A New BTN LCD with High Contrast Ratio and Large Cell Gap

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Abstract

The optical properties of a (0, 2π) transmissive BTN LC cell is optimized by parameter space method. Experimentally the high contrast ratios above 80 within -80° to 80° viewing angle ranges were first obtained. The highest contrast ratio is 250. The large dΔn makes this new BTN large cell gap and low operating voltage possibility.

Introduction

Bistable twisted nematic (BTN) liquid crystal displays (LCD) that could be switched between two metastable twist states using an electrical pulse was discovered by Berreman et al in 1981[1]. A 0 to 2π bistability was demonstrated in that paper. Recently, Tanaka et al[2] developed a driving method for passive-matrix addressing of such BTN displays. This high performance LCD rekindled much interest in BTN LCD[3-12].

Because of its bistability, the BTN LCD can be driven with the behaviour of an active matrix display, without any cross talk problems associated with passive multiplexing. Another advantage of BTN is that since both bistable twist states of BTN have in plane alignment, the viewing angle of a BTN is much better than TN and STN displays. In some sense, the BTN is actually similar to the wide viewing angle in-plane-switching mode LCD.

For (0, 2π) BTN LCD developed by Tanaka et al[2] have lots of advantages, such as high contrast, vide viewing angle and fast response time. But due to dΔn= λ/2, the cell gap must be selected about 2 μm, and such thin cell gap is very difficult to performance industry fabrication. On the other hand, the low Δn is responding to low Δε which results in high driving voltage and increasing cost.

In this paper, the optical properties of a (0, 2π) transmissive BTN LC cell is optimized by parameter space method[13]. The new optimized BTN cell experimentally obtained higher contrast ratio within wide viewing ranges than the BTN cell reported by Tanaka[2]. The lager dΔn makes the new BTN cell larger cell gap and lower operating voltage.

Experimental

The BTN LC cell comprised a pair of transparent electrodes and alignment layers on the upper and lower ITO glasses which were separated by a gap of *d*. The rubbing directions on the two alignment layers were anti-parallel each other. The cell was filled with commercial LC material and a chiral additive S-811. The concentration of S-811 was varied to adjust a proper ratio of the cell thickness to the inherent pitch (d/P_0).

Two stable twist states of 0 and 2π can be clearly distinguished by the birefringence effect in the system including the LC cell and polarizers.

<u>Results and discuss</u>

For the case of a BTN, both bistable twist states operate at V=0. So the static parameter space is ideal in analyzing its optical properties. We showed previously that a (ϕ, dΔn) parameter space for fixed α can be used to calculate the contrast ratio of BTN for any value of ϕ and dΔn by calculating the transmittance of the 2 bistable twist states (ϕ, ϕ+2π) separately[13]. The contrast ratio is defined as

$$\boldsymbol{CR} = \boldsymbol{T}(\phi)/\boldsymbol{T}(\phi+2\pi) \text{ or } \boldsymbol{T}(\phi+2\pi)/\boldsymbol{T}(\phi) \qquad (1)$$

depending whichever ratio is larger. ϕ is used as the independent parameter though it should be remembered that the bistable states are ϕ and ϕ+2π.

Fig. 1 shows the dependence of iso-contrast ratio on twist angle ϕ and dΔn for the BTN mode with α=45° and a cross polarizer geometry. Each contour line in Fig.1 represents an increase of 10 in the contrast ratio. It can be seen that there many regions where good contrast can be obtained for the case of ϕ=0. The operating condition of the BTN in Tanaka et al[2] corresponds to the large island at ϕ=0 and *d*D*n* = 0.2m*m* (about λ/2). Notice that the contrast is not as large in this island as compared to the others. But it is nevertheless a good choice for the operation of the BTN.

Fig. 2 shows the same BTN with α=0° and cross polarizers. The parameter space is now quite different. The region of the best contrast is dominated by large elongated island at ϕ=0° and dΔn =0.78 m*m*. Clearly it has higher contrast ratio and larger dΔn value than Tanaka's operating condition.

