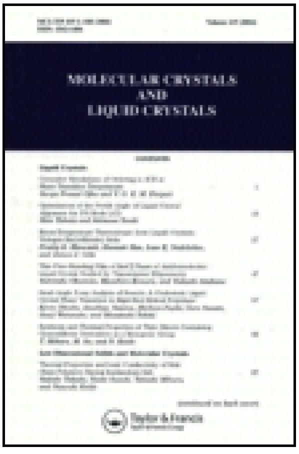

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Resonant-Thermal Optical Hysteresis in Liquid Crystals

L. Zagainova [a] , G. Klimusheva [a] , L. Yatsenko [a] & V. Danilov [a]
[a] Institute of Physics Ukr. Acad. of Sci., Kiev, USSR
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RESONANT-THERMAL OPTICAL HYSTERESIS IN LIQUID CRYSTALS

L.ZAGAINOVA,G.KLIMUSHEVA,L.YATSENKO,V.DANILOV
Institute of Physics Ukr.Acad.of Sci.,Kiev,USSR

Abstract An optical hysteresis has been achieved for the first time in an impurity liquid crystal with a helicoidal distributed feedback at comparatively low light intensities (the power of the laser pump is on the order of a few kilowattes)with short response time(10^{-8} s).

INTRODUCTION

The helical structure of cholesteric liquid crystals (CLC)gives a natural possibility for the observation of the optical bistability and optical hysteresis (OH) by the unresonant way.[1]

An important condition for achieving optical hysteresis is the presence of a feedback,which is usually arranged by means of cavities or a hybrid circuit.[2,3] A cavity-free optical hysteresis with an artificially distributed feedback in a phase-conjugation arrangement was first observed experimentally in CdS (the light power density was P=100 MW/cm^2,with τ =50 ns).[4] In periodic structures,on the other hand,a distributed feedback can be arranged by means of Bragg diffraction of light.[1,5]

In the present letter we report a new principle for achieving optical hysteresis and optical bistability,on the basis of the resonant absorption of light by an impurity in a cholesteric or nematochiral liquid crystal,which has a natural helicoidal distributed feedback.The resonant absorption in this system leads to an optical hysteresis at comparatively low light intensities,with a short response time and a simultaneous polarization of the light.

RESULTS AND DISCUSSION

According to the theory of ref.6,the equation for the dimensionless intensity ($\bar{\rho}$) of the reflected wave,normalized by dividing by the saturation intensity (under the condition that the saturation of the resonant transitions is slight), is

$$\frac{d\bar{\rho}}{dz} = \sqrt{A\bar{\rho}^2 + B\bar{\rho} + I} \qquad (1)$$

where $A = 2\Gamma(\Delta + \Gamma)$; $B = 1 - (\Delta - \Gamma)^2$; $I = \bar{\rho} - \bar{\sigma}$ - const; $\bar{\sigma}$ is the dimensionless intensity of the passing wave; $\Delta = 4(\omega - \omega_B)/\omega\delta\epsilon_r$ is the relative deviation of the laser frequency ω of the selective reflection ω_B; $\delta\epsilon_r$ is the amplitude of the helicoidal modulation of the dielectric constant; $\Gamma = (8\pi/3)(N\chi_r/\delta\epsilon_r)$, χ_r is the real part of the resonant susceptibility; N is the population difference of the resonant transitions of the impurity; and Z is the thickness of the sample. Solving eq.(1),we can find the necessary conditions for observing an optical hysteresis,and we can calculate the behavior for various parameters.Estimates of the threshold intensity for optical hysteresis yield values on the order of 1 kW/cm^2 (at Z=10^{-3}cm). This threshold intensity of the incident light is required in order to change (Δn) the refractive index of the medium sufficiently to cause a phase shift $\Delta n(\omega/c)Z = \pi$ of the light wave[6] and a deviation from Bragg reflection conditions.

The impurity in the cholesteric liquid crystal is pumped by an LGI-21 pulsed nitrogen laser,with an output wavelength of 337.1 nm.After passing through a Nicol prism,the linearly polarized light strikes a quartz cell holding the liquid crystal.The cell is in a temperature-regulated furnace.The temperature of the mesophase is held constant (155°C) within 0.01°C.The thickness of the liquid-crystal layer in the cell is 1 - 20 μm.The incident light beam propagates along the axis of the helix of the cholesteric liquid crystal.The intensity of the light transmitted through the liquid crystal is measured with an FK-2 photodetector and an S8-14 oscilloscope.

