

# The depolarization effect of nematic liquid crystal

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The depolarization effect of nematic liquid crystal (NLC) cell as a polychromatic depolarizer was discussed in this paper. The experiments show that the polychromatic linearly polarized light can be depolarized effectively when the angle between the polarized direction of polychromatic light and the optical axis of NLC is  $\pi/4$  and the residual degree of polarization were under 10%. In the case of the variation of the applied voltage, temperature and the rotation angle of the NLC cell, the NLC cell depolarization was followed.

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## 1. Introduction

As polarization element, the depolarizer was applied to the astronomical observations from the old times of astronomy. But almost any optical instrument especially spectrometer has polarization sensitivity. The depolarizers are essential in order to remove the undesired polarization sensitivity of optical instruments and improve the measurement precision. Now the depolarizers are used extensively in many photoelectric measuring instruments, such as astronomical instrument, laser processing, laser medicine and optical fiber communication. [1-3]. So, further research of depolarizers is of actual significance.

Depolarization is more difficult than polarization. Let polarized light pass through the scattering medium or birefringent material of gradient phase difference are the two basic methods of depolarization. Because the transmissivity of light intensity is low when the polarized light passes through the scatter depolarizer, the depolarizers are usually made with birefringent material (such as calcite, quartz and optical fiber) in fact. When a linearly polarized light beam passes through the birefringent material of gradient phase difference, the beams will interfere each other in a small area and the ordered state will change. So the degree of polarization of emergent light drops. This is the fundamental principle of depolarization.

According to the type of polarized light that will be depolarized, depolarizers can be divided into two types: monochromatic depolarizer [4-6], polychromatic depolarizer [7,8]. The polychromatic depolarizer is of two types: the single birefringent crystal plate and the lyot

depolarizer. The lyot depolarizer consists of two thick retarders oriented with their fast axes at an angle of  $\pi/4$  to one another and the thickness ratio of two retarders is 2:1.

But detailed researches about the depolarization effect of liquid crystal are lacking. Zhang D.Y reported a monochromatic liquid crystal depolarizer. The depolarizer is a wedge-shaped cell filled with cholesteric liquid crystal material [9]. Nicholas demonstrated a scattering type liquid crystal depolarizer [10].

In this paper, the polychromatic depolarization effect of nematic liquid crystal cell was discussed. The nematic liquid crystal is an anisotropic material. The optical properties of the liquid crystal cell are the same as those of birefringent single axis crystal.

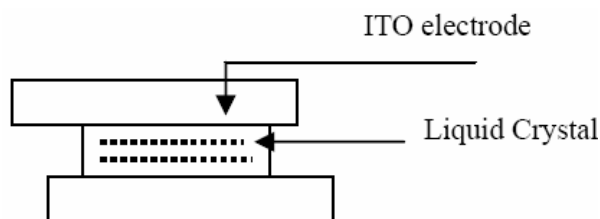


Fig. 1. The schematic of nematic liquid crystal cell.

## 2. Experiment

The nematic liquid crystal cell has been adopted in the experiment is BL-009 ( $\geq n = 0.283$ ). The structure of nematic liquid crystal (NLC) cell is illustrated in Fig. 1. The NLC material is sandwiched between two transparent

glass substrates coated with film as ITO electrode. The thickness of NLC is 11 microns. The ITO glass has been processed specially. After the surface of the ITO glass was rubbed along a direction, the axis direction of NLC molecular is as same as the friction direction of glass surface. This is to say, the direction of optical axis parallels the surface of ITO glass.

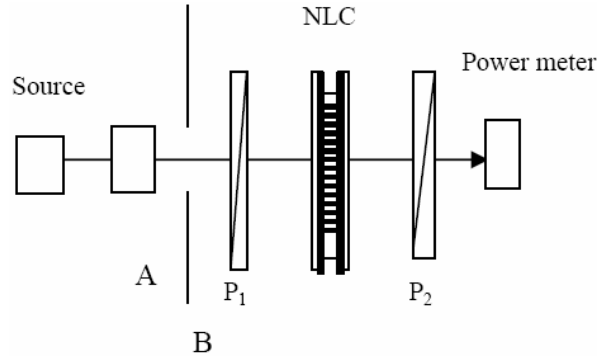


Fig. 2. Experimental setup for testing the depolarization effect of the NLC cell.

