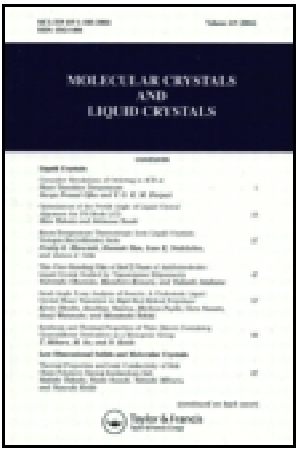

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Experimental Study of Laser-Induced Orientational Effects in Twist and Planar Aligned Azobenzene Nematic Liquid Crystals

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Laser-induced orientational effects are experimentally studied in BAAB-1005 type azobenzene NLC. Excitation of cis-form of azobenzene was induced by green laser with 0.532 μm wavelength. Nonlinearity was studied by He-Ne laser. 100 μm thick twist-aligned and planar-aligned LC-cells were used in the experiment. During the experiment occurrence of ring pattern was registered on the screen, which was formed during long time (about 10 seconds). Depending on direction of He-Ne laser polarization two types of rings were registered in case of twist-cell. This means that we have two nonlinear mechanisms. In case of planar-aligned LC cell only one type of rings was registered.

Keywords Liquid crystyals; orientational nonlinearities; thermomechanical effects; trans-cis isomerism

Introduction

Liquid crystals (LC) containing azobenzene in their molecular structure (azo LCs) [1] are very sensitive to radiation from UV to green. The phase of the azo LC can be changed by controlling the ratio of the numbers of trans and cis isomers in a sample. Cis isomers can be activated by illuminating the azo LC with radiation of UV-green region [2]. After illumination rod-shaped trans form of an azo molecule, showing anisotropic behavior, is transformed into its cis form reducing the order parameter of the medium. Azo LC's photoisomerization [3] is a reversible process and the phase of the sample can be controlled by changing the wavelength of impinging light [4–6].

Azo LCs showing unusual behavior are very interesting for practical usage. It was shown that these materials having a nonlinear refraction index comparable to that of LC's, can be effectively used for light modulation even in isotropic phase in which all the observations are independent from light polarization [2,7]. It is possible to generate "red" or azo solitons in azo LCs in microwatts power level which can be used for switchable and auto-aligning fiber coupling, as switchable polarizers, optical gates, as well beam combining [2].

In the present paper we experimentally study laser beam propagation in BAAB 1005 type azobenzene nematic liquid crystals with twist and planar-alignments and the associated light-matter nonlinear interaction.

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Experiment

Experimental setup given in Fig. 1 was used for investigation of orientational nonlinearities in BAAB 1005 liquid crystals. Excitation of cis-form of azobenzene was done by green laser with 0.53 μm wavelength. Cis-trans transition and reorientation of molecules of LC were induced by linearly-polarized He-Ne single-mode laser. He-Ne laser beam was focused on LC cell, plane of which was perpendicular to the direction of propagation of the laser beam. Radial distribution of intensity of the beam on the screen was registered by digital camera. The radiation of green laser, exciting a trans-cis transition of isomers, fell on a cell sideways under certain angle. 100 μm thick twist-aligned LC-cells were used in the experiment. Experiment was done at room temperature.

At the switched off green laser when the polarization of linearly-polarized He-Ne laser beam was adjusted parallel to the direction of director at a forward wall of twist-aligned cell, and in the absence of reorientation of LC molecules, the polarization of laser radiation rotates and on the exit of cell receives polarization, direction of which is perpendicular to primary polarization.

In the absence of irradiation by the green laser and at ~3,5 kW/cm^2 intensity of He-Ne laser no orientational effects were registered (He-Ne laser beam was focused on LC cell by lens with 2 cm focal length), i.e. the light passed through the system without change of the intensity distribution. However, at significant growth of intensity of He-Ne laser it may be possible to register orientation of molecules in the trans-form due to thermomechanical effect [8–10]. After irradiation of the cell within several seconds by widened beam of green laser (I = 15 mW/cm^2), regardless the green laser is on or switched off, occurrence of ring-pattern was registered on the screen by He-Ne laser, image of which is shown in Fig. 2(a), testifying the nonlinear interaction of radiation of He-Ne laser with LC molecules. Dependence of number of the rings on laser power in this case is given in Fig. 3.

