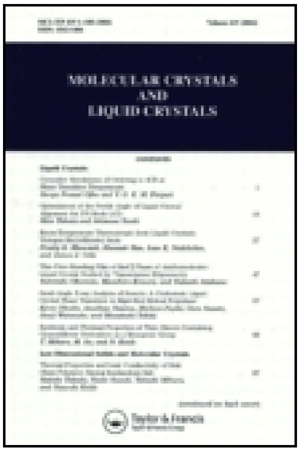

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

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M. I. Barnik [a], V. F. Kitaeva [b], V. G. Rumyantsev [a] & A. S. Zolot'ko [b]

[a] Russian State Center of Science "Organic Intermediates and Dyes Institute", ul. BoÌshaya Sadovaya 1-4, Moscow, 103787, Russia

[b] P.N.Lebedev Institute, Leninsky pr. 53, Moscow, 117333, Russia

Version of record first published: 04 Oct 2006

To cite this article: M. I. Barnik, V. F. Kitaeva, V. G. Rumyantsev & A. S. Zolot'ko (1997): Thermomechanical Effect in Liquid Crystal, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 299:1, 91-95

To link to this article: http://dx.doi.org/10.1080/10587259708041979

Mol. Cryst. Liq. Cryst., 1997, Vol. 299, pp. 91–95
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THERMOMECHANICAL EFFECT IN LIQUID CRYSTAL

M.I.BARNIK[1)], V.F.KITAEVA[2)], V.G.RUMYANTSEV[1)] and A.S.ZOLOT'KO[2)]
[1)]Russian State Center of Science "Organic Intermediates and Dyes Institute", ul. Bol'shaya Sadovaya 1-4, Moscow, 103787,Russia
[2)]P.N.Lebedev Institute, Leninsky pr. 53, Moscow, 117333, Russia

Abstract The interaction of narrow light beam with homeotropic liquid crystal 8CB in the region of phase transition smectic-nematic has been investigated. It was found out that the action of light beam leads to nonplane distortion of the director field (appearance of optically inhomogeneous anisitropic structures in the illuminated region) The deformation can be "frozen" in smectic phase in the course of liquid crystal cooling. The formation of deformation is explained by thermomechanical effect.

INTRODUCTION

It is well known that light radiation changes optical properties of liquid crystals (LC). It may be due to distortion of initial director field (orientational action) and due to change of refraction indices (thermal and photoconformational action). The director reorientation may be connected both with electric field of light wave[1-4] and with inhomogeneous thermal field of light beam. The latter phenomenon - thermomechanical effect - was theoretically considered in [5], but was not observed.

In the present paper the thermomechanical effect is applied for explanation of experimental results of publication[6], in which the interaction of LC 8CB, being in the region of smectic-nematic phase transition, with narrow light beam, producing strongly inhomogenious thermal field, has been studied. The physical mechanism of this interaction remained unclear.

EXPERIMENTAL CONDITIONS AND EXPERIMENTAL RESULTS

The investigations were carried out with homeotropically aligned LC 8CB (thickness L=150 μm). The smectic and nematic phases of this LC exist in the following temperature ranges:

$$21^0C < t_S < 32.5^0C < t_N < 40^0C.$$

LC cell was placed in a temperature-controlled chamber. The experiments were fulfilled at a temperature near the point t_{SN} of smectic-nematic phase transition.

A light beam of argon-krypton or argon ion cw laser was focused into LC cell by means of a lense. A double Fresnel rhomb was inserted in the beam path in front of the cell in order to rotate the light polarization plane. A film polarization analyzer was placed behind the LC cell. Profile of the beam transmitted was observed on the screen.

Let us summarize the results.

In the course of crystal heating at the temperature being near t_{SN} a "cross" appeares in crossed polarizers (Figure 1). It existed for several seconds (the beam power necessary for its appearence was $P \approx 30$ mW (power density $p \approx 1.5$ kW/cm^2) for $\lambda = 647$ nm and P ≈ 40 mW-50 mW ($p \approx 2$-2.5 kW/cm^2) for $\lambda = 515$ nm). If the temperature regulator is

