Pretilt Angle Measurement using PEM

Y. W. Li, F. S. Y. Yeung, L. Tan, J. Y. L. Ho and H. S. Kwok

Center for Display Research
Hong Kong University of Science and Technology
Clear Water Bay, Hong Kong

ABSTRACT

A new method of measuring arbitrary pretilt angle for LCD using photo-elastic modulator is discussed. Different from crystal rotation method, it is able to measure pretilt angles accurately from 0 to 90 degree. No cell gap and wavelength information is required. It is also possible to determine two-dimensional liquid crystal cell parameter distributions at real time.

INTRODUCTION

Pretilt angle is one of the important factors in designing LCD. It is becoming more important in new applications that are based on large pretilt angles. For example, in order to improve the response time of ECB, OCB or NBB mode LCD, 10^o to 70^o pretilt angle is required. For compensation film, o-plate or wide view angle films can be fabricated using high pretilt angle alignment surface. As well, for bistable mode display, obtaining pretilt angle from 45^o to 80^o is the essential for bistable bend splay, bistable twisted bend display.

All the new applications mentioned require high pretilt angles from 10^o to 80^o. Therefore, it is indeed important to control the pretilt angle accurately and evaluation of the pretilt angles is indispensable. It is well known that conventional crystal rotation method[1,2] is not applicable to the whole range of 10 to 80 degree. It is because of the shift of the center of the fringe pattern. Therefore, we propose a simple method to handle such problem. In addition, this method can also be modified for determining two-dimensional cell parameter distributions by using a high resolution CCD camera.

METHODOLOGY

Figure 1 shows the optical setup for the measurement. L – is the Helium Neon laser with wavelength 632.5nm, LCD sample is placed at the rotator and the PEM-90 is photoelastic modulators from Hinds Instruments, P and A is the polarizer and analyzer and D is the detector. The setup is simple and similar to crystal rotation.

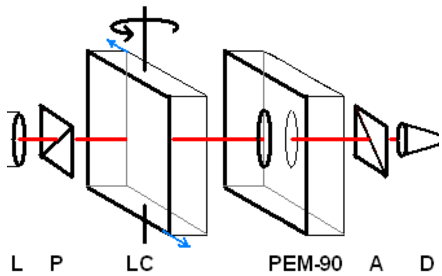


Fig. 1 The optical setup of our proposed method
L is the He-Ne laser at 632.8nm; P is the polarizer at +45 degree to the direction of the rubbing; LC is the LC sample; PEM-90 is the photoelastic modulators; A is the analyzer at –45 degree to the rubbing direction; and D is the detector; the blue arrows mean the rubbing direction of 1st and 2nd alignment layer.

However, rather than measuring the light intensity, we measure the absolute retardation of the LCD at oblique incident angle using photo-elastic modulator. Basically, the retardation of homogenous LCD[3] corresponding to different incident angle are formulated as [1]

$$\Gamma(\alpha,\theta,d) = \frac{2\pi d}{\lambda}(\sigma_{ez} - \sigma_{oz}) \qquad [1]$$

Where

$$\sigma_{ez} = \frac{(n_e^2 - n_o^2)\sin 2\alpha \sin\theta}{2\left[n_o^2 + (n_e^2 - n_o^2)\sin^2\alpha\right]} + \frac{n_o n_e}{n_o^2 + (n_e^2 - n_o^2)\sin^2\alpha} \times \sqrt{n_o^2 + (n_e^2 - n_o^2)\sin^2\alpha - \sin^2\theta} \qquad [2]$$

$$\sigma_{oz} = \sqrt{n_o^{\,2} - \sin^2\theta} \qquad [3]$$

Here Γ is the retardation of the LC cell, d is the cell gap of LC, λ is the wavelength of the incident light, α is the pretilt angle, θ is the laser incident angle. Also n_e and n_o are the extraordinary and ordinary refractive indices of LC, respectively.

