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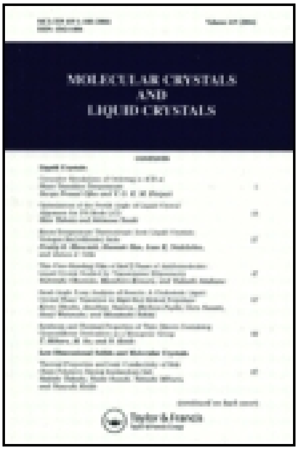

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One Beam Controllable Grating in a Liquid Crystal Cell with an Azo Polymer Surface

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One Beam Controllable Grating in a Liquid Crystal Cell with an Azo Polymer Surface

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We propose a novel grating in a nematic liquid crystal cell with an azo polymer surface (APS). In this system, the polarization grating inscribed on APS modulates the liquid crystal director. The grating effect can be enhanced or reduced by polarization switching of only one pump beam due to strong polarization sensitivity of azobenzene chromophores.

Keywords: liquid crystal grating; polarization grating; azo polymer

INTRODUCTION

It is known that the grating effect can be generally realized by two-beam illumination. In some cases, the grating effect can be increased by only one beam after initial grating formation, and even decreased by

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simple switching of pump beam polarization. This novel control is realized by liquid crystal (LC) grating in an LC cell with a photoresponsive surface.

The LC gratings have several advantages due to their high birefringence and low voltage control scheme. It has been suggested that the LC grating could be driven by a photorefractive-like mechanism in a dye-doped LC cell[1]. Another research demonstated that the LC grating could be operated by optical reorientation of the LC director in a dye-doped LC cell in which the mechanism is related to the surface adsorption of LC and azobenzene chromophore[2-4]. All these gratings are obtained by two wave mixing.

In this paper, we propose a new mechanism for a single beam control of the LC grating induced by polarization modulation, and demonstrate the main features of the LC gratings by a single beam control.

EXPERIMENTAL

The azobenzene copolymer was spin-coated onto a glass substrate in a few hundreds of nm thickness. The azo polymer surface was composed of a photoresponsive side-chain copolymer (SCCP) in which azobenzene chromophores and liquid crystalline chains are attached as side groups. In the previous work[5,6], we reported that the stable LC alignment can be obtained on a SCCP layer with a photocrosslinking group when it is exposed upon a linearly polarized ultraviolet light. The study was mainly focused on the collective reorientation and the alignment stability. Here, we report on a very interesting phenomenon of one beam controllable grating by the SCCP layer without the photocrosslinking group. Figure 1 shows the absorption profile of the SCCP film. The homeotropic polyimide, JALS-204 (Japan Synthetic Rubber), was spin-coated onto the other glass substrate without the rubbing process. Glass spacers between two substrates maintain 10μm cell gap. This cell was filled with a nematic LC, EN-40 (Chisso

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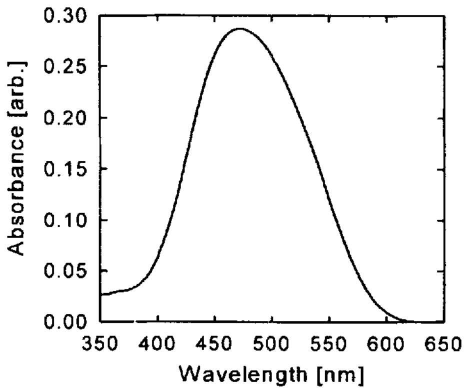

