Drive Scheme for Cholesteric Liquid Crystal Display by Pulsed Laser

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A laser-addressing method that has high power and a small spot size is proposed. Cholesteric liquid crystal display with a simple structure is addressed using a laser source. A high quality image with 300 dpi resolution can be easily achieved; meanwhile, the panel can be driven at the lower laser power. The contrast ratio of the Ch-LCD images can be also enhanced by voltage assistance or thermal assistance technology.

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1. Introduction

Cholesteric liquid crystal displays (Ch-LCDs) have been widely investigated in recent years for use as e-paper due to their paper-like characteristics and ultra-low power consumption. Ch-LCDs are bi-stable and are usually used in low-power applications such e-books [1-5]. Planar and focal-conic textures are the two stable states of a Ch-LC. The planar texture can reflect a range of light frequencies to display a specific color. The focal-conic texture can transmit most of the light through the panel [6-7]. Ch-LC has an unstable state called the homeotropic texture. When a sufficient electric field is applied, the focal-conic texture of a Ch-LC can be transformed to the homeotropic texture. If the electric field is quickly removed, the homeotropic texture of the Ch-LC will relax to the planar texture through a transient planar texture. If a low electric field is subsequently applied, the planar state will change to the focal-conic state. The necessary applied voltages for the required state transitions should be determined according to the reflectivity-voltage (R-V) curve of the Ch-LCD [8-9].

For many practical applications, it is unnecessary to update e-paper content frequently. Furthermore, a significant part of e-paper cost comes from its driving electronics. Therefore, using one driving system per e-paper panel is not cost-effective for applications where content updates are not frequent [10]. For this reason, many drive schemes for Ch-LCDs have been proposed in recent years [11-16]. With photo-addressing method, driving electronics are completely separated from Ch-LCD panels. Furthermore, Ch-LCD structure could be simplified because of un-patterned upper and lower electrodes. Comparing with traditional papers, resolution and contrast ratio are the basic requirements of e-Paper image quality. With electronic driving method, it is very hard to achieve the required high resolution [17].

In the present study, a laser-addressing-based method that has high power and small spot size was developed. Ch-LC panel with simple structure can be accurately addressed by pulsed laser; meanwhile high resolution and contrast ration image can be easily achieved using voltage assistance or thermal assistance technology.

2. Experimental

The proposed laser-addressing panels are a simplified version of this developed [3]. Laser addressing system was developed for a Ch-LCD with the panel structure shown in Fig. 1. The laser system consisted of 1064 nm wavelength, 9.3 mm incident beam, 160 mm focal length and 1.8 M^2. When raw beam passed through our optical delivery system, the spot size was 40 µm. A flexible Ch-LCD composed of a polymer dispersed cholesteric layer and a dark layer sandwiched between top and bottom electrodes on a polyethylene terephthalate substrate. These conductors of the Ch-LCD panels are un-patterned and can be fabricated by roll-to-roll process. Therefore, the fabricated panels will have the advantages of high yield and low cost.

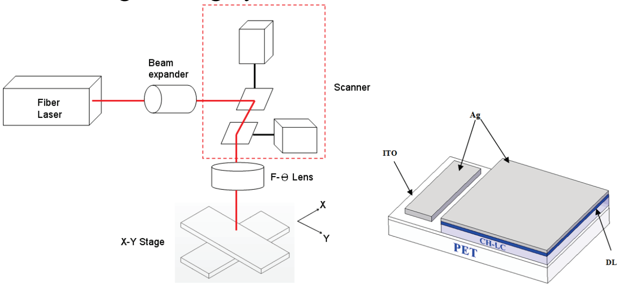


Fig. 1 Illustration of laser system for a Ch-LCD panel addressing.

The laser system for a Ch-LCD panel consists of a fiber laser which has a wavelength of 1064 nm, a repetition rate of 25 kHz, a pulse duration of 30 ns and a stability of less than 6%, a scanner with a 160 mm focal length lens, and an XYZ stage. The laser powers are operated from 150 mW to 500 mW. The reflectance measurements are performed using an X-Rite 938 spectrodensitometer.

