A Novel -π/2 and 3π/2 Twist Bistable TN LCD

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Abstract

We have developed a novel bistable TN LCD that switches between -π/2 and 3π/2 twist states. The range of d/p for obtaining bistability was obtained experimentally. The swithing behavior using several different switching waveforms was also inveestigated. A high contrast of 30:1 was obtained. the Novel bistable TN LCD can be driven by a passive-matrix addressing method.

Introduction

Bistable twisted nematic liquid crystal cell that can be switched between two twist states by application of electric fields was discovered by Berreman in 1981 [1]. Recently, Tanaka at al [2] developed a driving method of addressing this bistable twisted nematic (BTN) display and prodused a BTN display with good quality. A specially shaped pulse has to be used. Hoke et al [3] investigated the dynamics and optics of this BTN LCD and reported sub-microsecond selection. Kim et al [4] and Qian et al [5] calculated dynamic switching behavior of the BTN LCD. Bryan-Brown et al [5] proposed a grating aligned BTN LCD that can be switched by sub-millisecond pulses. Finally Martinot-lagarde et al [6] developed a novel fast BTN LCD controlled by simple monostable anchoring and obtained very fast switching times. In all above-mentioned reports, the bistable states are either 0 or 2π twist states. Miyama [7] has been reported the field-induced transition between -π/2 and 3π/2 twist states in wedge shaped cell. But so far the swithing behavior of a BTN LCD in regular cell for -π/2 and 3π/2 switching has not been reported.

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A TN cell with perpendicular alignment on the two surface and zero pretilt will have an equilibrium twist that is an odd integer multiple of π/2. The elastic energy minimum of the -π/2, π/2, 3π/2 twist states occur at d/P_0 ratios of -0.25, 0.25, and 0.75 respectively. The -π/2 and 3π/2 states are topologically equivalent and can be continuously transformed each other through a barrier state. If the LC alignment favors a -π/2 twist, then for some value of d/P_0, the LC cell can exist -π/2 or 3π/2 twist state. Roughly speaking, in the absence of pretilt of the LC director, the natural twist of the LC should be about π/2 in order for bistability to occur. Hence the d/P_0 ratio should be about 0.25.

In this paper, a novel mode of BTN LCD that can be switched between -π/2 and 3π/2 states by the temporary voltage pulses has been developed. several switching waveforms were used to switch the BTN cell. A high contrast ratio has been obtained between the two states.

Experimental:

Bistable TN LC regular cell comprised a pair of transparent electrodes and alignment layers on upper and lower separated by a gap of d. The rubbing directions of the two alignment layers are perpendicular each other. The cell was filled into a LC MLC-6218 and a chiral additive S-811 (Merck). The concentration of S-811 was varied to adjust a proper ratio of the cell thickness to inherent pitch (d/P_0).

Two stable states of -π/2 and 3π/2 can be clearly distinguished by the birefringence effect in the system including the cell and polarizers. The input and output polarizer axes are an angle of α and γ to the input director of the liquid crystal cell, respectively. The transmission of this optical arrangement is given by [8]

$$T = \left| \begin{pmatrix} \cos\gamma & \sin\gamma \end{pmatrix} \cdot M \cdot \begin{pmatrix} \cos\alpha \\ \sin\alpha \end{pmatrix} \right|^2 \qquad (1)$$

For the case of α=π/4 and γ=α+π/2, Eq. (1) can be expressed by

$$T = 1 - \quad \sin^2 \phi \sqrt{1+\mu^2} \qquad (2)$$

where $\mu=\pi d\Delta n/\lambda\phi$, d and ϕ are the cell thickness and the twist angle of the LC cell, and λ is the wavelength of the incident light. $\pi\phi$ According to the above formula, when $d\Delta n=\sqrt{2}\,\lambda$, the $-\pi/2$ twist state shows dark state, and the $3\pi/2$ twist state display bright state. Therefore high contrast ratio between the two states can be realized.

The driving waveforms designed according to the switching principle proposed by Berramen [1] and Tanaka [2] are shown in Fig. 1.

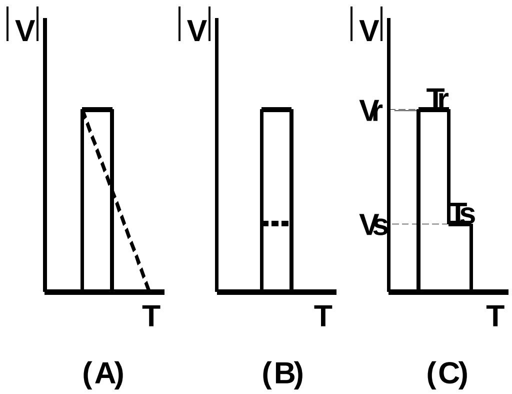

Fig. 1. Switching waveforms for the BTN LCD.

