Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl17

Holographic Diffraction Grating Controlled by Means of Nematic Liquid Crystal

Simeon Sainov [a], Margarita Mazakova [a], Marga Pantcheva [a] & Dimitar Tontchev [a]

[a] Central Laboratory of Optical Storage and Processing of Information, Sofia, 1113, P.O. Box 95, Bulgaria

Version of record first published: 13 Dec 2006.

To cite this article: Simeon Sainov , Margarita Mazakova , Marga Pantcheva & Dimitar Tontchev (1987): Holographic Diffraction Grating Controlled by Means of Nematic Liquid Crystal, Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics, 152:1, 609-615

To link to this article: http://dx.doi.org/10.1080/00268948708070979

Mol. Cryst. Liq. Cryst., 1987, Vol. 152 pp. 609-615
Photocopying permitted by license only

Printed in the United States of America

HOLOGRAPHIC DIFFRACTION GRATING CONTROLLED BY MEANS OF NEMATIC LIQUID CRYSTAL

SIMEON SAINOV, MARGARITA MAZAKOVA, MARGA PANTCHEVA, DIMITAR TONTCHEV
Central Laboratory of Optical Storage and Processing of Information, Sofia 1113, P.O. Box 95, Bulgaria

Abstract Results are reported on the investigations on an electrically controlled phase holographic grating. It has a nearly sinusoidal profile with 1,4 μm deep grooves spaced at 12,5 μm. The control voltage applied to the nematic liquid crystal has an amplitude of 0-25 V and frequency 1-10 kHz. A light beam from a He-Ne laser (0,633 μm) with a polarization parallel, perpendicular and at 45° to the grooves of the grating is used.

INTRODUCTION

Diffraction grating structures are used successfully for studying various physical properties of liquid crystals. Thus, Strigazzi[1] at al. has studied the behaviour of the permeability of a periodically grooved cell full of nematic liquid crystal (NLC). In his thesis Marcerou[2] measures the light diffracted from a grating with interdigital electrodes in order to investigate the flexoelectric properties of NLC. Electrooptic diffraction devices are used for modulating laser beams.[3-6] If an electric voltage is applied to a system of plane electrodes on a liquid crystal

cell, a phase diffraction grating is obtained which changes the angle of propagation of an incoming beam.[7]

Of practical importance is a similar device which does not change the diffraction angle, but controls the intensity of the diffracted light in different orders. A plane phase grating that produces many orders of diffracted light is most appropriate for this purpose.

BASIC PRINCIPLES AND EXPERIMENTS

The device used in our experiments is presented

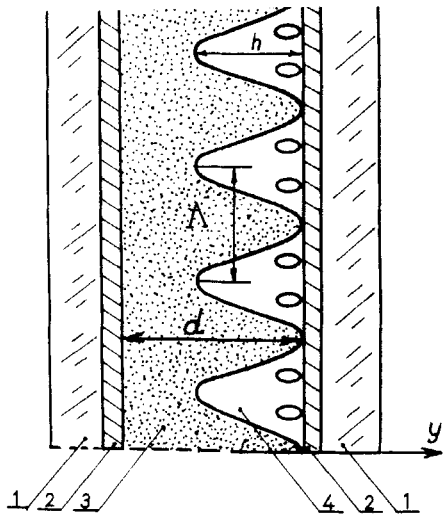


FIGURE 1. Diffraction grating on the basis of a liquid crystal cell: 1 - glass substrate; 2 - transparent electrodes; 3 - relief phase diffraction grating; 4 - liquid crystal

schematically in Figure 1. The phase holographic grating with a nearly sinusoidal profile is coated on one of the transparent electrodes of a li-

quid crystal cell. The liquid crystal fills the volume between the grooves with depth h and the second transparent electrode on whose surface it is homeotropically oriented. According to Ref.8, the additional phase difference between the ordinary and extraordinary beam, passing orthogonally through the liquid crystal layer, is given by the relatioship

