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# Magnetic field effects on the optical properties of an azo-dye doped liquid crystal

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## Abstract

Homeotropically aligned nematic liquid crystals doped with azo-dye were subjected both to a linear polarized light of a He–Ne laser and to a magnetic field perpendicular to the incident light beam. We found that the emerging light was elliptically polarized when using magnetic field strengths higher than the threshold value for the magnetic Freedericksz transition. The light transmission, the rotatory power (induced by azo-dye) and the ellipticity varied quasiperiodically when increasing magnetic field strength. The number and positions of maxima and minima depend on the cell thicknesses. Changes in the phase difference between the emergent ordinary and extraordinary rays were computed from the experimental data and the magnetic field dependence of the birefringence was determined.
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## 1. Introduction

Dye doped liquid crystal guest–host systems were intensively studied in the last years, due to their potential applications to optoelectronic devices and information processing [1–7]. When the dye contains the azo- group, the photoinduced reversible conformational transformations are very promising for reversible optical memories or photochemical switching operations. There are also many studies which investigate the phenomena occurring in such systems [8–13]. Most of these studies are focused on molecular reorientation produced by electrical or optical fields.

Still, less works were dedicated to the study of the magnetic field effects on nematic liquid crystal (NLC) doped with azo- dyes [14,15]. These effects could be important to elucidate the type of the interaction between the nematic host and the guest dye.

Unlike the electric field which is a vectorial one and induces a linear optical anisotropy, the magnetic field is an axial field and, consequently, induces a circular anisotropy [16]. Therefore, the magnetic fields acting upon such guest–host systems could produce interesting optical effects.

In this paper we investigate the magneto-optical effects in nematic liquid crystals doped with azo-dyes, when subjecting them to laser irradiation. The studies were performed with the magnetic field applied normally with respect to the optical beam propagation direction (Voigt configuration). The laser beam falls at normal incidence on the homeotropically aligned liquid crystal cells.

The paper is organized as follows. First, the experimental set-up and procedures are described. Second, experimental results referring to magnetic field effects on light transmissions, induced rotatory powers and ellipticities are shown and discussed. Finally, the plots showing the phase retardation variation as a function of the magnetic field strengths, for two different cell thicknesses, are computed from the experimental data. The maximum birefringence of the cell was determined using the extrapolation method.

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## 2. Experimental

Liquid crystal cells with 50 and 180 μm thicknesses were obtained using Mylar spacers with uniform thickness. The cells were filled by capillarity with a mixture of nematic liquid crystal (Merck MLC-6601) and a small amount (1.8% by wt) of Methyl Orange (MO) as azo-dye. The host NLC has the clearing point at 77 °C and the refractive indices $n_e = 1.5498$, $n_o = 1.4735$, $\Delta n = 0.0763$ (determined for $\lambda = 589.3$ nm at 20 °C).

Before filling the cells, the glass substrates were coated with DMOAP surfactant, in order to obtain a homeotropic alignment of the liquid crystal (the long molecular axis normal with respect to the glass substrates).

The experimental set-up is shown in Fig. 1.

A He–Ne laser beam (632.8 nm, 1 mW) falls at normal incidence on a liquid crystal cell (LC) placed in the middle of the electromagnet (E). The magnetic field direction was set to be normal with respect to the light propagation direction (Voigt configuration).

At the exit, the plane of polarization was determined by rotating a Glan–Thomson polarizer (P) to obtain the extinction of the transmitted light. The intensity of the transmitted light was recorded by means of a photomultiplier (Ph), connected at a multimeter (M).

Changes in the magnetic field strength were achieved by a DC power supply (PS) which allowed both current adjustment and change of polarity.

The current through the electromagnet was slowly increased and for each fixed value of the magnetic field the angle of rotation corresponding to maximum extinction was measured.

The intensity of the transmitted light, registered by the photomultiplier, was recorded before and after rotating the polarizer.