In the experiment by rotation of the plane of the cell, the angle between polarization of He-Ne laser and direction of director at a forward wall of the cell was smoothly changed. Thus, the image observed on the screen was changed: besides the rings shown on Fig. 2(a), other rings with smaller size and higher brightness also appeared ($\alpha = 45^o$, Fig. 2b).

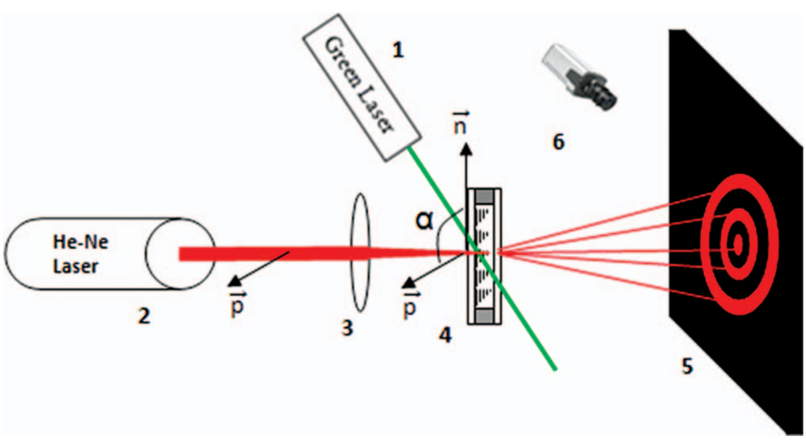

Figure 1. Experimental setup: 1) green laser, 2) He-Ne laser, 3) lens, 4) LC-cell, 5) screen, 6) digital camera.

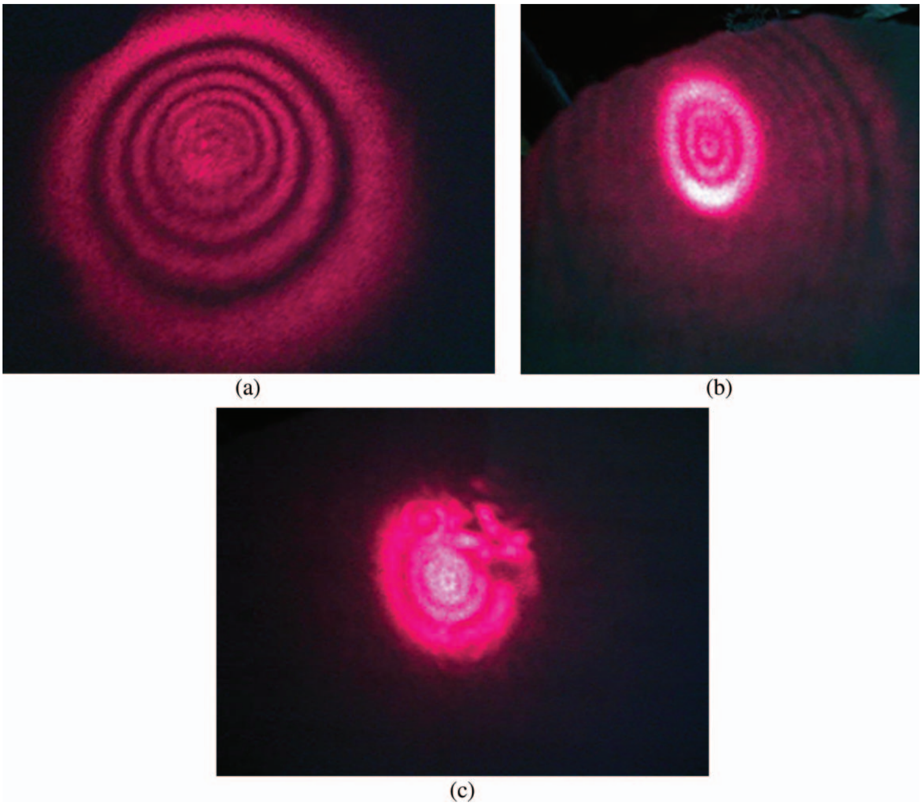

Figure 2. Image of He-Ne laser on the screen at 0° (a), 45° (b) and 90° (c) angles between laser polarization and direction of director at a front wall of the cell.

