

Cholesteric liquid crystal depolarizer

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Abstract. The design and performance test of a cholesteric liquid crystal depolarizer (CLCD) is presented. This new depolarizer is a wedge-shaped cell filled with cholesteric liquid crystal material. By placing a CLCD in its path, the incident light beam is divided into a great number of micro beams in space, and each micro light beam has different polarization state and orientation, hence achieving the depolarization effect. Over a conventional optical depolarizer, the CLCD is easy built and insensitive to the polarization orientation of incident light. © 2007 Society of Photo-Optical Instrumentation Engineers.

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1 Introduction

Many photodiodes are in fact polarization sensors. For some applications, a polarization sensitive photodiode might cause considerable error. If an optical device contains birefringent material or nonbirefringent material under stress in its light beam path, its performance may be affected as well. The most practical way to control the optical instrument polarization sensitivity is to depolarize the light beam by using a depolarizer.

There are two common forms of optical depolarizers: wedge depolarizers and Lyot depolarizers. A wedge depolarizer consists of a crystalline quartz wedge together with a compensating fused silica wedge to correct the angular deviation.¹ The optical axis of the quartz wedge lies in the plane of the wedge and at 45 deg to the input polarization orientation, so a wedge depolarizer is sensitive to the polarization orientation of the incident light beam. Lyot depolarizers consist of two crystalline quartz plates assembled with their optical axes lying in the plane of the plates, aligned at 45 deg.^{2,3} One plate is twice the thickness of the other. This combination creates various degrees of elliptical polarization as a function of wavelength. Therefore, the Lyot depolarizer is not suitable for monochromatic light.⁴

2 Depolarizing Mechanism

Cholesteric liquid crystal (CLC) is thermodynamically equivalent to nematic liquid crystal except for the chiral-induced twist in the directors. When the incident light wavelength is comparable to the helical pitch of CLC, the famous Bragg reflection occurs.^{5,6} Because the helical pitch is much larger than the incident light wavelength, both the reflected and transmitted waves are plane-polarized.^{7,8} If

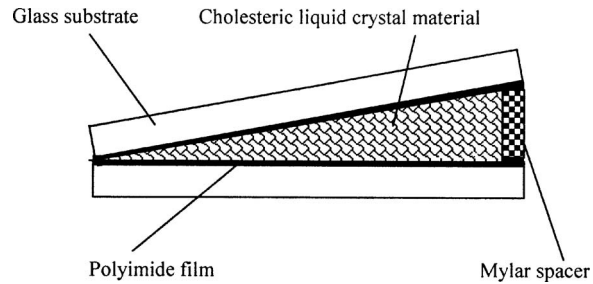


Fig. 1 The structure of the cholesteric liquid crystal depolarizer.

the helical pitch is between the two conditions mentioned previously, the polarization orientation and state of transmitted light is periodically modulated by the helical structure of CLC.

A cholesteric liquid crystal depolarizer (CLCD) is a wedge-shaped cell filled with CLC material whose helical pitch is several times the length of the incident light wavelength. The structure of the CLCD is illustrated in Fig. 1. The CLC material is sandwiched between two transparent glass substrates coated with thin polyamide films. The liquid crystal molecules are planar aligned by rubbed polyimide films. Mylar spacers of different thickness are used to adjust the wedge angle.

When polarized light is incident on a CLCD, the light beam can be viewed as divided into a great number of micro light beams. Each micro light beam with its polarization orientation and state will be differently modulated by the wedge-shaped CLCD, hence achieving the depolarization effect in space.

3 Experimental Results

The nematic liquid crystal SLC9023 ($\Delta n=0.22$) and chiral dopants R811 are used to prepare CLC mixtures of different mixing ratios. A 532-nm continuous laser is used as the test light source. The diameter of the laser beam is 2 mm. With a $\lambda/4$ wave plate, the output beam polarization state from the 532-nm laser is changed from linear to circular. The CLCD was placed between a polarizer and an analyzer. As the analyzer rotated, the transmitted laser light was recorded, as illustrated in Fig. 2.

To examine the depolarization performance of the proposed CLCD, CLCD cells of different wedge angles were made. Figure 3 illustrates the test results of a CLCD with a wedge angle β of 1.43 deg and a chiral dopant mixing ratio c of 10%.

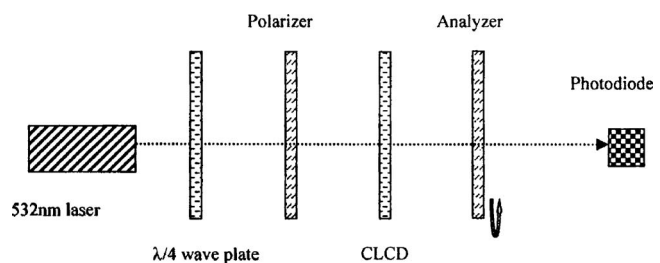


Fig. 2 Experimental setup for testing the depolarization effect of the CLCD.