The driving waveform (A) can be used to switch the bistable states by turning the voltage pulse off suddenly for one state, or slowly for the other. For the driving waveform (B), we can adjust the amplitude of the voltage pulse to switch the transition between $-\pi/2$ and $3\pi/2$ states. Driving waveform (C) is consists of the reset pulse to switch the LC to the near homeotropic state, followed by the selection pulse to select the one of the two metastable states, where Vr and Tr are the amplitude and the time of reset pulse, and Vs and Ts are those of the selection pulse.

Results and discuss

After the LC was filled into the cell, the cell is of the initial $\pi/2$ twist state and displays violet color between two cross polarizes. The initial $\pi/2$ state was removed complexly by switching the cell between two states for several times. the higher the voltage amplitude was applied or the longer the voltage pulse was applied, the less the switching times needs for removing the initial state.

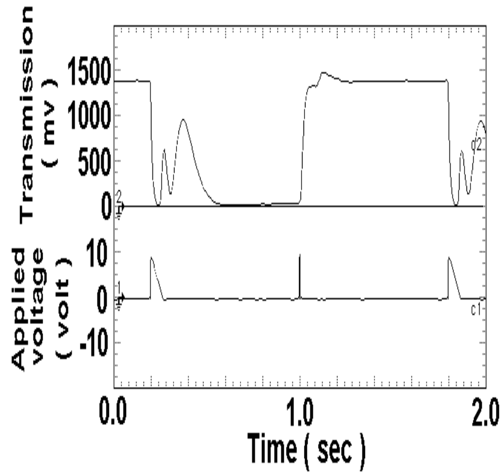

Fig. 2. Transmission of the LCD (upper) and applied voltage pulses (lower) as a function of time. Waveform (A) in Fig.1 is used. The $-\pi/2$ state has low transmission and the $3\pi/2$ state has high transmission

Fig.2 shows the time-dependent transmission curve and the time-dependent voltage pulse curve for the BTN LC cell switched by the waveform (A). It can be seen that the $-\pi/2$ twist state which corresponds to low transmission can be switched by turning the voltage pulse off slowly, and the $3\pi/2$ state witch corresponds to high transmission can be switched by turning the voltage pulse off suddenly. The measured contrast ratio in normal direction is about 30:1. The $-\pi/2$ twist state displays violet color, and the $3\pi/2$ twist state shows yellow or green color.

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Both $-\pi/2$ state and $3\pi/2$ twist states can stay for several seconds after the electric filed is removed, After which time they would relax to the initial $\pi/2$ twist state. So the $-\pi/2$ and $3\pi/2$ twist states are metastable states. It was found that the memory retention time was only slightly dependent on $d/p_{\circ}$ and d.

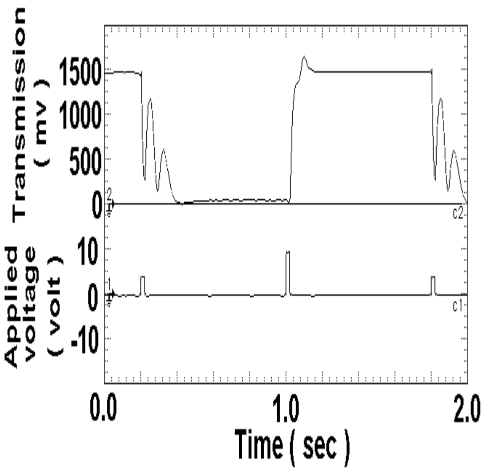

Fig. 3 Transmission of the LCD (upper) and applied voltage pulses (lower) as a function of time. Waveform (B) in Fig.1 is used. The $-\pi/2$ state has low transmission and the $3\pi/2$ state has high transmission.

Fig. 3 shows the time-dependent transmission curve and driving pulse curve for the BTN LC cell switched by the waveform (B). It can be seen that the $-\pi/2$ twist state which corresponds to low transmission can be switched by using the lower voltage pulse, and the $3\pi/2$ state witch corresponds to high transmission can be switched by using the higher voltage pulse. The contrast ratio is also about 30:1.