Then, at 90^0 angle between polarization of He-Ne laser and direction of director at a forward wall of the cell only second type of rings were registered on the screen (Fig. 2(c)). The experiment showed that the process is reversible when changing the angle between polarization of He-Ne laser and direction of director at a forward wall of the cell from 90^0 to 0^0.

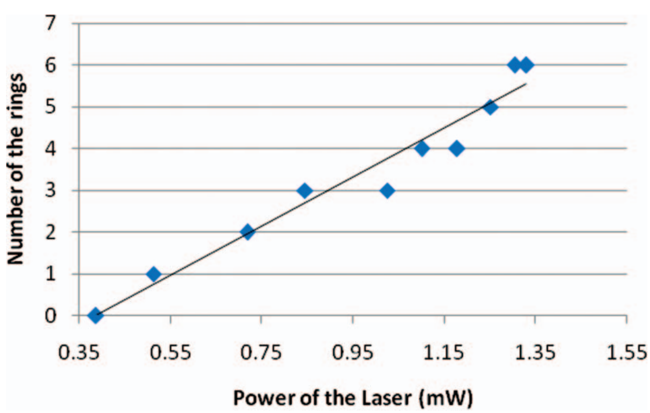

Figure 3. Dependence of number of the rings on laser power for twist aligned cell.

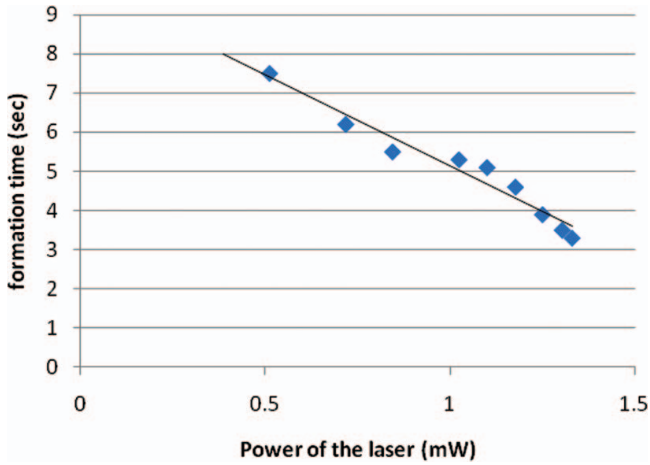

Figure 4. Dependence of stabilization time of the rings on laser power for twist aligned cell.

Unlike results presented in the article [6] we have got two ring patterns. The cause of the first one is the cis-trans transition of isomers and related change of the refractive index of the azo LC. The cause of the second pattern may be the thermomechanical effect.

Measurements of stabilization time of the rings were also implemented. The dependence of stabilization time of the rings on laser power is given in Fig. 4. However, the registered ring-patterns were formed enough slowly (several seconds) for all values of α.

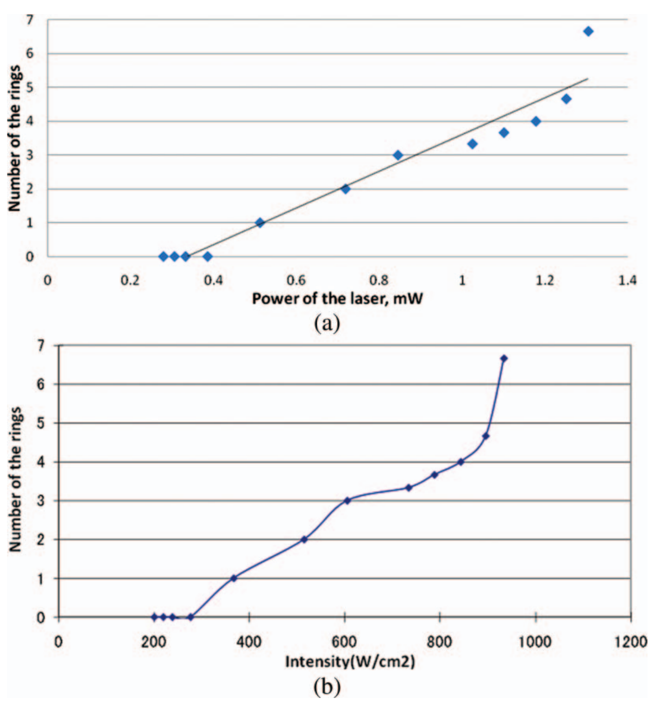

Figure 5. Dependence of number of the rings on laser power (a) and intensity (b) for planar aligned cell.