3. Results and Discussion

The R-V curve of the proposed Ch-LC panel shows in Fig. 2. The initial-P-state reflectance of the Ch-LCD is about 33.7%, and its critical voltage is 15 V. To avoid crosstalk in the photo-addressed image, the auxiliary voltage below 15 V is modulated. Fig. 3 shows the results of laser addressing under various conditions. The regions A1~D1 are the results of laser addressing at various laser powers and zero-driving voltages. The laser powers were 160, 225, 300 and 385 mW, respectively. The regions A2~D2 are addressed at as the same laser powers as the regions A1~D1 but the regions A2~D2 are addressed with an auxiliary 15 V. As can be seen, the focal-conic state reflectance can be decreased by increasing laser power. The reflectance can be changed when the laser power is operated at or over 300 mW (region C1). In addition, the regions C1 and C2 are addressed at the same laser power of 300 mW, but the region C2 is addressed with the auxiliary 15 V. Comparing with the region C1, the region C2 of the Ch-LC panel with the auxiliary voltage can effectively decrease the black-state reflectance and improve the contrast ratio.

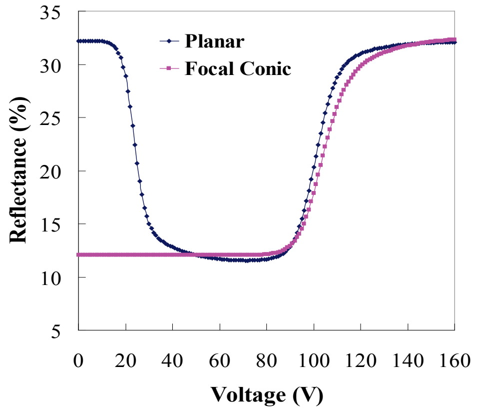


Fig. 2 The R-V curve of the proposed Ch-LCD.

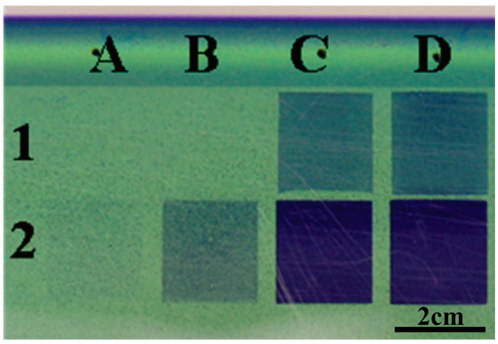


Fig. 3 Laser addressing images in different driving conditions.

The reflectance spectra of a Ch-LCD with or without an auxiliary voltage under different laser power conditions are summarized in Fig. 4. From the results, the reflectance variation is proportional to the laser power; the reflectance saturates at a power of 300 mW. When laser power was set to below 300 mW, the voltage assistance technology was more effective in decreasing reflectance. Table 1 lists the focal-conic state reflectance and contrast ratio of a Ch-LCD driven by voltage only, a laser, and a laser with an auxiliary voltage. The contrast ratio of a Ch-LCD was increased by the voltage assistance technology. In terms of resolution and contrast ratio, the image quality obtained using the voltage assistance method is better than that of directly electrical driving. Due to the high reflectance of the dark state, the contrast ratio of the Ch-LCD was only about 2.8. However, with an auxiliary voltage, the focal-conic state reflectance decreased to 10.14 and then the contrast ratio was increased to 3.3. It is apparent that the Ch-LCD image can be enhanced.

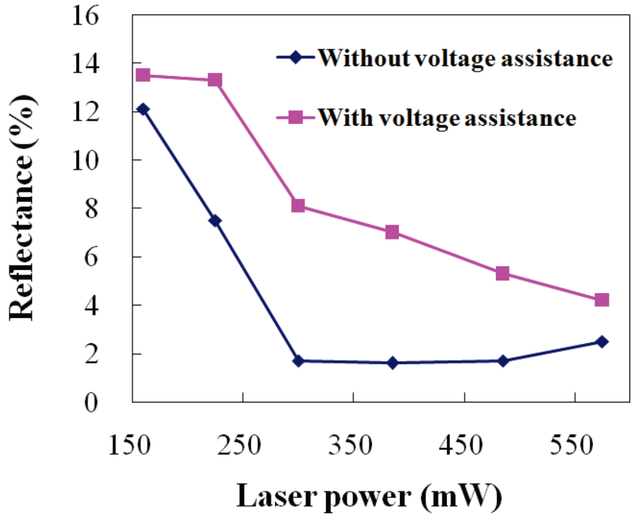
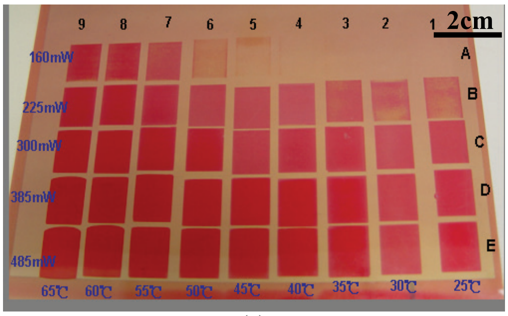


