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Optically addressed holographic gratings in LC cells with different layers and high optical anisotropy liquid crystals

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Dynamic optical data storage and other applications in the field of optical data processing would be possible due to development of suitable nonlinear optical materials. In this paper, we present experimental investigations of an orientation photorefractive effect in nematic liquid crystal mixtures with different optical anisotropy and various layers of cell.

Keywords: dynamic holography, optical light modulator.

1. Introduction

Nematic liquid crystals (NLC) can be used as media for different optical applications [1]. In our previous investigations, the liquid crystal mixtures were chosen among isothiocyanate mixtures, for which the obtained diffraction efficiency results were relatively good. Dynamic optical data storage and other applications in the field of optical data processing would be enabled by the development of suitable nonlinear optical materials. Large dielectric and optical anisotropies have made nematic liquid crystals a very attractive class of materials for a wide range of applications [2–4]. One of possible methods is the dynamic holography. Our experiments were concentrated on this type of application. Grating properties also depend on liquid crystal parameters and cell construction [5]. The mechanism of grating recording in thin liquid crystal cells with different LC mixtures and layers is not complete and understandable. There are minimum two possible mechanisms which are responsible for grating formation in the LC cell, bulk and/or surface [6]. In this paper, we attempt to give an answer to the question which mechanism plays a major role in orientation photorefractive effect in NLC for the cells with different orientation layers and coatings.

According to the theory, one of the important elements of LC mixture, which can give increasing diffraction efficiency, is an optical anisotropy. In this experiment, the diffraction gratings were written in LC cells containing LC mixtures with different optical anisotropies: Δn = 0.35–0.6 at the temperature 25°C.

2. Experiment

The basic (writing/reading) LC cell parameters were tested in the DWTM setup [6]. The DWTM setup consisted of 632.8 nm laser, laser power meter, and oscilloscope (Fig. 1). LC cell was put on a rotational holder which made possible to measure the dependence between the projected beams. Using that simple setup, static and dynamic measurements of the LC cells were done.

The cells with different orientation layers: rubbed polyimide, without and with SiO_2 as a protection layer (50–100 nm), and ITO and photo-oriented surface fluorinated-polyvinyl-cinnamate (PVCN+F) were used [8]. LC cells containing pure nematic liquid crystal mixtures with

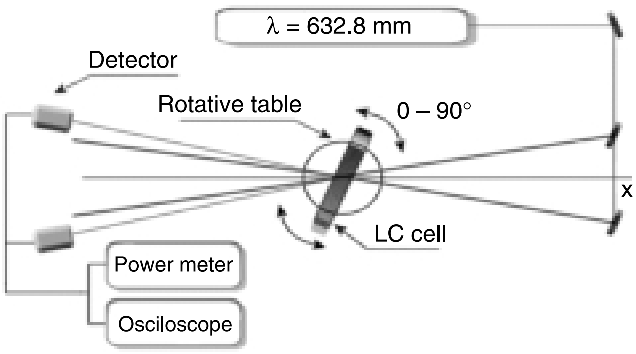

Fig. 1. Experimental setup.

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high optical anisotropy (Δn = 0.35–0.6) were investigated. LC cells had a gomogeneusly planar, twist, and homeotropic orientation. The cells' thicknesses were 6–8 μm. For this kind of a cell thickness and period, the Raman-Nath regime was fulfilled.

3. Results

All the cells filled with LC mixtures were tested in DWTM setup. For every experiment (each cell), the maximum diffraction efficiency and voltage applied to obtain that efficiency were chosen. LC cell was put in constant two interfered beams perpendicular to the cell (λ = 632.8 nm, "P" type polarization) and the diffraction efficiency was examined for different applied DC voltages. We obtained different diffraction efficiency values for different orientations of the LC cell layers for liquid crystal with Δn = 0.35 (Fig. 2). In the case of ITO orientation surface, a homeotropic NLC orientation was obtained. Therefore, geometry experiment for the cells with ITO substrates was different from the cells with a planar orientation. LC cells were set normally to a writing/reading beam in the case of a planar orientation but at the angle 45° for the cells with a homeotropic orientation [8].

