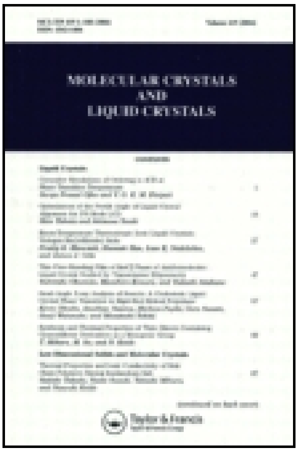

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Optical Memory Based on Azo-Dye-Doped Nematic Liquid Crystals

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In this work the dynamic of formation of permanent holographic grating have been investigated. Also the effect of cell thickness and intensity of writing beams on the grating permanency in Azo Dye Doped Liquid Crystals (ADDLC) is studied. Homogeneously aligned pure 1294-1b liquid crystal and doped with Methyl Red (with 1% wt) are used to achieve this purpose. The results are compared with literatures, and showing the optimized properties for constructing an optical memory with high diffraction efficiency and long duration.

1. Introduction

Recently liquid crystals (LCs) and also dye doped liquid crystals (DDLCs), have attracted significant attention. This is mostly because of their large birefringence and their possible application in photonic devices such as optical switches, broad band filters and holographic devices [1, 2]. Additionally as a result of their strong surface effects in some DDLCs such as Methyl Red doped LCs, they look promising in optical memory and holographic fields [3, 4]. As it is well understood, optical data storing in this case is performed by interfering the data and reference beams on the sample, and cause to change the optical properties of material through interfering pattern, due to reorientation of LC molecules. Here, the optical data storage by light induced effects is investigated.

It is observed that in DDLC sample after illumination of cell with a proper wavelength which is in the range of dye absorption, the photoisomerization cycle of Methyl-Red molecules begins. Because of their large dipole moment and molecular shape the Cis isomer of Methyl-Red has the capability to make interaction with polymer surface of the cell (PVA) [5]. This anchoring of Cis isomers would result in the dimethylamino wings of the Cis-isomer orienting upward from the surface, and therefore stimulates the homeotropic alignment in the bright regions. In addition to former procedure after a long exposure time as adsorbed dyes to the surface increase enough, a ripple structure is also created in the direction of the exposured light polarization that changes the orientation of LC molecules [6]. Such that, the latter mentioned photoalignment effect due to hard anchoring of dye and LC molecules which keeps ripple structures permanently on the cell's surface, can be used to make a permanent optical storage.

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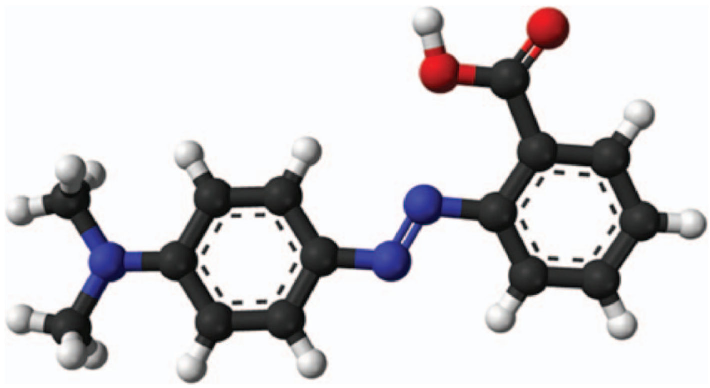

Figure 1. The trans isomer of Methyl Red.

2. Experiments

Using a Shimadzu 2450 spectrophotometer the samples thickness were measured as 20 and 50 μm. This is possible to measure the cell's thickness using ($d = \frac{k}{2n}, \frac{\lambda_2\lambda_1}{\lambda_2-\lambda_1}$), in which "d" is the cell's thickness and "k" is the number of the interference cycles between wavelengths λ_1 and λ_2 and for an empty cell $n = n_{air} = 1$ [7]. The Nematic Liquid Crystal (NLC) mixture (1294-1b) and the cells were purchased from AWAT PPW Company (Poland). The NLC mixture (1294–1b) is a high birefringence ($\Delta n = 0.318$) NLC mixture that comprises fourteen components (isothiocyanates) with a wide temperature interval of the nematic phase (3° N 155° Iso.) [8, 9]. Dye doped NLC mixtures are prepared by dissolving about 1% weight of Methyl-Red (MR) from Aldrich (Fig. 1) into the LC.

The Fig. 2 shows the experimental setup for the investigation of dynamic photoalignment in the samples. The absorption spectrum of the sample is shown in (Fig. 3).