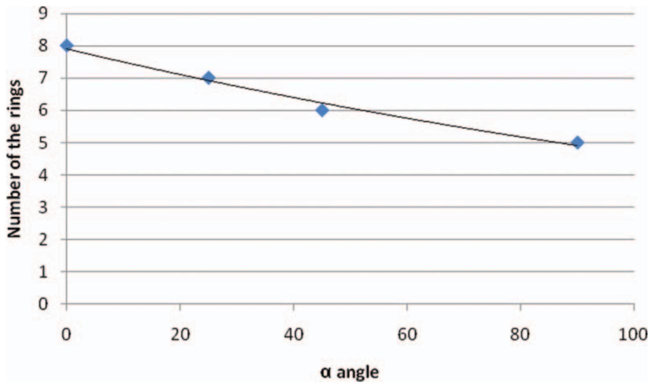

Figure 6. Dependence of number of the rings on angle (α) between laser polarization and planar cell director direction.

For registration of dynamics of reorientation of molecules at excitation of isomers in liquid crystals, at switched He-Ne laser the green laser was also switched. Before switching the green laser no change of Gaussian beam profile of He-Ne laser was registered. After switching the green laser, after several seconds, transition of the medium from trans-form to cis-form occurred, and rings started to appear on the screen.

We have also made an experiment using planar-aligned cell (with the same experimental setup, given in Fig. 1). Before irradiation with green laser no reorientation was registered. After irradiating the cell with green laser a ring pattern was registered on the screen. After keeping the cell in dark place for relaxation for more than 5 days the same effect was registered without irradiating with green laser. The dependences of ring number on laser power and intensity are given in chart form in Fig. 5. At all angles between incident light polarization and planar-cell director orientation almost same amount of rings were registered (Fig. 6). Both at normal and tilted incidence of the He-Ne laser same results were obtained.

Measurements of stabilization time of the rings for different values of laser power were also done. The results of those measurements are depicted in Fig. 7.

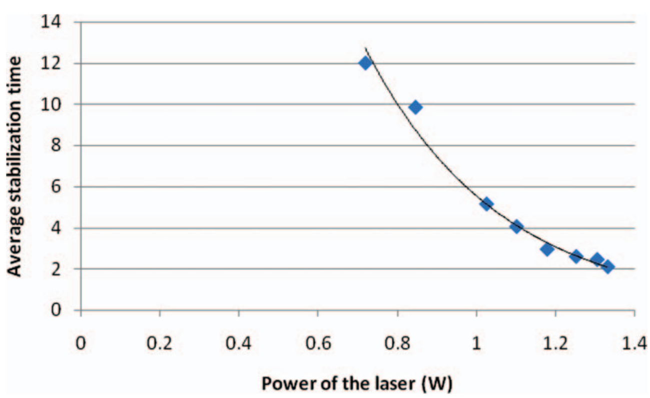

Figure 7. Dependence of reorientation stabilization time of molecules on power of the laser for planar aligned cell.

Conclusion

We can conclude that laser beam propagation in twist and planar cells of BAAB 1005 type azobenzene nematic liquid crystals results in nonlinear interaction of the light with the medium, mechanism of which is different for abovementioned two types of cells. Analyzing the ring patterns formation on the screen for different impinging light polarizations, it was shown that two orientational mechanisms are working in twist cell, whereas one type of ring pattern is obtained for the planar cell. It was concluded that one type of the ring patterns emerges due to the cis-trans transition of isomers and the cause of the second one may be the thermomechanical effect.

Acknowledgment

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