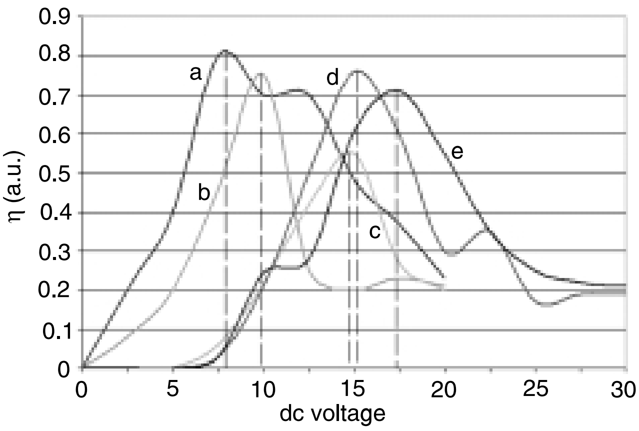

Fig. 2. Dependence of diffraction efficiency on dc voltage value for different orientation layers and LC with Δn = 0.35: (a) ITO, (b) ITO+orientation layer, (c) ITO+PVCN+F, (d) ITO+SiO_2 (50 μm) + orientation layer, and (e) ITO+SiO_2 (100 μm) + orientation layer.

Dependence of the first order intensity of diffraction on a grating period and cell rotation angle respectively, by optimal dc voltage value for different LC cells, orientation and Δn were measured. The results are presented in Fig 3. We noticed that diffraction efficiency has maximum value when the cell is rotated about 45 degrees from its perpendicular position to the X axis.

In the case of a homeotropic orientation of the LC (ITO surface), the change of diffraction efficiency was observed as a response to the change of the electric field polarization (Fig. 4).

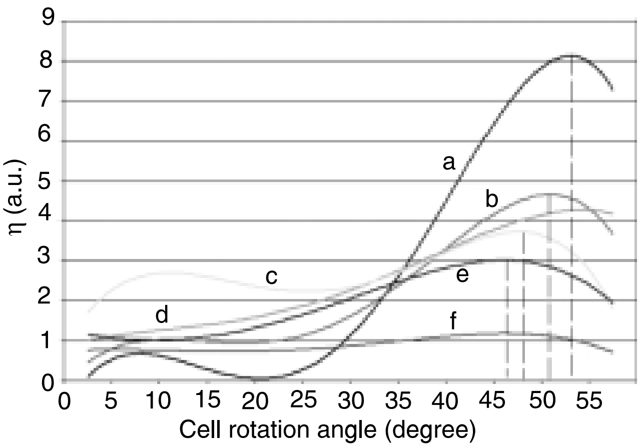

Fig. 3. Dependence of diffraction efficiency and period diffraction grating on cell rotation angle for different LCs parameters: (a) ITO, (b) ITO + orientation layer (Δn = 0.4), (c) ITO+SiO_2 (100 μm) + orientation layer, (d) ITO + orientation layer, (e) ITO + orientation layer (Δn = 0.6), and (f) ITO + SiO_2 (50 μm) + orientation layer.

Electric dc voltage (7.5 V), by being applied to LC cell, changed the polarization of electric field thorough LC cell. The obtained results show that the dependence of diffraction efficiency on time measure has an asymmetrical distribution and the type of LC cell switching on. Also, the decreasing of zero order intensity diffraction during the measured time (blue color) was investigated. These effects evidently gear to "swapping" energy.

Experimental data are presented in Figs. 5 and 6, where we can see a curve of photocurrent and speed writing/reading diffraction grating for the cell thickness 8 μm, filled LC with Δn = 0.35, and homeotropic orientation in the cell.