A diode Pump Solid State (DPSS) laser with wavelength of 532 nm that exposures in the range of MR absorption with "s" polarization is used as writing beams. Also a "p" polarization He-Ne laser (1mw) as probe beam (633 nm) is used to readout the grating. Two photodiode detectors were used to eliminate the fluctuation of laser and to achieve the absolute diffraction efficiency (Fig. 2). This parameter is the criterion of grating resolution

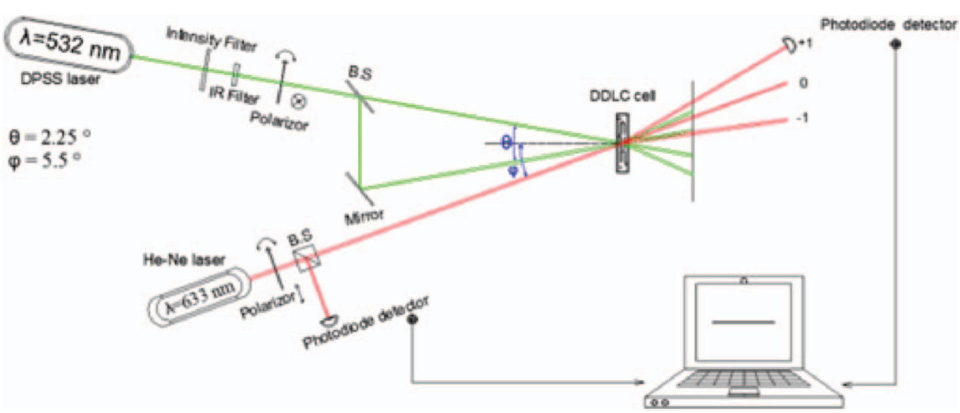

Figure 2. Experimental setup (Beam Splitter (B.S), Polarizer, Photodiode).

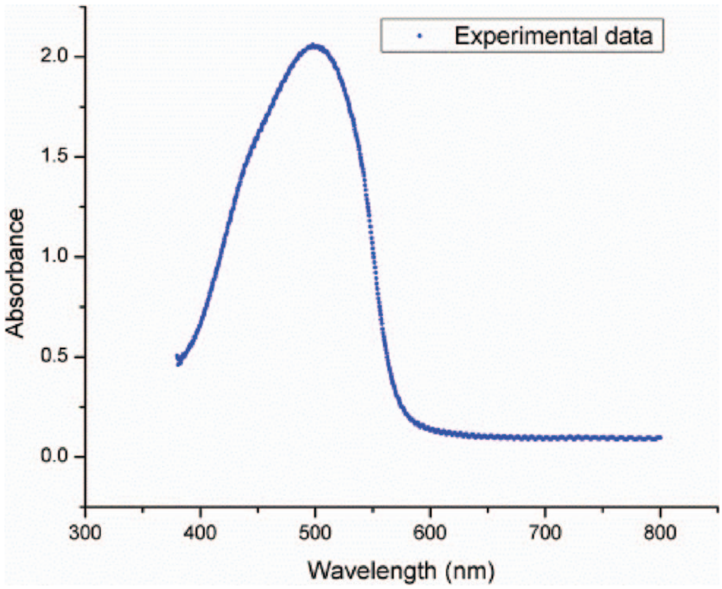

Figure 3. Absorption spectrum of the cell with thickness of 20 μm.

that is defined as: $\eta_A = \frac{I^{+1}}{I_0}$, in which I^{+1} and I_0 are intensities of first order diffracted and main incident probe beams, respectively, which have been measured by mentioned photodiodes (Fig. 2). Using this setup the dynamic behavior of grating formation and the influence of several parameters is investigated.

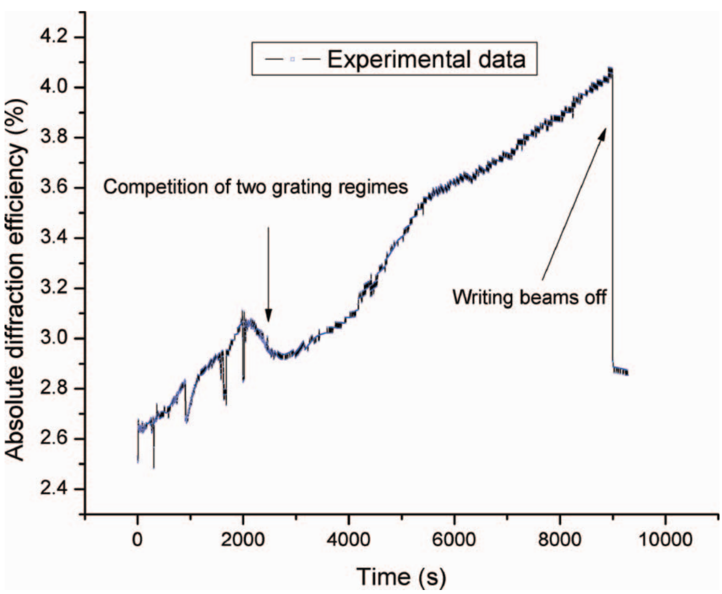

Figure 4. Absolute diffraction efficiency versus time for HG aligned cell with thickness of 20 μm and s polarization of the 17 mw/cm^2 writing beams.