The schematic of the experiment is shown in Fig. 2. The optical source is a tungsten-halogen lamp. A in the Fig. 2 is a collimating system. B is a diaphragm.  $P_1$  and  $P_2$  are polarizers. The degree of polarization of emergent beam can be measured by rotating the polarizer  $P_2$ . If the  $I_{\max}$  and  $I_{\min}$  remark the maximum and minimum light intensity of emergent beam. The expression of the degree of polarization (DOP) is:

$$P = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \quad (1)$$

### 3. Results

Fig. 3 shows that the DOP of emergent beam changes with the angle between the polarization direction of incident linearly polarized light and the optical axis of NLC cell at the room temperature. It demonstrated that the DOP is cosine oscillations when the angle change. It was also found that the residual DOP of polychromatic light reached under 10% when the angle called  $\theta$  is  $\pi/4$ . The NLC cell has the same depolarization effect as a birefringent crystal plate.

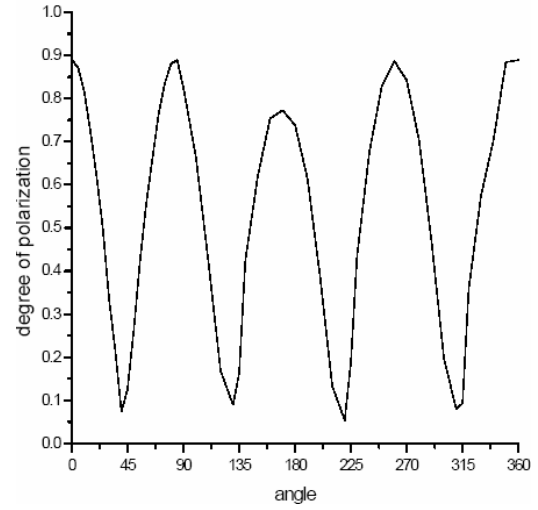


Fig. 3. The degree of polarization vs the angle  $\theta$ .

At the room-temperature, the NLC cell was given to voltage by a XD1002 low-frequency signal-generator. Fig. 4 shows the relationship between the DOP of emergent light and the voltage when the angle between the axis of  $P_1$  and the optical axis of NLC is  $\pi/4$ .

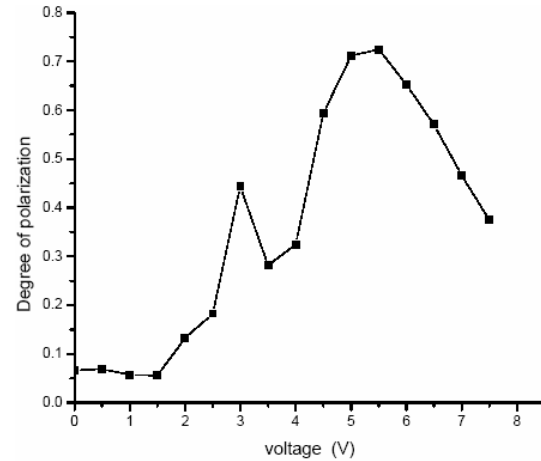


Fig. 4. The degree of polarization vs the applied voltage when  $\theta$  is  $\pi/4$ .

The DOP curve of emergent light is very flat under 1.5 V. This is to say the threshold voltage is 1.5 V. The DOP increase obviously when the applied voltage varied from 1.5 V to 8 V. Because let it in the electric field, the orientation of liquid crystal molecule will change. It induced the optical axis of NLC cell to change. This causes that  $\theta$  diverges  $\pi/4$  and the DOP increases directly. It demonstrated that the NLC cell with different applied

voltages cannot improve the depolarization characteristic under this condition.

We also discussed the variation of DOP during rotation of the NLC cell when  $\theta$  is maintained at a constant value under this condition. Fig. 5 shows the relationship between the degree of polarization and the rotation angle when the  $\theta$  is  $\pi/4$ . The DOP decrease slowly at the range from  $0^\circ$  to  $30^\circ$  and reached the lowest value at  $30^\circ$ . But DOP increase fast when the rotation angle range varied from  $30^\circ$  to  $60^\circ$ . In order to contrast, the relationship between the DOP and the rotation angle was discussed when the  $\theta$  is  $\pi/3$ . Fig. 6 shows the curve when  $\theta$  is  $\pi/3$ . The DOP decrease fast when the NLC cell rotates. It was obvious that the NLC cell can not be suitable as a polychromatic depolarizer in this condition. The DOP of emergent beam is above 35%.

