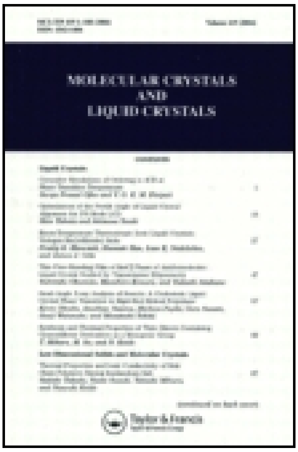

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Light-Controlled Rotation of the Light Polarization Plane in Weakly Twisted Nematics

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LIGHT-CONTROLLED ROTATION OF THE LIGHT POLARIZATION PLANE IN A WEAKLY TWISTED NEMATICS

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Abstract The effect of a light polarization plane rotation in a cell with weakly twisted nematic liquid crystal (LC) caused by phototransformation of chiral molecules has been found. Such a behavior was stimulated by trans-cis isomerization of twisting agent resulting in a strong decrease of its twisting power. Non-stimulated cholesteric spiral unwinding was observed after an exciting light had been switched off.

INTRODUCTION

It's well-known that photochemical transformations of molecules might lead to a drastic change of LC-properties.[1] In particular, a substantial photo-alteration of the twisting ability of chiral dopant in cholesteric LC results in a helix pitch change and in a shift of the Bragg selective reflection band.[2,3] The main idea of this work is that the analogous process in a weakly twisted nematic LC has to result in a rotation of light polarization plane. We present the first results of a such effect observation.

EXPERIMENTAL SETUP AND RESULTS

The induced cholesteric LC was compounded from nematic matrix (n-pentylcyanobiphenyl) and the photosensitive chiral dopant (CD) (1-ariliden-mentanone). Initial twisting ability of CD was $\beta = 30\mu m^{-1}$ and decreased practically to zero due to trans-cis isomerization around C=C-bond caused by the irradiation in UV/blue spectral region.[2] CD concentration was chosen 0.1 wt.% so that helical pitch P was 30 μm.

Cell thickness (L = 10 μm) was given by teflon strips placed between glass substrates. One plate of the cell was covered by a neutral isotropic polymer, i.e., it has no preferable direction for LC-molecules orientation. Another one was covered by a rubbed polyimide. This surface provided a strong anchoring and induced planar director orientation through the whole cell. The angle between directions of LC director on rubbed and isotropic surfaces was $\phi_L = 2\pi P / L = 120^{\circ}$.

Cell was irradiated by He-Cd-laser beam (λ_{ex} = 440 nm, P_{exc} = 10 mW) and tested from the rubbed side with a weak beam of the He-Ne-laser (λ_{test} = 633 nm) (Fig.1). Beam diameters were 1 mm and 0.5 mm respectively. Probe beam polarization was given by polarizer **P** parallel to the LC-director on the incoming rubbed surface. The Maugen regime ($\lambda \langle\langle P \cdot \bar{n}(n_e - n_o)$; $\bar{n}, n_e, n_o$ - average, extraordinary and ordinary refractive index, respectively) was valid for the testing beam, i.e., its polarization followed the director orientation through the cell[4] and was inclined at the outcoming surface at 30° as referred to incoming polarization. As the transmittance axis of an analyzer placed behind the cell was perpendicular to the initial polarization plane of the outcoming testing beam the light intensity after the analyzer initially equals zero.

Switching on of the exciting light led to a signal appearance behind the analyzer. Rotation of the analyzer on the angle ϕ allowed to cross it to the initial "zero" signal. Thus we can conclude that effect of the signal appearance was caused mainly by the polarization plane rotation while a possible light-induced birefringence could be neglected.

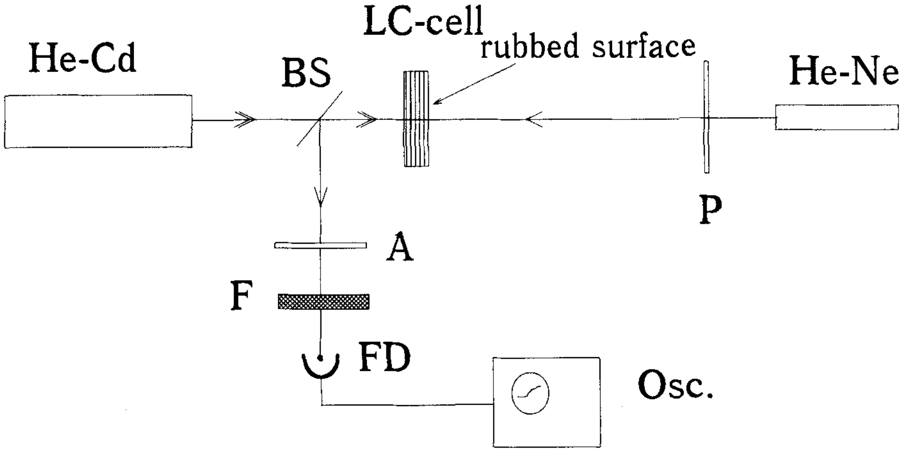

FIGURE 1 Experimental setup: A - analyzer, BS - beam splitter, F - red filter, He-Cd - excitation laser (λ_{exc} = 440 nm), He-Ne - probe laser (λ_{pr} = 633 nm), LC-cell - investigated sample, Osc. - oscilloscope, P - polarizer.