Fig. 4 Reflectance of the Ch-LCD for different driving conditions.

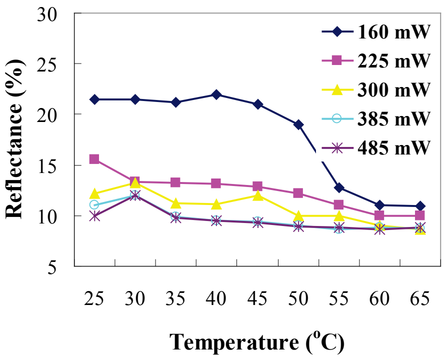
Table 1. The reflectance and contrast ratio of a Ch-LCD driven by voltage assistance methods.

	68 V (V3)	Laser 200 mW	Laser 200 mW + AC 15 V
R (%)	**11.97**	**18.37**	**10.14**
CR	**2.82**	**1.83**	**3.33**

Figs. 5 (a) (b) show the image and reflectance of Ch-LCD panels which are addressed under various conditions. The regions A1~E9 are addressed under various laser power levels and temperatures. The phase transition is due to the laser irradiation induced by photo-thermal effect. As can be seen, the reflectance can be changed by increasing laser power and the reflectance variation is proportional to laser power. The reflectance saturates at a power of 300 mW. When the laser power was set to below 300 mW, the reflectance of a Ch-LCD will be decreased using a thermal assistance method. However, laser addressing at 300 mW, the reflectance variations of the Ch-LCD panel at 60 ºC and 65 ºC are almost equivalent. Therefore, in general, the Ch-LC panel with saturated laser power should be addressed at the temperature ranges. In addition, when the power of the laser source is below the saturation power, the contrast ratio of a Ch-LCD panel can be improved by testing on the critical temperature. In this study, the panel is driven by thermal assistance technology. After heating the panel, the R-V curve will shift to left side (lower voltage) and then panel is easily driven at these lower laser power conditions.



(a)



(b)

Fig. 5 (a) Image and (b) reflectance of the Ch-LCD for different driving conditions.

In order to lessen the deviation of a Ch-LCD panel, the panel with and without thermal assistance method was addressed shown in Fig. 6. The left area was addressed without an auxiliary temperature; its contrast ratio is much lower than that in the right area. Table 2 lists the focal-conic state reflectance and contrast ratio of a Ch-LCD driven by different methods. The contrast ratio of a Ch-LCD panel was increased by thermal assistance method. The image quality obtained using the thermal assistance method is better than that using the electrical driving method in terms of resolution and contrast ratio. Due to the high reflectance of the dark state, the contrast ratio of the image can reach to 2.53.

Fig. 6 Laser-addressed patterns under two driving conditions (7 cm x 5 cm).

Table 2. The reflectance and contrast ratio of a Ch-LCD driven by thermal assistance methods.

	74 V (V3)	Laser 300 mW	Laser 300 mW + 60 °C
R (%)	8.68	12.37	8.74
CR	2.54	1.79	2.53

According to these results, it is apparent to observe that the voltage assistance or thermal assistance technology not only lowered the addressing laser power but also enhanced the contrast ratio of the image.

4. Conclusions

Ch-LCD laser-addressing has the advantages of direct writing and high resolution. The feasibility of the developed technology was experimentally verified and satisfactory results were obtained. The different reflectance spectra of planar texture and focal conic texture can be applied for a Ch-LCD panel. The contrast ratio of the Ch-LCD images can be improved by voltage assistance or thermal assistance technology.

Acknowledgments and Appendixes

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