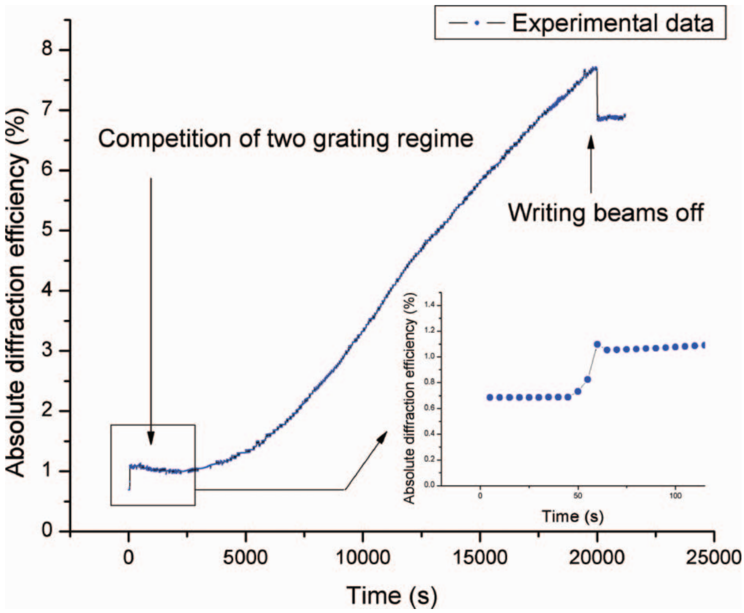

Figure 5. Absolute diffraction efficiency versus time for HG aligned cell with thickness of 50 μm and s polarization of the 17 mw/cm^2 writing beams.

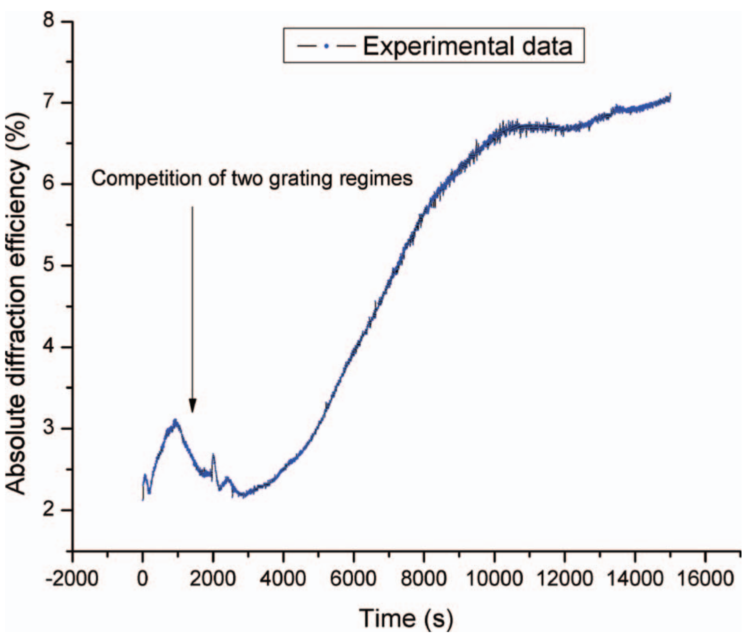

Figure 6. Absolute diffraction efficiency versus time for HG aliged cell with thickness of 50 μm and s polarization of the 55 mw/cm^2 writing beams.

3. Results and Discussion

According to the experimental setup the light induced grating in Azo Dye Doped Liquid Crystal (ADDLC) and the parameters involved in the diffraction efficiency has investigated. The dynamic behavior of the holographic gratings as shown in (Fig. 4) represents the diffraction efficiency with respect to writing time, in different conditions.

As it is mentioned before, the grating formation includes the competition of two different regimes which obviously has been shown in (Figs. 4, 5 and 6). These experimentally obtained results show that at first, a grating formation due to homeotropically aligned of LC cells in bright region, follows by the second kind of ripple structure grating.