As the Maugen regime was valid, the transmitted light intensity was determined by the angle ϕ as follows:

$$I_{out} \propto I_{in} \cdot Sin^2(\phi) \qquad (1)$$

In the Fig.2 a typical oscilloscope trace is shown. The subsequent growth of the signal displays the rotation of the testing beam polarization according to (1). As was found out the steady value of the angle ϕ was about 15° and slightly depended on the exciting intensity and lasted during at least few hours after irradiation.

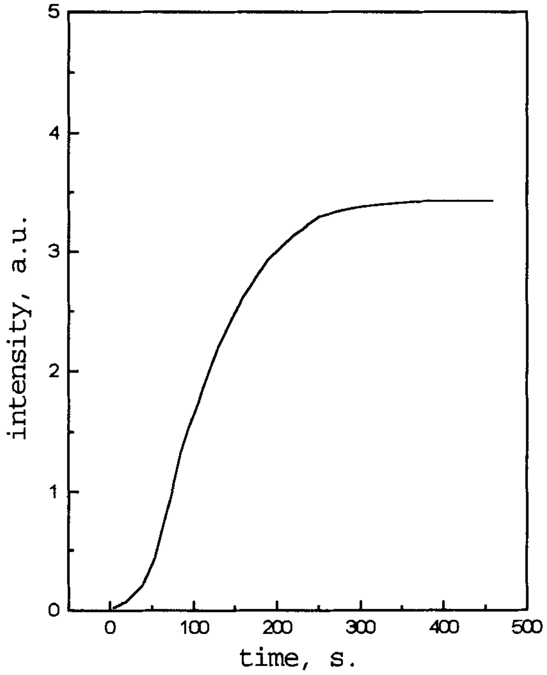

FIGURE 2 Transmitted light intensity of the probe beam vs exposure time.

The interesting effect of polarization plane post-rotation without exciting beam action was observed. After He-Cd-laser radiation was switched off (point **B** on Fig.3) the further substantial signal growth went on. When the illumination started again (point **A'**) the rotation of polarization plane went on as if it was no interruption.

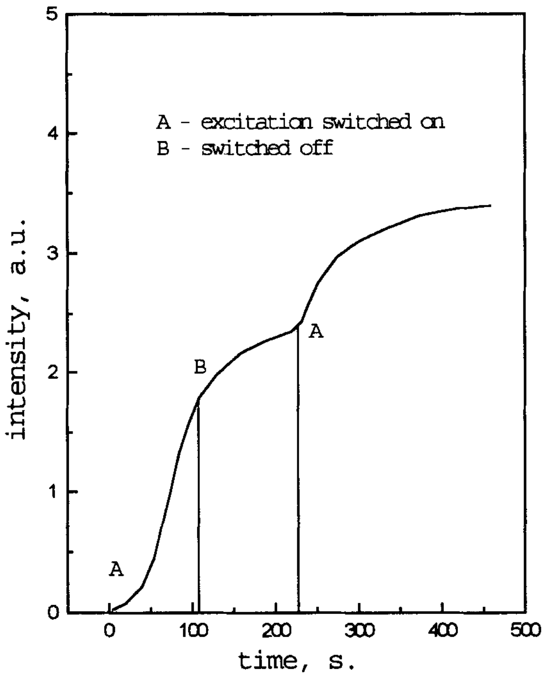

FIGURE 3 Transmitted light intensity of the probe beam vs exposure time.
A - excitation switched on;
B - switched off.

The obtained results can be naturally explained by the following.

The initial helical twisting of cholesteric LC was determined by the concentration c_O of the CD molecules as $P = 1/(c_o\beta)$. The influence of the exciting light results in the effective decreasing of CD concentration as the twisting ability of phototransformed molecules is negligible. This leads to the increase of P on the value $\Delta P \propto (c_o^2\beta)^{-1} I_{exc}$ and the decrease of the angle ϕ_L on the value $2\pi\Delta P / L$. As the Maugen regime is valid in our case, the corresponding turn of the testing beam polarization proportional to the concentration of phototransformed molecules appears.

It is known that cis-isomers of C=C-bond containing molecules are time-stable.[5] Therefore the rotation angle ϕ has to be proportional to the exposure of light and the steady state ought to correspond to the homogeneous untwisted LC structure ($\phi = 120^\circ$). Much smaller $\phi = 15^\circ$ obtained in the experiment should be associated with an induced anisotropy on the initially isotropic surface due to an adsorption of LC molecules onto the polymer surface ("surface memory" effect[6]).

The effect of the post-rotation requires the additional study. It may be suggested that at used values of light intensity the characteristic time of excitation of chiral molecules is much less then the director relaxation one. Hence, the non-equilibrium director deformation occurs at the each instant of the irradiation and the transient process of the transition to the equilibrium state takes place after the light interruption.

As the director volume relaxation time (~0.1 s) is sufficiently less then our time scale (~100 s) we can conclude that observed director behavior is only guided by the LC surface viscosity. The observed effect of the post-rotation seems to be one of the rare occasions where this parameter might be observed in experiment so clearly.

CONCLUDING REMARKS

We believe that the observed effect is of a strong interest at least due to the following two reasons.

- The new type of a spatially sensitive light modulator can be developed. The work of such device is based on the turn of the polarization plane of a passing through controlled beam by the irradiation of a region of LC-cell by the exciting beam, which results in the CD-molecules phototransformation.

- The observed phenomena might be useful for obtaining the information about the LC-aligning surface interaction. In particular, the study of post-illumination pitch untwisting will allow to estimate the value of surface viscosity and influence on it of an aligning material.

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