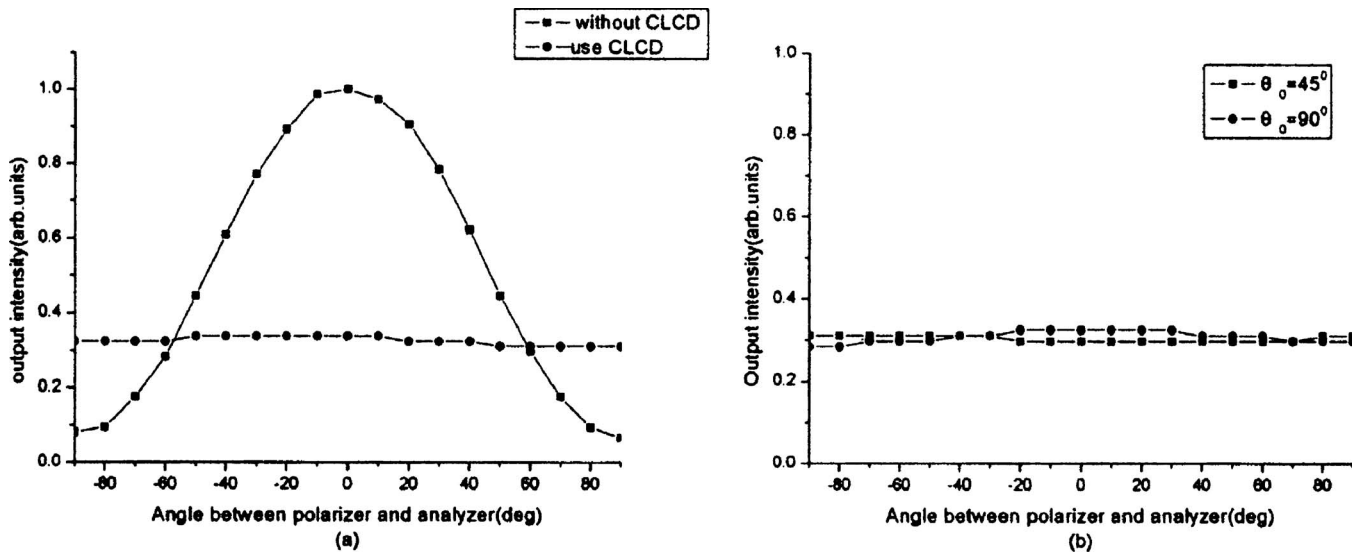


Fig. 3 The depolarization effect of the CLCD ($\beta=1.43$ deg, $c=10\%$): (a) comparing a system with CLCD ($\theta_0=0$ deg) and without CLCD, θ_0 is the angle between the input polarization orientation and the CLCD rubbing direction; and (b) The depolarization effect with different θ_0 .

Test results show that without the CLCD inserted between the polarizer and the analyzer, the transmitted laser light intensity varies greatly as the analyzer was rotated. After inserting the CLCD cell, the amount of transmitted laser intensity variation is reduced to 4% while the analyzer was rotated. By changing the angle between the input polarization orientation and the rubbing direction of the CLCD cell, the transmitted laser intensity varies little. Fig. 3(b) shows that the variations of laser intensity are 2%, 6% with $\theta_0=45$ deg, 90 deg, respectively.

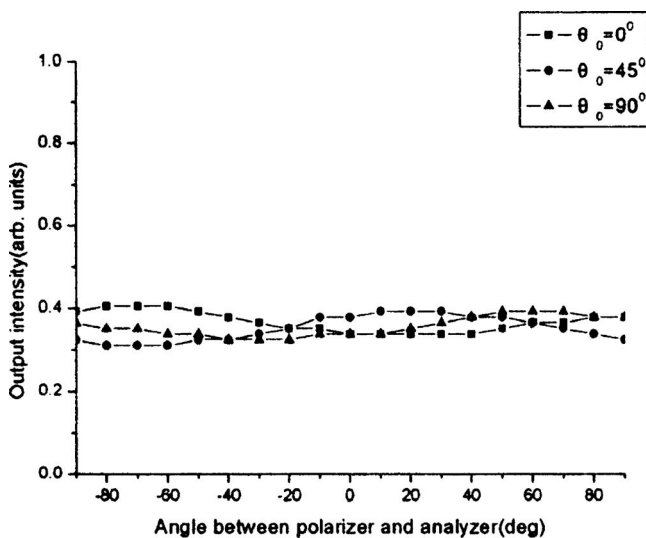


Fig. 4 The performance of the CLCD with wedge angle $\beta = 0.86$ deg

For testing the relationship between the depolarization effect and the wedge angle, another CLCD ($\beta=0.86$ deg, $c=10\%$) is detected. Figure 4 shows the depolarization effect of the CLCD ($\beta=0.86$ deg, $c=10\%$). The variations of laser intensity are 9%, 11%, 9% with $\theta_0=0$ deg, 45 deg, 90 deg, respectively. Experiment results show that the depolarization performance of the CLCD strongly depends on the wedge angle.

4 Conclusions

Wedge cells filled with properly mixed CLC material show good depolarization performance for monochromatic light. This type of depolarizer is insensitive to the polarization orientation of the incident light.

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