From [1], it is found that both pretilt angle – α and cell gap – d are unknown yet. In order to eliminate the cell gap variable, two different incident angles are applied. The equation of the [1] can be rewritten as [4].

$$\frac{\Gamma(\alpha,\theta_1)}{\Gamma(\alpha,\theta_2)} = \frac{\sigma_{ez1} - \sigma_{oz1}}{\sigma_{ez2} - \sigma_{oz2}} \qquad [4]$$

It is found that there is only one variable pretilt angle – α in [4]. It is possible to calculate the pretilt angle directly without any cell gap information. Such method is also insensitive to dispersion of liquid crystal. It is because the pretilt angle is obtained from the ratio of retardation. The effect of dispersion is not very significant. After obtained the pretilt angle, we can also calculate the corresponding cell gap at the same time [5]. However, it is not a very good method to obtain cell gap data. It is because it is highly depends on the accuracy of the value of n_e and n_o. It is known that there is dispersion according different measurement wavelength exact value of n_e and n_o is difficult to obtain. Therefore we can only obtain a roughly range of cell gap. From the experimental results, it is found that the error is about 5%.

$$d = \frac{\Gamma \times 10^{-9}}{(\sigma_{ez} - \sigma_{oz})} \qquad [5]$$

RESULTS AND DISCUSSIONS

In order to verify the proposed measurement method, several homogenous cells (A, B, C, D) with different pretilt angles, Figure 2, are fabricated using different mixing ratio of H and V polyimides[3]. The cell gap is around 5μm. Liquid crystal is MLC-6080.

Figure 3 shows their corresponding measured retardation against different laser incident angles. We arbitrarily pick 2 retardation values at different incident angles such as 0 and –45 degrees, and then calculate the pretilt angles. The experimental results are summarized at Table 1.

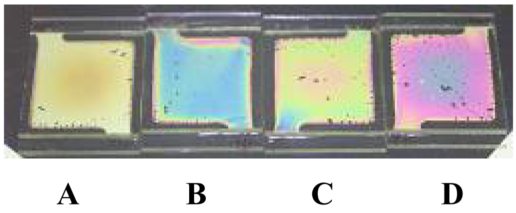


Fig. 2 The test cells A, B, C, D using 5μm Spacer, liquid crystal is MLC-6080 (Δn is 0.2026, n_e is 1.71) provided by Merck.

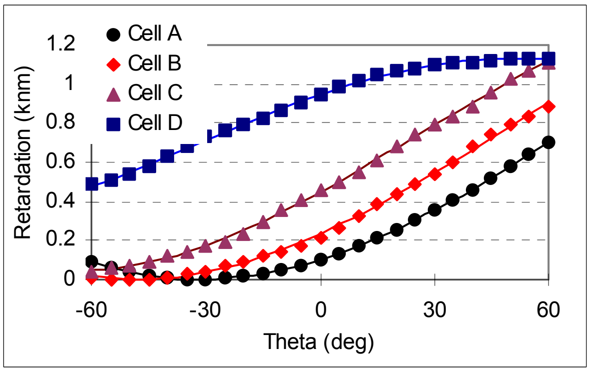


Fig. 3 Measured retardation of cell A, B, C, D at different incident angle.

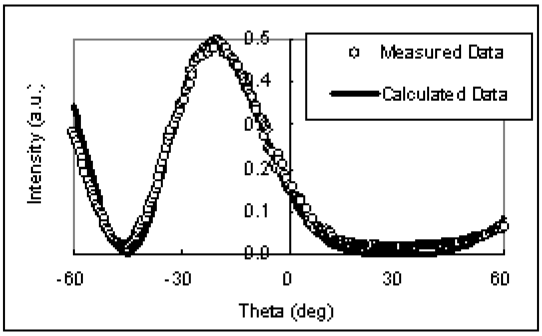
Table 1 Measured Results using proposed method.

LC Cell	Pretilt Angle (deg.)	Cell gap (μm)
A	70.36	5.33
B	57.58	5.32
C	44.25	4.83
D	15.08	5.24

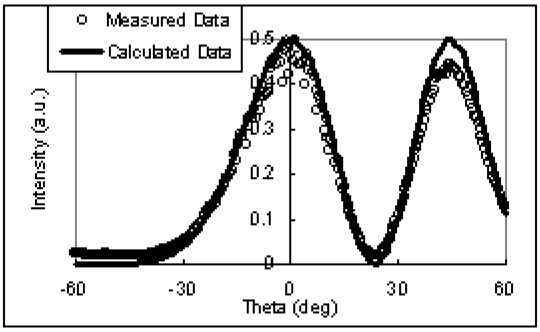
Based on the measured parameters, the corresponding LCD transmission intensity at different incident angles can be calculated as [6].