FIGURE 1 Absorption profile of SCCP film

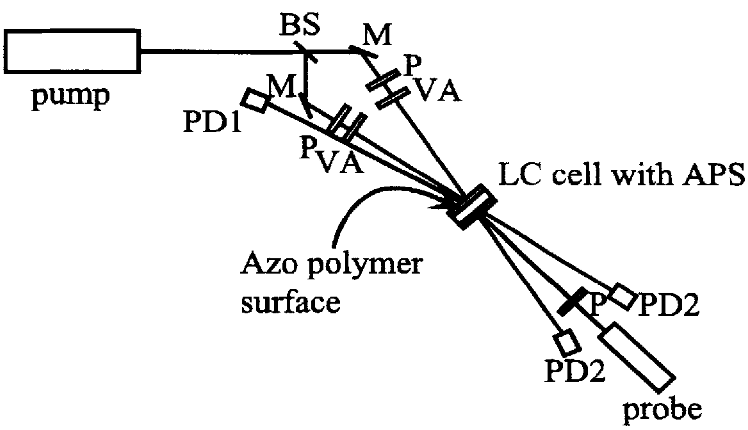

FIGURE 2 Experimental setup: BS – Beamsplitter, M – Mirror, P – Polarizer, pump – Ar ion 488nm laser, probe – He-Ne 633nm laser, VA – Variable attenuator, PD1 – Photodetector for measuring the first-order diffracted probe beam, PD2 – Photodetectors for measuring the zeroth and the first-order diffracted pump beams.

Petrochemical Co.), which has negative dielectric anisotropy. Optical

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microscopic measurements show that the LC molecules have hybrid-type alignment due to planar alignment promoted by SCCP. We used a 488nm Ar ion laser as a pump beam for photo-induced action and a 633nm He-Ne laser as a probe. Each incident pump power is a few tens of mW/cm^2. Figure 2 illustrates the experimental setup.

The initial absorption of the pump beam depending on the polarization state at the azo polymer surface was observed in the LC cell. The rotation of the LC director by continuous illumination of a linearly polarized pump parallel to the average molecular axis of azobenzene chromophores was measured. The polarization grating was formed at the spot exposed to the S and P polarization pair, and the grating was illuminated only by the S polarized pump beam. Subsequent switching processes of the polarization of this single pump beam were performed from the $S(P)$ polarization to the $P(S)$ polarization. Two pump beams were incident with a relative angle of 7°. The first-order diffraction efficiency of the probe beam was measured during the illumination of a single pump beam or two pump beams.

RESULTS AND DISCUSSION

In our configuration, when the cell was initially assembled, some degree of the orientational order of the LC molecules was present at area by area on the SCCP layer. The average molecular axis of azobenzene chromophores of SCCP was determined from the initial LC director. The azobenzene chromophores of SCCP with some orientational order in the LC cell are more dichroic than the case of an isotropic bare SCCP which is not included into the LC cell but just coated on the glass substrate. This results in a large absorption difference depending on the polarization state of the pump beam. When a linearly polarized pump beam passes through the azo polymer layer, the transmitted intensity significantly decreases depending on the light polarization and the initial specific orientation of azobenzene chromophores.

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It is known that the LC director in the cell with the azo polymer surface can be rotated due to an optical torque exerted by the azobenzene chromophores present on the light-controlled surface[7]. Our experiment shows that such rotation also occurs. As the pump polarization parallel to the average molecular axis of azobenzene chromophores is incident, the transmitted linear polarization of probe beam initially parallel to the average molecular axis of azobenzene chromophores changes into the elliptic polarization by the LC director reorientation. The magnitude of the optic axis rotation is less than 45°. It may be related to the copolymer interactions in our system. Note that the rotation angle of the average molecular axis of the pure SCCP layer not interacting with LC molecules is as large as 90° for the direction of pump polarization.

The polarization grating stands for a spatially periodic modulation of light polarization. It can be inscribed on the photoresponsive surface sensitive to the light polarization[8]. The SCCP layer with the azobenzene chromophores as side chains would be a good candidate for the polarization grating. Two orthogonal linear polarizations (OLPs) incident coherently with each other can produce the polarization grating

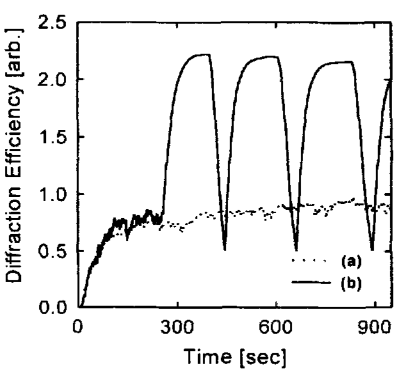

FIGURE 3 First-order diffraction efficiency of the probe beam: (a) Two-beam illumination by the S and P polarization pair. (b) A single pump beam illumination after initial two-beam illumination.

