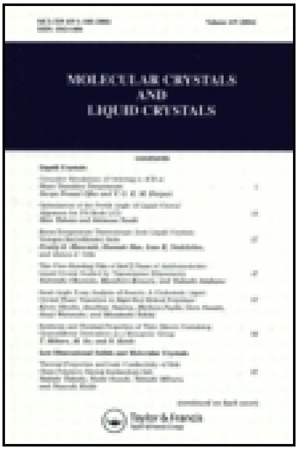

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PHOTOREFRACTIVE EFFECTS IN PURE MULTICOMPONENT ISOTHIOCYANATE LIQUID CRYSTALS UNDER LOW POWER ILLUMINATION

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In this paper the relation between the diffraction efficiency in liquid crystal mixtures and DTWM (Degenerated Two Wave Mixing) systems is described. The aim of this work is to study the most important compound of the measured before LC mixture using diffraction efficiency system under low power illumination.

Keywords: liquid crystal photorefractivity; real time holography

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INTRODUCTION

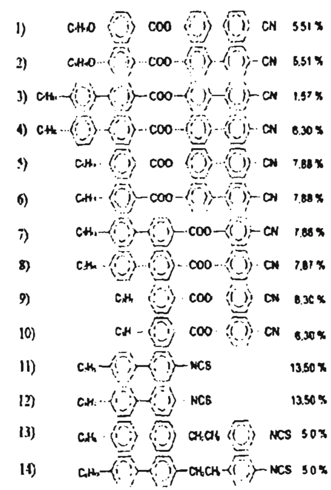
High speed and efficiency holographic data storage and other applications in the field of optical data processing would be enabled by the development of suitable nonlinear optical materials. Large dielectric and optical anisotropies have made nematic liquid crystals a very attractive class of materials for a wide range of application [1–3]. One of the possible methods is the dynamic holography and so we tried to converge our material investigations on that type of application. Our previous articles [4] were concentrated on the cell and one mixture with a photosensitive anisotropic dye combination. The experiments described in these papers were focused on the cell construction (specifically on the photosensitive layers, like PVK doped by trinitrofluorene). Obtained results were relatively good but further dynamic applications required more sensitive materials. In our previous papers we discovered that some isothiocyanate nematic liquid crystals can give very high diffraction efficiency–higher than other NLC materials [5] and NLC materials doped by dye.

In this article we present an experimental investigation of the orientation photorefractive effect in nematic liquid crystals [6]. The molecular orientation, which is described by the director, can be easily turned or modulated by externally applied dc electric or optical fields. The reorientation of the molecules can lead to a large refractive index change due to the large optical anisotropy of the liquid crystal. Our early investigations showed that the orientational optical sensitivity of liquid crystals, can be greatly enhanced by an external electric and optical applied field. The photorefractive volume space charge field is the result of charge generation in the bright regions of interference pattern and charge transportation. The dependence of the diffraction efficiency according to the multi-compound liquid crystal mixture is given. The measurements on the dependence of the diffraction efficiency on the multi-compound mixtures directed us to one selected mixture. The mixture is symboled as 1294-1b and we divided it into three parts. The most effective parts were discussed.

EXPERIMENTS

The measurements reported in this paper were preformed in 90° twisted nematic liquid crystal cells. The thickness of a nematic liquid crystal layer was 5 and 9 μm. Every part of 1294-1b was examined in a simple two-wave mixing technique using linearly s-polarized input light from He-Ne 40 Mw laser. The angle between the laser beams inciting on the sample was well matched to give a simple interference grating in Raman-Nath regime (grating spacing $\Lambda = \lambda/\sin\theta = 12\,\mu\text{m}$. The main beam and diffraction light beam

TABLE 1 Measured Mixtures

Symbol	LC mixture	Nematic range	Optical anisotropy Δn (50°C)	1294-1b
1294-1b	All Fourteen Components	3°C to 155°C	$\Delta n = 0{,}35$	
1294-1-2	Eight main Components of 1294-1b	47.2°C to 230°C	$\Delta n = 0{,}30$	
1294-1-3	1294-1-2 Mixture Plus Components Nine and Ten	26°C to 220°C	$\Delta n \sim 0{,}28$	
1294-1-1	1294-1-3 Mixture Plus Components Eleven and Twelve	22°C to 16°C	$\Delta n \sim 0{,}2$	
1437		0°C to 152°C	$\Delta n = 0{,}44$	

intensities were analyzed using two-head laser power meter (Labmaster Ultima–Coherent).

The 1294-1b liquid crystal used consists of a mixture of fourteen components. The mixture had the birefringence $\Delta n = 0.35$ and nematic range from 3°C to 155°C. The mixture 1294-1b as a holographic medium was discussed [5]. The mixture was then divided into three parts. Every one contained some amount of the 1294-1b and had characteristic properties as showed in Table 1.

We also tested the new mixture with birefringence $\Delta n = 0.4$ for comparison to 1294-1b. The remaining two 13 and 14 ingredients of the 1294-1b mixture had influence only in the scope of nematic range, and decreased it to 3°C.

