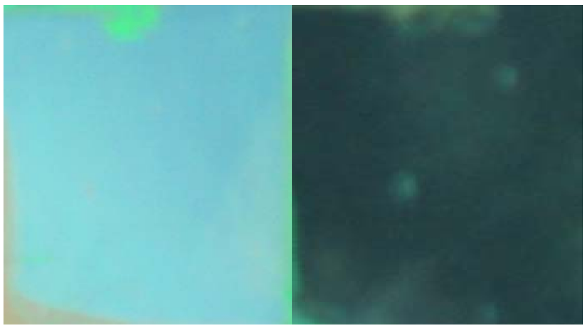
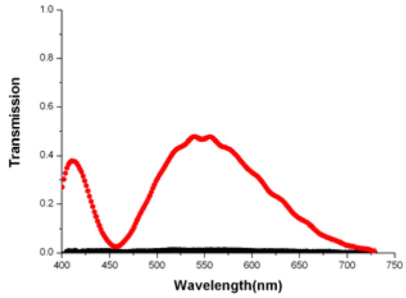
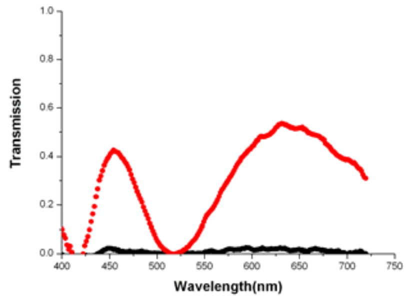


Figure 3 Bright and dark states of the double cell FLC display

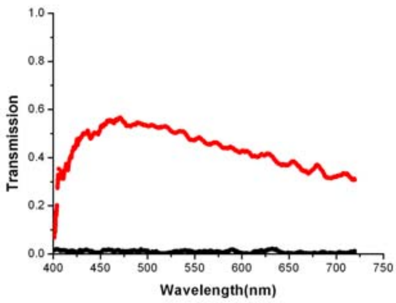
To verify the coincidence between the simulation results and the experimental data, the transmission spectra of the single and double cell display were measured using CG-100 measurement system. The figure 4 shows the measured transmission spectra in experiment. The experimental results show a perfect agreement with the simulation outcome except the near UV region. This is because the detector of the CG-100 measurement system is only sensitive to the visible region of the incident light. Thus the data obtained in the near UV region is not that accurate as the green and red region. Despite the inaccuracy of the transmission in near UV region, the black-to-white contrast ratio can reach at over 46:1. If given a more sophisticated measurement system, the result should be much better and closer to the simulated optimum.



(a)



(b)



(c)

Figure 4. Measured transmission spectra of FLC display. (a) 5 μm; (b) 6 μm; (c) double cells.

Conclusion

FLC display using two parallel-aligned cells is demonstrated. The achromatic switching is well predicted in the simulation. The perfect agreement with the simulation results is achieved in experiment. Such a display provides notable black-to-white switching with high contrast ratio. It proves that the full color switching in FLC display is possible.

References

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