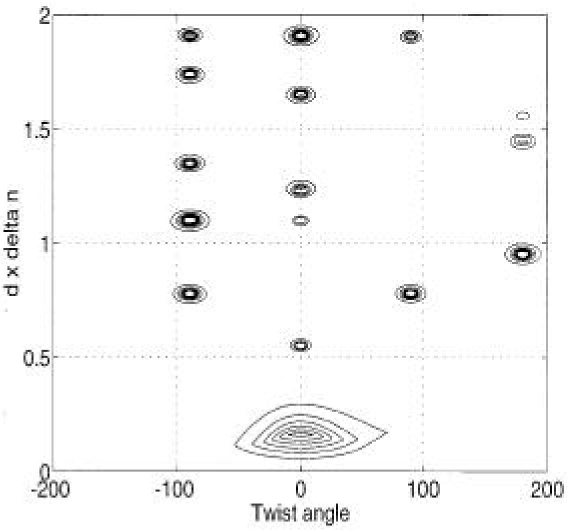

Fig. 1 Parameter space showing contours of iso-contrast ratio. ($\alpha = 45°$ with cross polarizers)

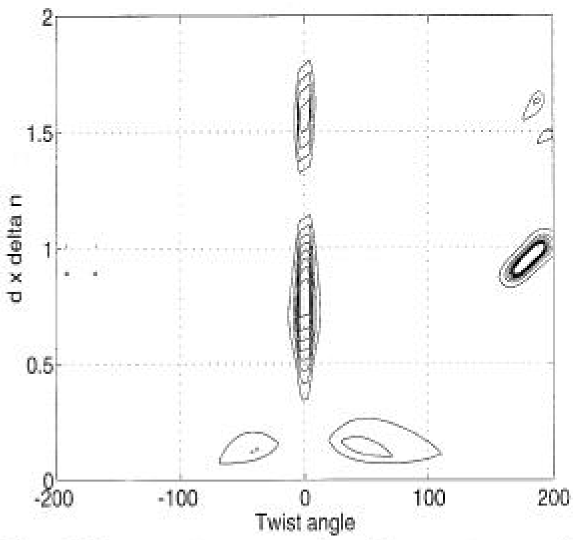

Fig. 2 Parameter space showing contours of iso-contrast ratio. ($\alpha = 0°$ with cross polarizers)

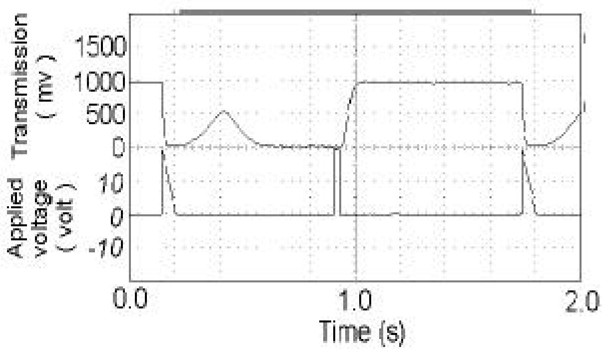

Fig.3 Time-dependent transmission and driving pulse curve of BTN cell with d△n=0.78.

Fig.3 shows the electrical-optical properties of the new BTN cell with $d\Delta n = 0.78\mu m$. It can be seen that the 0 twist state which corresponds to low transmission can be switched by turning the voltage pulse off slowly, and the 2π state witch corresponds to high transmission can be switched by turning the voltage pulse off suddenly. Since the high transmission is 980 mv and the low transmission is 6 mv, the contrast ratio in normal direction is 163.