At the beginning of the experiments, LC cell was put in the constant two interfered beams and the diffraction efficiency was measured for different dc applied voltage. As it had been previously expected, a mixture with the highest

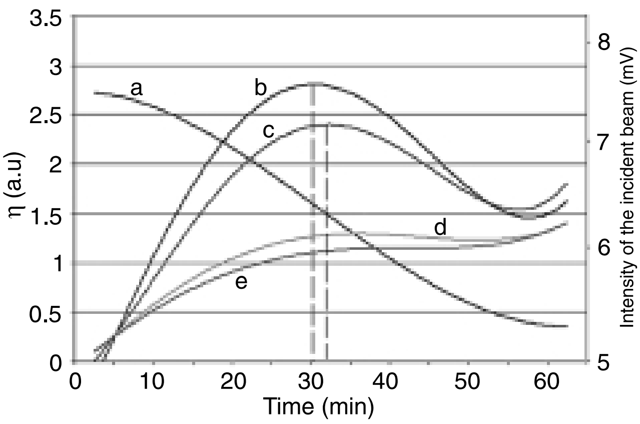

Fig. 4. Dependence of incident writing beam and first order diffraction efficiency as a function of different value DC electric field for LC cell with homeotropic orientation: (a) I_o intensity, (b) applied voltage polarisation (– +), (c) applied voltage polarization (+ –), (d) applied voltage polarization (– +), and (e) applied voltage polarization (+ –).

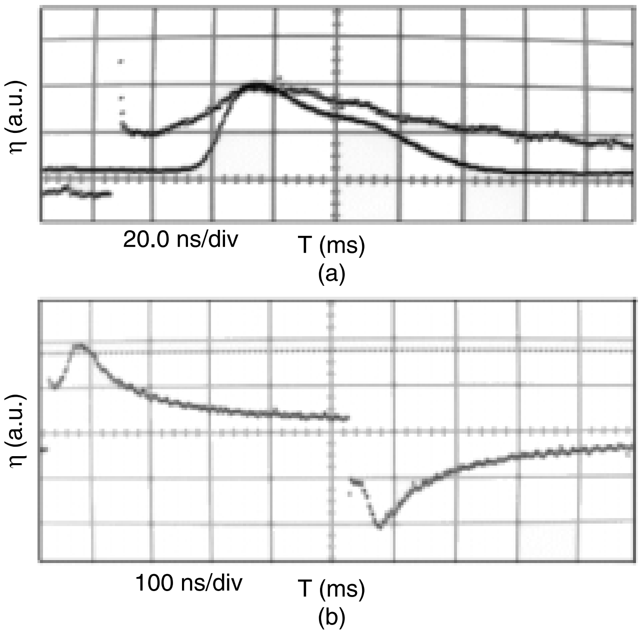

Fig. 5. Dependence of the photocurrent (a) and the first order of the diffraction (b).

Δn was the most effective in our experiment. The maximal diffraction efficiency obtained for each mixture is shown in Fig. 7.

The measured dynamic characteristics of the mixtures with different n were divided into two important groups. The grating building time is very essential for applications. The most effective dynamic diffraction efficiency (using AC sinusoidal power supply) was obtained for the same mixture as in the static experiments. The worst dynamic parameters were observed for the mixture with Δn = 0.4.

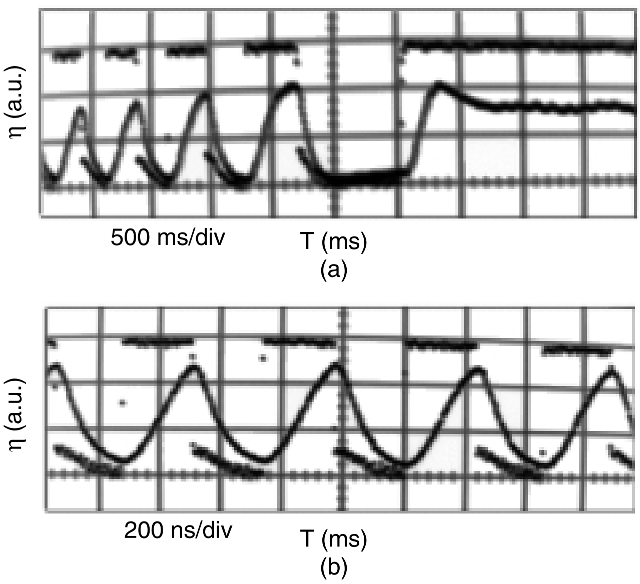

Fig. 6. Dependence of writing (a) and reading (b) diffraction grating for homeotropic LC cell.