It is found by experament that

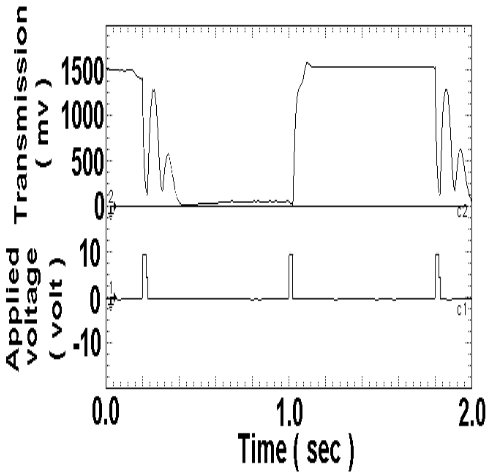

Fig.4 shows the time-dependent transmission curve and the time-dependent voltage pulse curve for the BTN LC cell switched by the waveform (c). It can be seen that the $-\pi/2$ twist state which corresponds to low transmission can be switched by using the weaker selection pulse which follows the reset pulse, and the $3\pi/2$ state witch corresponds to high transmission can be switched by using the stronger selection pulse. The contrast ratio is 30:1

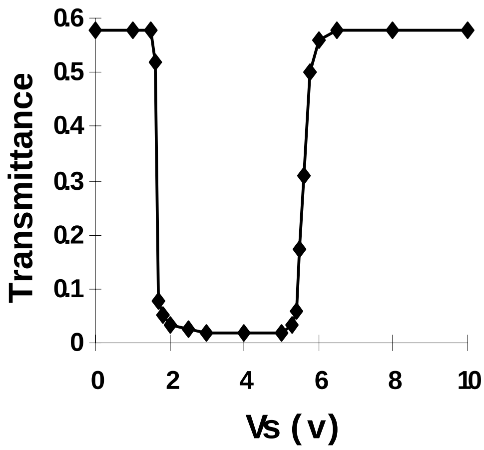

Fig. 5 shows the transmittance-dependent selection amplitude (T-V) curve of BTN LC cell when reset time is 20 ms, the reset amplitude is 10 volt and selection time is 4 ms. The high transmittance is correspond to $3\pi/2$ state , and the low transmittance is correspond to $-\pi/2$ state.. The transmittance vs. the selection voltage has two very steep transition between high and low transmittance; the γ value (Von/Voff) are all abort 1.10; the selection amplitude range of -π/2 state is from Vmin to Vmax. Since the switching between the two states can be performed by adjusting the amplitude of the selection pulse, the driving waveform is easily divided into the common scanning signal and segment data signal to facilitate the passive-matrix addressing, therefore we can select proper selection voltage to performance the passive-matrix addressing.

Conclusion

We have developed a novel BTN LCD mode that can be switched between -π/2 and 3π/2 states by the temporary voltage pulse. Three switching waveforms can be used to switch the cell from one state to another. A high contrast ratio can be achieved. The transition between two bistable states can be performed by adjusting the magnitude of the voltage pulse, so the Novel BTN LC display can be driven by a passive-matrix addressing method.

Acknowledgments

This research is supported by the Hong Kong ITDC Grant No. AF/155/94.

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The effect of driving pulses on the bistable switching characteristics of the BTN LC cell was investigated as we vary time (Tr) of a reset pulse as well as amplitude (Vs) and time (Ts) of a selection pulse, respectively. We began our investigament by measuring the relationship between Vr and Tr of the 1kHz reset pulse. The results is shown in figure 6. It can be seen that the minimum reset amplitude, Vrm, decrease as the Tr increase. When the Tr is large enough (>80ms), the Vrm is down slowly, however when the Tr less than 20 ms, the Vrm is up rapidly as the Tr decrease.

The relationship between the selection amplitude range of -π/2 state, from Vmin to Vmax, and the reset time (Tr) at difference d/p value was investigated when the reset voltage is 10 volts and the selection time is 4ms. The measuring results is shown in figure 7. It can be seen that, either Tr=20 ms or Tr=40ms, the selection amplitude range becomes narrow rapidly as the d/p increase from 0.286 to 0.289, however the selection amplitude range vary unremarkable as the d/p increase from 0.289 to 0.303, The selection amplitude range of -π/2 state is independent of Tr (from 20 ms to 40 ms).

Figure 8 shows the effect of the selection time (Ts) to the relationship between the selection amplitude range of -π/2 state and d/p values, where Tr is 40ms, and Vr is 10 v. It is found that the selection amplitude range in all over the d/p values increases with the increase of Ts.