All measurements were performed at room temperature and the experimental procedure was identically applied for both cells with two different thicknesses.

## 3. Results and discussion

Nematic liquid crystals consist of rodlike molecules which, on the average, line up parallel to a preferential direction named molecular director. The trans isomer of the guest azo-dye has also rodlike shape. It aligns in a parallel direction with respect to the host molecules favoring the nematic order, unlike the bent shaped cis isomer which tends to disturb the nematic phase. The torques induced by the trans/cis azo-dye's isomers on the nematic molecules were intensively studied in the last years [10]. When a magnetic field is applied on guest–host mixtures, the molecules of the NLC and azo-dye receive a magnetic torque from the magnetic field and the molecular orientation will change. The NLC molecules have the tendency to orient with their long molecular axis along the magnetic field direction. The initial homeotropic alignment of the mixture molecules is disturbed (tends to change into a parallel one), except for two very thin layers in contact with the glass substrates. The equilibrium molecular orientation of the entire system depends on the balance between the magnetic, azo-dye and glass surface induced torques.

If a polarized monochromatic light beam propagates through such anisotropic medium an interference of the ordinary and extraordinary rays in the emergent light could be observed [16].

The plots showing changes in the light transmission as a function of applied magnetic field, for two cells with different thicknesses, are given in Fig. 2. In all figures from below the lines are drawn to guide eyes.

The homeotropic cells exhibit dark states for magnetic field strength below the threshold value for the magnetic Freedericksz transition, since the incident linearly polarized light behaves like an ordinary ray and experience no phase retardation [17]. Above the threshold value, the NLC directors are reoriented by the magnetic field and phase retardation between the ordinary and extraordinary rays takes place. It may be seen from Fig. 2 that the light transmission varies quasi-periodically when the magnetic field strength is increased above the threshold value. These changes are quite similar to those appearing in nematic

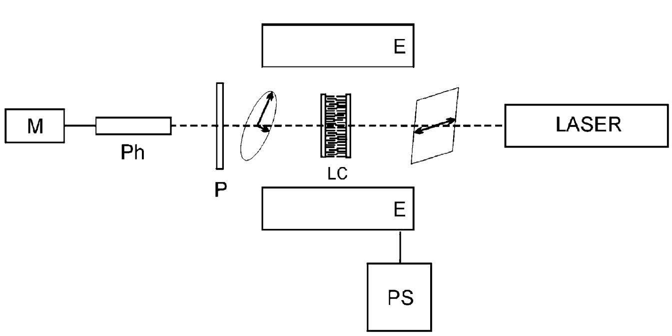


Fig. 1. Experimental set-up.

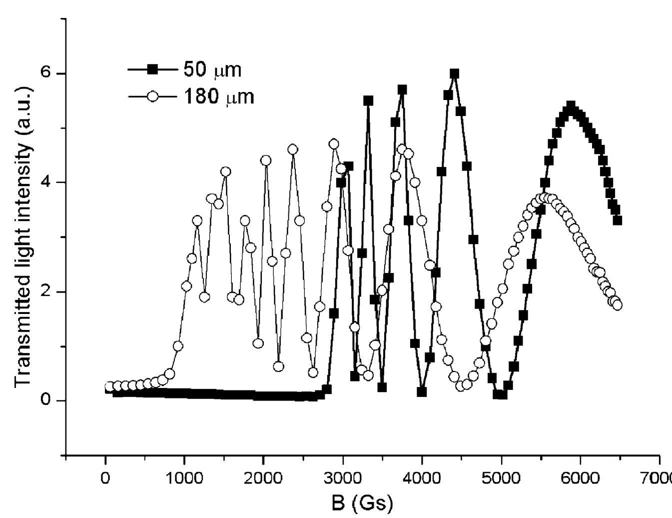


Fig. 2. The intensities of transmitted light (He–Ne, $\lambda = 632.8$ nm) as a function of the magnetic field strength, for fixed polarization angle.

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