The experimentally obtained results for 20 and 50 micron cells show that after 9000 sec illumination, the absolute diffraction efficiency of the ripple structure regime is about 1.3 and 2.5 folds of the pick of the first regime respectively (Figs. 4, 5). Also after turning off the writing beams, the diffraction efficiency shows a permanent grating in the samples, which for more illumination time in thicker one is higher.

Also in comparing the (Figs. 5 and 6) to investigate the writing beams intensity effect in the thick sample, it is clearthat after the illumination of the sample with 55 mw/cm^2 of writing beam's intensity, the absolute diffraction efficiency reaches to saturation after about 10,000 sec and it's about 7% (Fig. 6) but under 17 mw/cm^2 of light beam's intensity

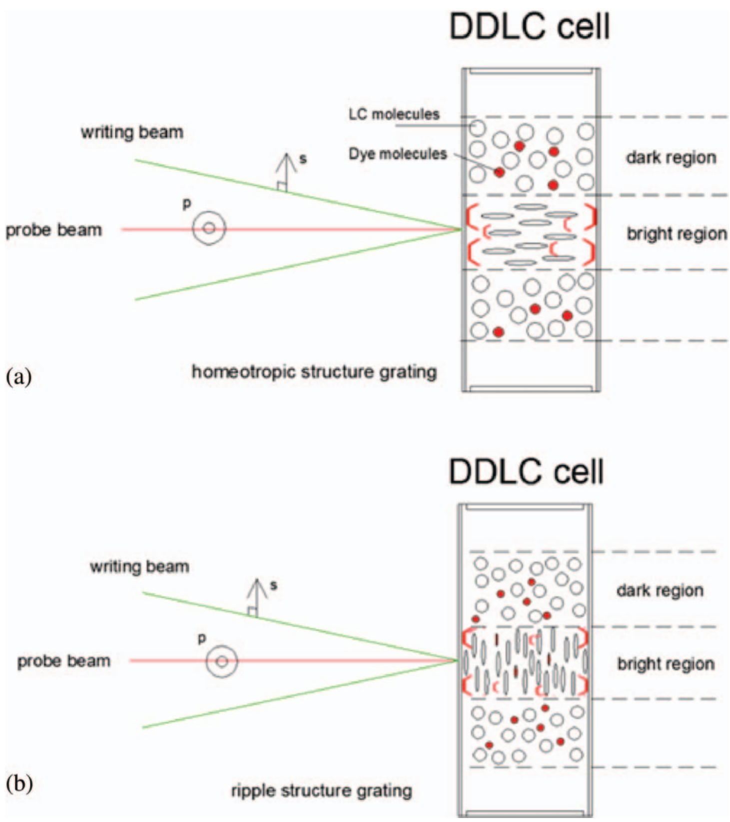

Figure 7. Initial grating (a) and ripple structure grating (b).

even after 20,000 sec the absolute diffraction efficiency is growing and has not reach to its saturation.

The gratings formed in the all cells after several weeks show their same absolute diffraction efficiency and it means that they are permanent gratings.

To explain the formation of both gratings, it has to be said that in first grating formation regime, the LC molecules change their alignment towards perpendicular to the cell surface. This reorientation can occur with small amount of dye molecules, so it is faster and results low diffraction efficiency. As time goes on, the amount of the adsorbed Cis isomers increases and because of the formation of the ripple structure the first grating decays, then the LC molecules tend to reorient in the direction of light polarization (Fig.7). This is when the second regime starts to dominate and molecular director tends to change its direction, as a result of the ripple structure which is provide stronger anchoring to the surface [6].

4. Conclusion

In this experimental work, formation of a permanent grating is investigated. The observed grating even after several weeks is explained by hard anchoring due to the adsorption of the dye (methyl red) molecules onto the surface. Methyl-Red is a photosensitive dye that enters to its isomerization cycle by absorption of light with proper wavelength. Then its cis isomers are adsorbed onto the cell's surface and induce heterogeneous alignment to LC's director. This phenomenon leads to formation of permanent grating in a rather short time, but its diffraction efficiency is low. So in order to reach higher diffraction efficiency, experimental setup shown in Fig. 2 is used, in which dye molecules have the capability of ripple structure formation in such a longer time. This ripple structure leads to the formation of the permanent grating with high diffraction efficiency (about 7.1%). Furthermore, studying the effect of sample thickness and pump beams intensity, concludes the possibility of constructing a static optical memory in industrial scales. According to these investigations it is concluded that thicker cell due to larger amount of dyes leads to stronger ripple structure formation and larger intensity of writing beams lead to faster saturation of grating.

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