$$\Delta\phi = \frac{2\pi}{\lambda}\left(-hn_o + \int_0^h n\,dy\right) \qquad (1)$$

where

$$n^{-2} = n_e^{-2}\sin^2\varphi + n_o^{-2}\cos^2\varphi$$

This additional phase difference which depends on the magnitude of the applied voltage dictates the change in the diffraction efficiency η of the grating. The diffraction efficiency is the ratio between the intensity of the diffracted light in the k-th order and the intensity of the incident beam and is determined by the second power of Bessel's function of first kind:[3]

$$\eta = \frac{I_\kappa}{I_o} = J_\kappa^2(\phi) \qquad (2)$$

where $\phi = \frac{2\pi}{\lambda}\Delta n\,h$, and Δn is the modulation of the refractive index n_g of the material of the grating relief:

$$\Delta n = n_g - 1 \qquad (3)$$

In order to obtain maximal additional phase modulation, it is necessary that one of the refractive indices coincide with that of the record-

ing medium. Since at $\lambda = 0{,}633\,\mu m$ MBBA has $n_o = 1{,}545$ and $n_e = 1{,}755$, an appropriate recording material is dichromated gelatin with $n_g = 1{,}55$. The layer is produced by coating a light-sensitive solution (low-molecular gelatin, ammonium dichromate and electron-donor substance, e.g. NN'-dimethylformamide) onto the transparent electrode. NN'-dimethylformamide improves considerably the sensitivity of the layer.[9] A surfactant is added to enhance the homogeneity of the layer. After drying at $20 \pm 1\,^{\circ}C$ the thickness of the layer is $20\,\mu m$.

The holographic grating is recorded with an Ar laser at $\lambda = 0{,}488$ m utilizing a Fresnel mirror. The depth ($h = 1{,}4\,\mu m$) of the profile after processing of the exposed layer is measured with a Taylor-Hobson Talystep profilometer.

An orienting layer of lecytin is deposited on the second transparent electrode and then the electrode is pressed firmly to the diffraction grating.

The laser beam falls orthogonally onto the NLC cell, its polarization being parallel, perpendicular and at 45° to the grooves of the grating. An alternating voltage with an amplitude 0-25 V and frequency 1-10 kHz is applied to the electrodes.

Figures 2a, b and c show the normalized diffraction efficiency in the zeroth and first diffracted orders for parallel, perpendicular and 45° polarization, respectively. The diffraction efficiency depends not only on the magnitude of the applied