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on the layer. Specifically, once both the *S* and the *P* polarizations to the plane of incidence are used, there is no intensity modulation. The possibilities of surface relief grating or photorefractive effect will be then eliminated.

Figure 3 shows the difference between two-beam grating process and one beam control process in grating efficiency. Figure 3(a) is the case of general polarization grating by two-beam illumination. Such polarization grating formed by two beams is very similar to that observed by other researchers[9]. The grating efficiency saturates at a certain illuminating time. In contrast to the above situation, as in Figure 3(b), two-beam illumination initially sets the polarization grating, and successive polarization switching processes of a single pump beam from the *S*(*P*) polarization to the *P*(*S*) polarization change the grating efficiency. The grating efficiency by a single beam case is higher than that of two-beam illumination.

Before two-beam illumination, we first adjust the average molecular axis of azobenzene chromophores to lie along the *S* polarization of the pump beam. The average molecular axis can be determined from the dichroic ratio for the *S* and the *P* pump polarizations. Each absorption measurement was performed upon alternating instantaneous shots of the *S* and the *P* polarizations. The *S* polarization parallel to the azobenzene chromophores acts a higher optical torque on the azobenzene chromophores than the *P* polarization. That is, if the *S* polarized pump beam is incident, the LC director rotation becomes large.

Two OLPs with the *S* and *P* polarization pair are incident onto the azo polymer surface in the LC cell. These pump beams initially make the polarization grating on the SCCP layer. Figure 4 shows the mechanism for the generation of the polarization modulation pattern. After the grating is formed to some extent, we block the *P* polarized pump beam. The illumination of only the *S* polarized pump beam results in more enhanced grating since the *S* polarization spurs up the LC director rotation toward the preferred direction during two beam illumination. These processes are explained in Figure 4. Once we

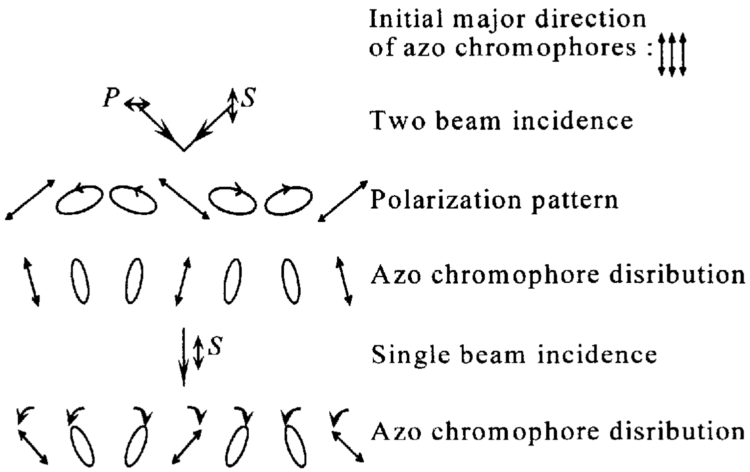

FIGURE 4 Polarization pattern of pump beams and induced azobenzene chromophore rotation patterns. Upon a single beam illumination, the optical torque becomes large along the preferred direction. The single beam process is independent of the incident direction. It just depends on the state of pump polarization.

convert the state of the *S* polarized pump to the *P* polarization by the polarizer rotation maintaining the same power with the variable attenuator, the grating is reduced because the *P* polarization induces the LC director to the initial undistorted direction.

As mentioned before, it should be noted that the optic axis rotation in the cell is at most 45° by the interaction between LC and SCCP. This enables the control of grating efficiency by only a single pump beam. In contrast, the grating on the bare SCCP layer containing no LC molecules will not be enhanced by only a single pump beam.

CONCLUSION

We showed that the LC grating can be controlled by only one pump

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beam after initial grating formation by two pump beams. The mechanism for controlling the grating by a single beam was suggested. By polarization switching of the pump beam from the *S*(*P*) polarization to the *P*(*S*) polarization, the grating effect increases or decreases. In a single beam case, this process can occur only when the LC director rotation is at most 45°. One beam controllable grating in the LC cell with the azo polymer surface would give numerous applications for optical data storage and optical signal processing.

Acknowledgments
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