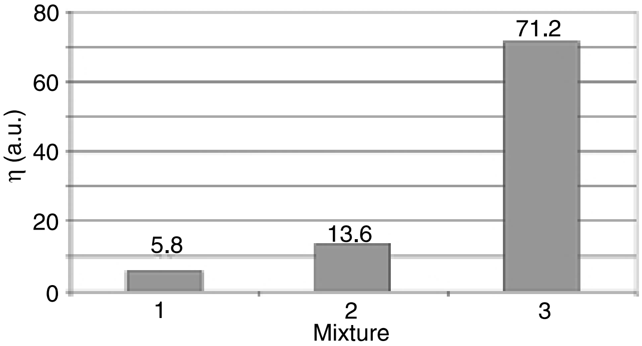

Fig. 7. Diffraction efficiency for LC cells containing mixtures with different optical anisotropy: 1 – $\Delta n = 0.35$, 2 – $\Delta n = 0.4$, 3 – $\Delta n = 0.6$.

4. Conclusions

1. The dependence of diffraction efficiency on different types of orientation surface was obtained. The maximum diffraction efficiency changes were caused by the condition changes of charge generation and distribution in the LC cell. For the cells without layer, the maximum was obtained for the lower external dc field values.
2. Our experiments showed also that diffraction efficiency can be increased by the rotation of LC cell. Experiments showed that this effect is independent of the direction of LC layer orientation in LC cell.
3. Asymmetrical distribution of diffraction efficiency for LC cell with homeotropic orientation by switching on electric field polarization was obtained.
4. As it had been expected, the refractive optical index of liquid crystal mixture extremely increases the diffraction efficiency. The tested cells with LC mixtures with high refractive optical index also showed that the time of response times of liquid crystals for external optical field does not correspond with optical anisotropy.

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References

1. A. Miniewicz, J. Parka, S. Bartkiewicz, and A. Januszko, "Liquid crystals as materials for real time holography", *Pure and Appl. Opt.* **7**, 179–189 (1998).
2. I.C. Khoo, *Liquid Crystals Physical Properties and Nonlinear Optical Phenomena*, J. Wiley, New York, 1995.
3. T. Grudniewski, M. Sutkowski, J. Parka, and A. Miniewicz, "The digital holograms projected in LC cells", *Bulletin MUT* **51**(1), 112–131 (2002).

4. G.P. Wiederrecht, M.R. Wasilewski, T. Galili, and H. Levenon, “Charge transfer reactions in nematic liquid crystals”, *Proc. SPIE* **3475**, 102–110 (1998).
5. K. Komorowska, A. Miniewicz, and J. Parka, “Holographic grating recording in large area photoconducting liquid crystal panels”, *Synthetic Metals* **109**, 189–193 (2000).
6. J. Parka, A. Miniewicz, A. Januszko, Yu. Reznikov, R. Dąbrowski, and Z. Stolarz, “Influence of nematic liquid crystal with dye and cell construction parameters on dynamic holographic grating formation”, *Proc. SPIE* **4147**, 355–399 (2000).
7. J. Zhang, V. Ostroverkhov, K.D. Singer, V. Reshetniak, and Yu. Reznikov, “Electrically controlled surface diffraction gratings in nematic liquid crystals”, *Optics Lett.* **25**, 414–417 (2000).
8. D. Andrienko, A. Dyadyusha, Yu Kurioz., Yu Reznikov, F. Barbet, D. Bormann, M. Warenghem, and B. Khelifa, “Photoalignment of pentyl-cyanobiphenyl on the fluorinated polyvinil-cinnamates induced by UV and visible light, *Mol. Cryst. Liq. Cryst.* **329**, 219–223 (1999).
9. F. Simoni, *Nonlinear Optical Properties of Liquid Crystal*, World Scientific Co., Singapore, 1997.