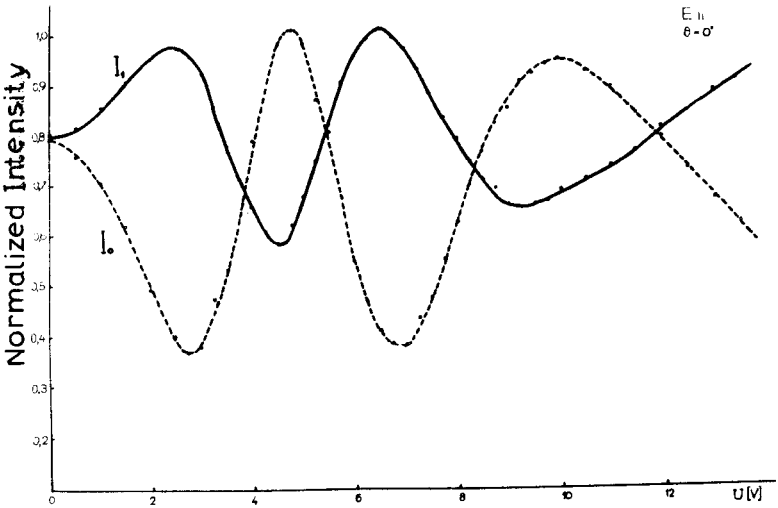


FIGURE 2-a

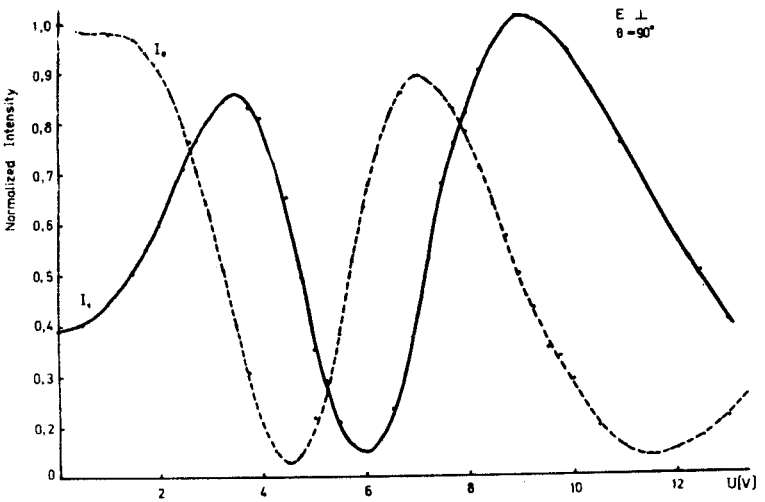
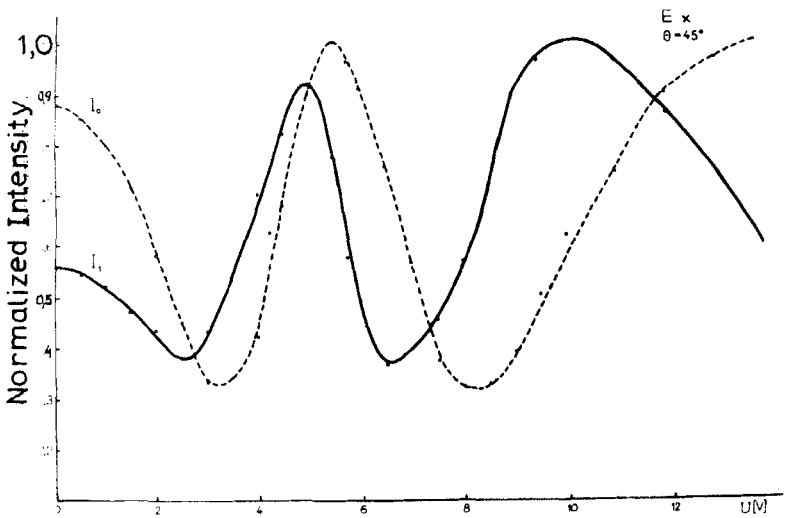


FIGURE 2-b



c

FIGURE 2. Dependence of the normalized intensity in the zeroth and first diffraction orders on the applied voltage: a - parallel polarization; b - perpendicular polarization; c - 45° polarization.

voltage, but on the laser light polarization as well. Probably, this is related to the orienting action of gelatin on the liquid crystal. Maximal modulation (90%) was obtained at perpendicular polarization.

CONCLUSIONS

The experimental results presented demonstrate the potential possibilities of diffraction gratings controlled by means of liquid crystal. Beside multichannel modulators they can be employed

for investigating the physical properties of thin NLC layers.

REFERENCES

1. A.Strigazzi et al., Mol.Cryst.Liq.Cryst., 82, 345 (1983).
2. J.P.Marcerou, Thèse l'Université de Bordeaux, (1982).
3. P.D.Lunsmann, Electron Lett., 4, 99 (1968).
4. J.M.Hammer, Appl.Phys.Lett., 18, 147 (1971).
5. M.A.R.P. de Barros and M.G.F.Wilson, Electron Lett., 7, 267 (1971).
6. M.A.R.P. de Barros and M.G.F.Wilson, Proc. IEE, 119, 807 (1972).
7. J.Borel et al., U.S.Pat. 3,843,231, Oct.22 (1974).
8. E.L.Aero, Optics and Spectroscopy (USSR), 60, 347 (1986).
9. M.Mazakova et al., Appl.Opt., 24, 2156 (1985).