To conclude the characteristic parameters of the mixtures, we chose a common temperature ($T = 50$°C) for all three mixtures included in 1294-1b, and then we tested the Δn parameter.

To measure the diffraction efficiency in characteristic nematic range temperatures DWTM two wave mixing setup was built inside a chamber (Fig. 1). That chamber allowed us to change environmental temperature in range from −20°C to 90°C (for example in the nematic range).

All three mixtures become liquid when their temperature is above 22°C, but we tested the mixtures in the whole range of temperatures attainable in the chamber. Every experiment started from room temperature, which is about 20°C. The possibility of slow heating of the chamber allowed us to observe three interesting aspects: the transition temperature, the moment when the diffraction spot appeared and the entire grating diffraction process until its end. To get rid of the influence of temperature on the silicon

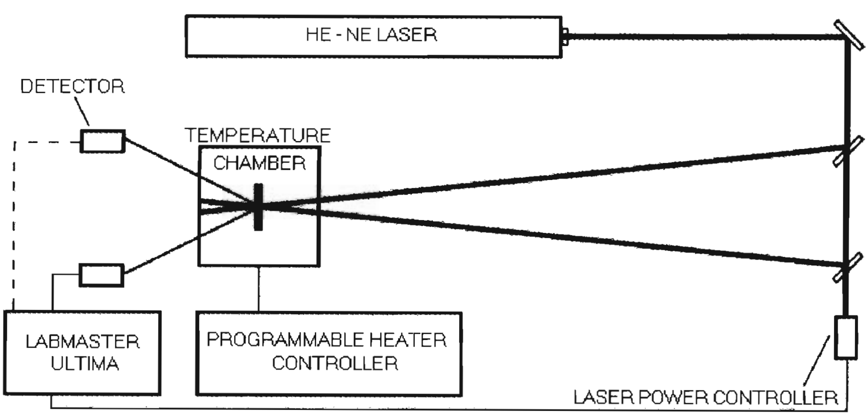


FIGURE 1 Measurement setup.

detectors, we placed them beyond the chamber. Only the diffracted beam was taken out from the chamber. As the diffraction levels were sometimes very low, the accurate laser power detector was needed. We also measured 1294-1b doped with dichroic dye ($\lambda_{max} = 550\,\text{nm}$) in temperature domain using Beckmann spectrophotometer combined with a controlled heater. The aim of that experiment was examining the influence of the order parameter S on the diffraction efficiency η (using $A_\perp$ and $A_\parallel$ measurements).

RESULTS AND DISCUSSION

The first tested mixture was 1294-1-2. We began an experiment from 20°C. After the temperature transformation phase, we observed that the solid crystal scattering was ended. In that place the diffraction efficiency beam appeared (20 μW). The temperature was slowly risen, we noticed that the diffraction beam falls down, as shown in Figure 2. Later on, we increased the temperature to maximum (80–90°C) and measured how the diffraction falls. An interesting process was observed, when we wanted to change the cell with liquid crystal, we had to decrease the temperature inside the chamber. The chamber was equipped with a cooling system based on dry ice (frozen CO_2 sunk in alcohol). That type of cooling makes it possible to reduce the temperature inside the chamber in a short time. We could decrease the temperature to -10°C in a few seconds. That type of decrease evidently supports the diffraction efficiency effect (overfrozen). The diffraction efficiency rises up to 70–120 μW between 10–10°C (Fig. 3). That effect was very unstable. The time of existence of the high energy diffraction beam was very short and appeared only when the gradient of the temperature was observed in the chamber.

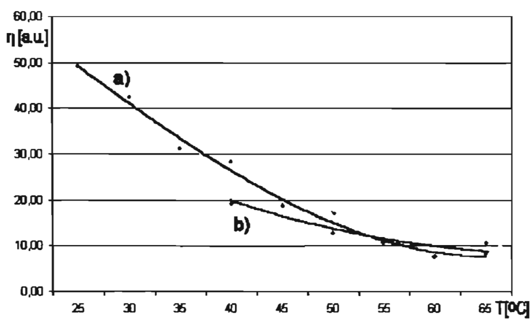


FIGURE 2 The diffraction efficiency vs. temperature: a) mixture 1294-1-3, b) mixture 1294-1-2.

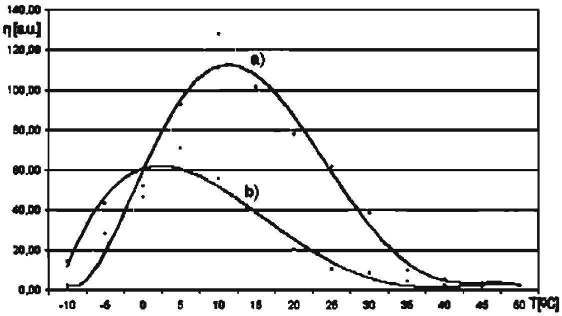


FIGURE 3 The diffraction efficiency vs. temperature: a) mixture 1294-1-3, b) mixture 1294-1-2.

The same experiments were done for 1294-1-2 mixture. Characteristic shapes of the diffraction efficiency were similar to the 1294-1-3, but diffraction was less about 50%. The characteristic shapes are shown on Figures 2 and 3.