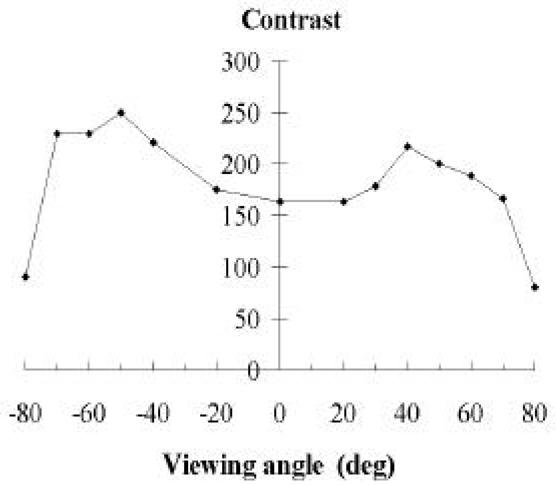

Fig. 4 Relationship between contrast and viewing angle in horizontal direction

We also measured the relationship between contrast ratio and viewing angle in horizontal or vertical direction. The results in horizontal direction were shown in Fig.4. It can be seen that the contrast ratio can be above 80 within the range between -80° and 80°. If the viewing angle is in the range from -70° to 70°, the contrast ratio can be above 160. The highest contrast ratio of 250 can be obtained when θ = -50°. It was the first time to achieve such high contrast ratio within such wide viewing angle range in BTN LCD.

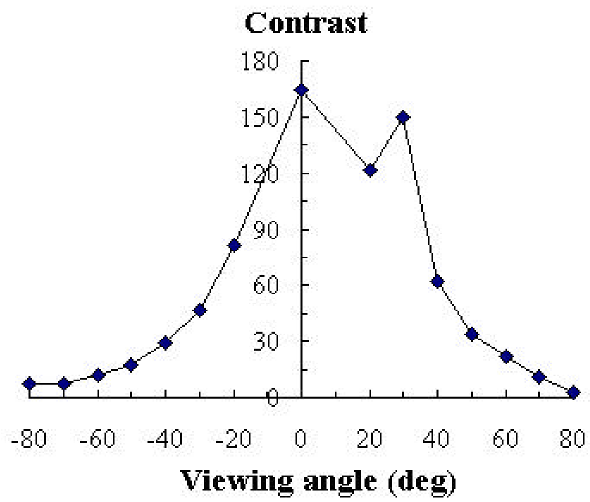

Fig. 5 Relationship between contrast and viewing angle in vertical direction.

Fig. 5 shows the results in vertical direction. The range of high contrast ratio above 30 was from -40° to 50°. Comparing with Fig.4, we found that the range of high contrast ratio was narrower in vertical direction than in horizontal direction.

due to the $d\Delta n$ is $0.78\mu m$, we can select larger cell gap and larger $d\Delta n$ value than Tanaka's operating condition. The new selection will bring two advantages. One advantage is that the volume-produce becomes easier by adopting large cell gap. Another one is that using large $\Delta\varepsilon$ LC material which responding to large Δn LC material can reduce driving voltage to decrease cost.

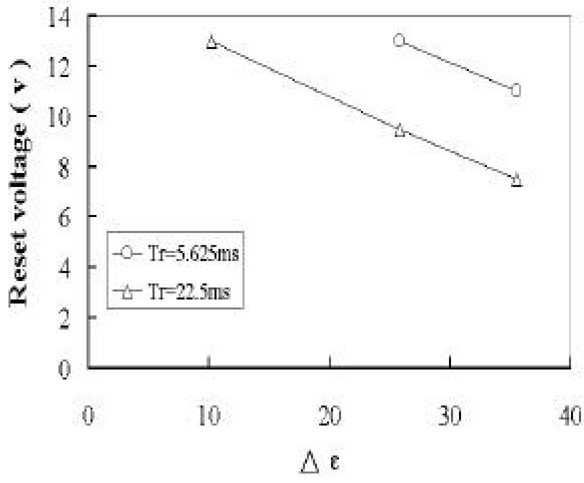

Fig. 6 Relationship between the reset voltage and Δ ε in diference reset time

Fig.6 shows the independence of the reset voltage of the new BTN cell on the Δε of LC material. It can be markedly seen that the reset voltages which responding to driving voltage decreased as the Δε increased. When reset time fixed at 22.5 ms and Δε was 35.5, the low reset voltage about 7 volts was obtained. It also can be seen that the change of reset time would influence the reset voltage, This will be discussed in the future.

Conclusion

We developed a new (0, 2π) BTN cell by parameter space method. The highest contrast ratio 250 and the high contrast ratios above 80 within -80° to 80° viewing angle ranges were first experimentally obtained. The large dΔn makes this new BTN easily to manufacture with good yield and to operate at low driving voltage.

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