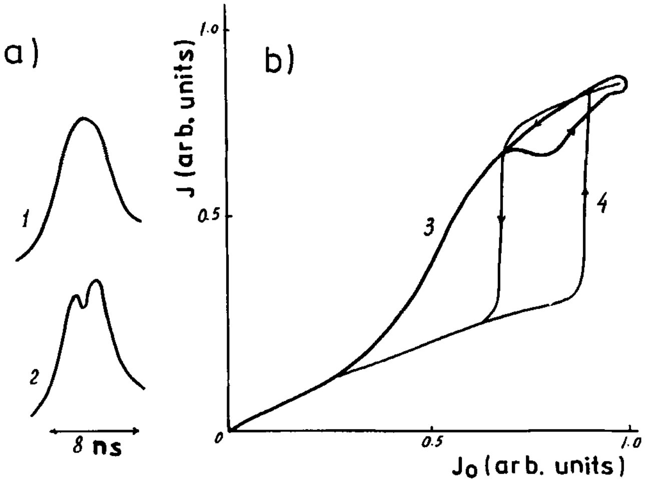

FIGURE 1

Figure 1a shows the oscilloscope traces of the intensity distribution in the pulses of (1) the incident light and (2) that transmitted through the impure CLC. Fig. 1b shows the optical hysteresis found from the experimental data (3) and predicted theoretically (4) too.

Optical hysteresis has been implement experimentally on the example of the impurity-doped cholesterol benzoate in the ultraviolet range at the temperature $T = 160^{\circ}C$.Conditions needed for the optimal realization of the OH in ultraviolet range,were investigated: impurity concentration in the CLC,critical falling light intensity,sample thickness,temperature range.The bounds of the different conditions alteration appear to be closely connected with a degree of molecular spirial ordering in mesophase.

A close relationship has been established between the observed optical bistability and the diffractive suppression of optical absorption in a cholesteric liquid crystal.For example,a maximum optical hysteresis is found in those intervals of the concentration, the temperature,and the thickness in which the suppression of absorption is at a maximum.[7]

High rate of response (10^{-9}s)and low threshold energies ($\sim 10^{-11}$ J/μm^2) for resonant optical hysteresis stimulated the search of new systems for operation in the visible spectral region at normal room temperatures.[8] Nematochiral mixture having the selective reflection band in the region of 530 nm with an impurity of a number of ketocyanin derivatives with the weight concentration of the impurity equalled 0.1% proved to be such a system.The oscillograms of the light intensity transmitted through the liquid crystal show the high changes in the shape of the incident laser pulse.It is possible to observe change in the pulse shape each 2 seconds and the disappearance of changes 16 seconds later.The dependence of the intensity of the light transmitted through the crystal on the intensity of the incident light is of hysteresis character.

We saw a high contrast in trasition.[8]

Changes in oscillograms depending on duration of illumination of the crystal by the laser light evidence for the influence of the temperature effects on the optical hysteresis. A high coefficient of the impurity absorption ($\sim 6.10^3 cm^{-1}$) causes the heating of crystal, that results in a thermooptic change in the refractive index and in variation of Bragg selective reflection conditions.

Thus, the presence of the distributed feedback due to the helical ordering of molecules and nonlinearity of the resonance absorbing cholesteric liquid crystal permits realizing the optical bistable cell with low inertial features and considerably low excitation intensity. It may be used in constructing the optical computer.

REFERENCES

1. N. V. Kukhtarev, Ukr.Fiz.Zh., 27,291 (1982).
2. V. N. Lugovoi, Kvantovaya Electron., 6, 2053 (1979).
3. R. S. Akopyan. B. Ya. Zeldovich, and N. V. Tabiryan, Pis'ma Zh.Tech.F., 9, 464 (1983).
4. A. A. Borsh, M.S. Brodin, V. I. Volkov, and N. V. Kukhtarev, Kvantovaya Electron., 8, 1304 (1981).
5. H. Winful, Phys. Rev. Lett., 49, 1179 (1982).
6. L. I. Zagainova, G.V. Klimusheva, I. P. Kryzhanovski, Pis'ma Zh. Eksp. Teor. Fis., 42, 353 (1985).
7. L. I. Zagainova, G.V.Klimusheva, and I. P. Kryzhanovskii, Fiz. Tverd. Tela, 25, 1025 (1983).
8. G. V. Klimusheva, et al., Kvantovaya Electron., 15, 793 (1988).