The worst parameters of our experimental mixtures has the 1294-1-1, even through that mixture nematic range starts in 22°C. We did not observe the diffraction efficiency beam in all reasonable temperatures. That effect is much stronger because 1294-1-1 includes 1294-1-2 and 1294-1-3. Probably the last two components added have influence on our process. The experiments and the characteristics showed that temperature requirements in our experiments extract to check the whole range of temperature. We supposed that diffraction efficiency is limited from below, by the nematic range temperature in liquid crystal mixture. As the characteristics show our suspicions were true. The diffraction efficiency starts in transformation temperature for each mixture.

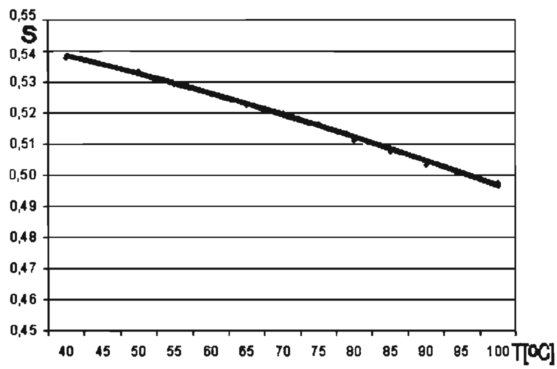


FIGURE 4 Profile of the order parameter S_D vs. temperature.

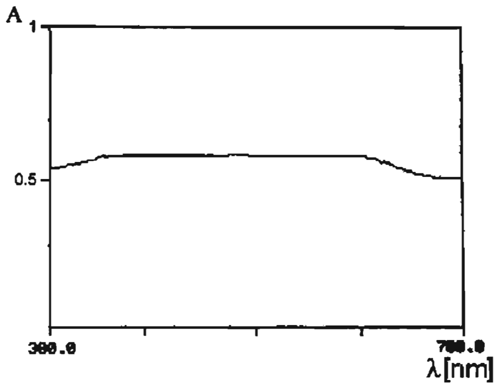


FIGURE 5 The absorption spectra for mixture 1294-1b.

The diffraction efficiency decreases when temperature is increased. We interpreted it as a decrease of an dye order parameter $S_D = (A_\parallel - A_\perp)/(A_\parallel + 2A_\perp)$, therefore we checked it in spectrophotometer (Fig. 4). Meantime we checked chromaticity co-ordinates using Prema spectrophotometer. As we mentioned [5] the 1294-1b starts to be yellow under illumination and gratings were most successfully written by red laser beam. We were very interested in absorption spectrum, then we tested that mixture and another one to compare the absorption (Fig. 5). The promising results were obtained for mixture with $\Delta n = 0.4$. The same group of components also makes it little yellow. We suspected that a larger Δn parameters should be very interesting from the holographic application point of view. First experiments of the mixture showed that the diffraction efficiency rises about two times in comparison to 1294-1b.

CONCLUSIONS

1. The characteristic spectra of the mixture 1294-1b show wide band changes which can be observed about 700–780 nm. Absorption spectra which is shown in Figure 4. suggests that charge transfer effect in the investigated isothiocyanate nematic mixture exists.
2. The order parameter S_D was slowly changed with temperature and probably has less influence on the diffraction efficiency than we previously expected.
3. The components which are added to 1294-1-2 (to obtain 1294-1-3) decreases viscosity and optical anisotropy. In this case decreasing of the viscosity probably has a positive influence on the diffraction efficiency which was expected.

4. As we predicted, the mixture with larger optical anisotropy ($\Delta n = 0.4$) is much more adequate for holography (dynamic holography application). The same power of the illuminated beam gives larger diffraction efficiency (that means better quality of the reconstructed hologram).

REFERENCES

[1] Komorowska ,K., Miniewicz, A., & Parka, J. (2000). Holographic grating recording in large area photoconducting liquid crystal panels. *Synthetic Metals*, *109*, pp. 189–193.
[2] Hara, T., Fukuchi, N., Kobayashi, Y., Yoshida, N., & Igasaki, Y. *Electrically addressed spatial light phase modulator*.
[3] Miniewicz, A., Parka, J., Bartkiewicz, S., & Januszko, A. (1998). Liquid crystals as materials for real tiem holography. *Pure and Appl. Opt.*, *7*(2), pp. 179–189.
[4] Grudniewski, T., Sutkowski M., Parka, J., & Miniewicz, A. (2002). *The digital holograms projected onto LC cells, Bulletin WAT*, Vol. *LI*, No 01.
[5] Grudniewski, T., Parka, J., Dąbrowski, R., Januszko, A., & Miniewicz, A. (2002). *Investigate of the diffraction efficiency in dye-doped LC cells under low frequency AC voltage*, Opto-Electronics Review, Vol. *X*, No 01, pp. 11–15.
[6] Agashkov, A., Parka, J., Serak, S., & Davidovich, T. (2000). *Space charge distribution in anthraquinone dyes doped nematic cells under optical and electrical fields*, 8 International Nonlinear Optic Conference, Crimea, Proc. of SPIE.