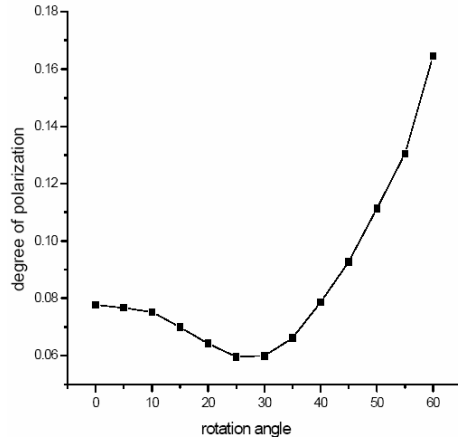


Fig. 5. The degree of polarization vs the rotation angle when  $\theta$  is  $\pi/4$ .

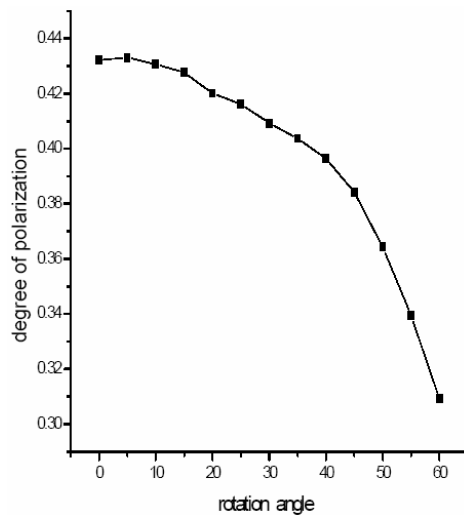


Fig. 6. The degree of polarization vs the rotation angle when  $\theta$  is  $\pi/3$ .

As a result, it is a key problem to depolarize the polychromatic polarized light when the angle between the polarization direction of incident light and the optical axis of NLC cell is maintained  $\pi/4$ .

The temperature effect of NLC cell as a polychromatic depolarizer was also discussed. The NLC cell was set into a temperature-controlled cabinet. The angle between the axis of  $P_1$  and the optical axis of NLC cell kept  $\pi/4$  at the same time.

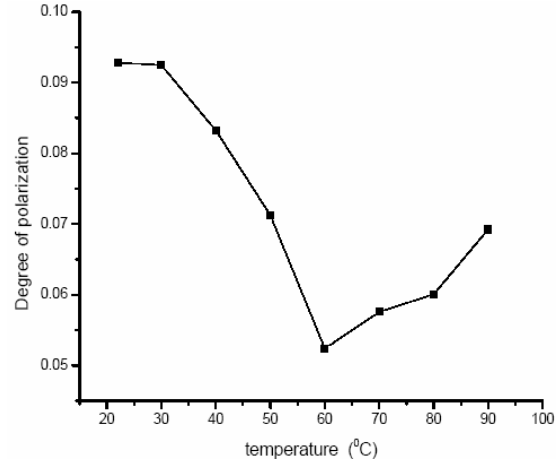


Fig. 7. The degree of polarization vs temperature.

Fig. 7 shows that relationship between the degree of polarization and temperature when the temperature varied from 20 to 90 degree centigrade. It was found that the degree of polarization reached the lowest level at the temperature of 60 degree centigrade and the residual degree of polarization reached about 5%.

#### 4. Conclusions

The depolarization effect of nematic liquid crystal BL-009 as a polychromatic depolarizer was discussed in this paper. The experiments show that polychromatic linear polarization light can be depolarized effectively when the angle between the polarization direction of incident light and the optical axis of NLC is  $\pi/4$ . When  $\theta$  is  $\pi/4$ , the depolarization worses when the applied voltage varied from 1.5 V to 8 V. Because the direction of optical axis of NLC cell change and the angle between the polarization direction of incident light and the axis of NLC diverges to  $\pi/4$ . When the NLC cell is rotated, the depolarization improves a little. But if the  $\theta$  diverges to  $\pi/4$ , the depolarization changes largely and the NLC cell cannot be as practical as a polychromatic depolarizer. Finally, the depolarization effect with the change in temperature was discussed.

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