$$I = \frac{1}{2}\sin^2\left[\frac{\pi}{\lambda}(\sigma_{ez} - \sigma_{oz})d\right] \qquad [6]$$

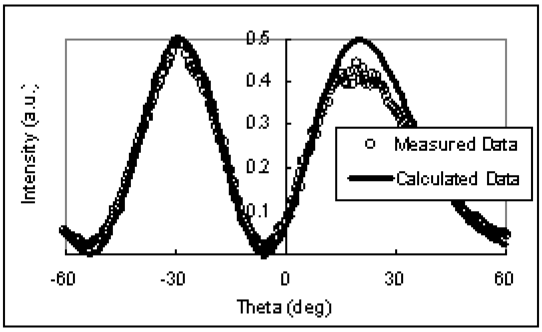
We also measure the transmission intensity and compare the calculated and measured results. Figure 4a – d shows there are good agreements between the calculated and measured data. It is also verified that our measurement method is able to measure the pretilt angle accurately.



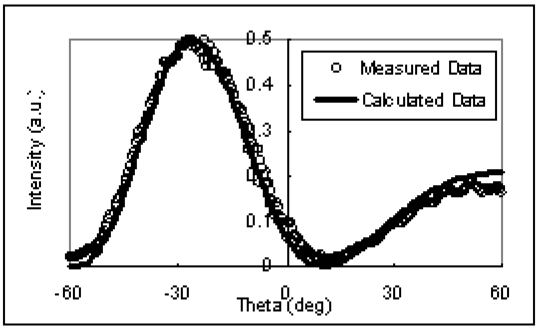
(a)



(b)



(c)



(d)

Fig. 4 (a) The pretilt angle is 70.36 degree. Cell gap is 5.08μm. (b) The pretilt angle is 57.58 degree, cell gap is 5.33μm. (c) The pretilt angle is 44.25 degree, cell gap is 5.08μm (d) The pretilt angle is 15.08 degree, cell gap is 5.49μm.

The selection of the incident angles actually is arbitrary. Figure 5 shows the results of calculated pretilt angle of cell C using different incident angles. We fix θ_1 equal to 0 degree and vary θ_2 from –60 to +60 degree. The deviation is less than 1 degree.

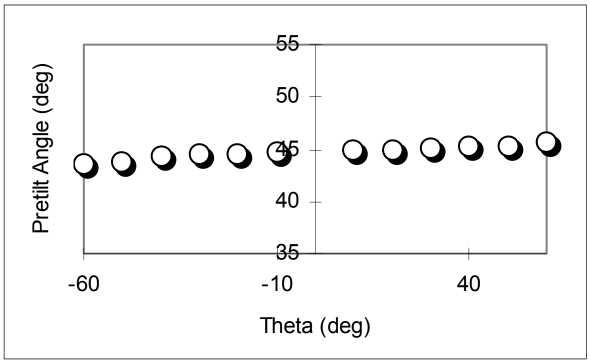


Fig. 5 the results of calculated pretilt angle of Cell C using different incident angles. Fix θ_1 equal to 0 degree and vary θ_2 from –60 to +60 degree. The deviation is about ±1 degree.

CONCLUSION

As mentioned before, many new LCD devices can be fabricated using high pretilt angles such as fast LCDs and bistable LCDs and retardation film by using LCP. Since our method can use any 2 incident angles, it can be as small as ±10 degree, to obtain the pretilt angle and cell gap the same time. It is a promising advantage for determining two-dimensional cell parameter distributions at real time. Also, by updating the retardation [1] for reflective display, we can measure the pretilt angle and cell gap for reflective LCD cell using such method as well.

ACKNOWLEDGEMENT

This research was supported by the Hong Kong Government Innovation and Technology Fund and the Research Grants Council.

REFERENCES

[1] G. Baur, V. Wittwer and D. W. Berreman, Phys. Lett. A, 56, 142, (1976).

[2] B. O. Myrvold and K. Kondo, Liq. Cryst., 17, 437, (1994).

[3] F. H. Yu and H. S. Kwok, Journal of Optical Society of America A, 16, pp. 2772-80, (1999).

[4] F. S. Y. Yeung, F. C. Xie, J. Wan, O. Tsui, P. Sheng and H. S. Kwok, SID Symposium Digest, 36, 1080, (2005).