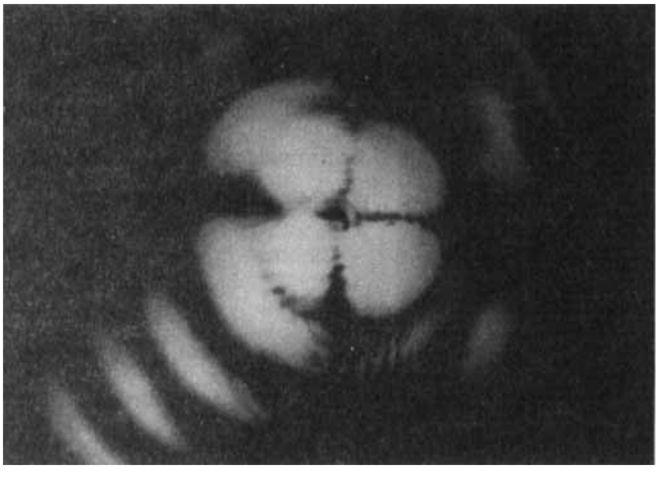

FIGURE 1 Light scattering on anisotropic structures in crossed polarizers.

switched off at the moment of the cross appearence for λ=647 nm the cross turns "frozen", that is it does not disappear. For wavelength λ = 515 nm the cross may be "frozen" too, but larger power values (P $\approx$ 200 mW, p $\approx$ 10 kW/cm^2) and the crystal temperature 1-2^{0}C below t_{SN} are required.

Under microscope the "frozen" structures are rings, darkened in directions of polarizer and analyzer (Figure 2) The diameter of rings depends upon focal length of focusing lense. The larger focal length correspond to smaller ring diameter.

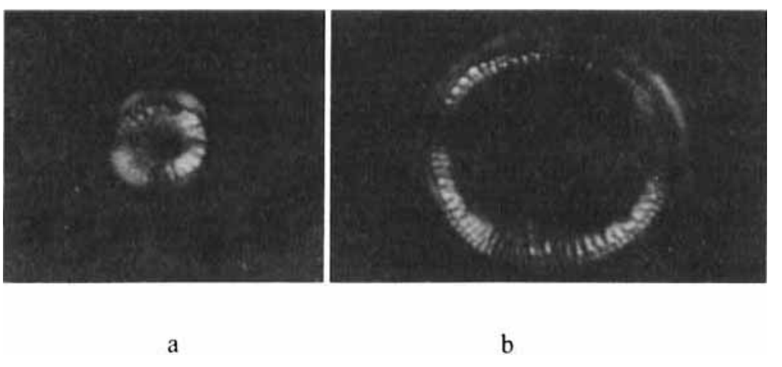

FIGURE.2. Anisotropic structures under microscope. a) ring diameter ~ 60 μm (focal length f=170 mm; b) ring diameter ~ 140 μm (focal length f=330 mm).

DISCUSSION OF THE RESULTS

The process by which the anisotropic structure is formed can be represented as follows. At light absorption in illuminated region additional crystal heating and crystal transition from smectic to nematic phase occur. The heating of crystal by light beam is, naturally, nonuniform: it is greater in the beam axis and weaker in the periphery. Due to the thermomechanical effect[5] the temperature gradient leads to director reorientation. Since the temperature field, produced by Gaussian beam is, evidently, axially symmetric the director deformation should have the same symmetry too. At crystal cooling the temperature decrease occurs faster than relaxation of crystal inhomogeneity, therefore the inhomogenity is "frozen" in smectic phase.

Let us discuss the thermomechanical effect, that reveals itself in our experiment in more detail. According to[5] the torque, reorienting the director, can appear for inhomogeneous director field only. This torque, however, can appear at fluctuational director distortion (in analogy to Freedericsz transition in the electric field perpendicular to director). The value of this torque is proportional to temperature gradient. Elastic torque counteracts to director distortion. The relation of torques mentioned determines whether the director field turns distorted or remains homogeneous. It follows from above consideration that the deformation of uniform directior field should be of threshold nature. This conclusion is in accordance with the experiment.

Since the value of thermomechanical torque is proportional to the module of temperature gradient, the maximum of director reorientation for the bell-like temperature profile, produced by Gaussian beam, is reached at some distance ρ from the beam axis. The observed ring-like deformation, characterized by radius ρ, correspond to such spatial distribution of thermomechanical torque (see Figure 2). (Fine structure is apparently due to Helfrich instability).

It was mentioned in[3] that the value of thermomechanical constant (that is the effectiveness of thermomechanical reorientation) is proportional to the temperature derivative of elastic constant. Since the elastic constants of nematic phase are characterized by fast increase in the region of smectic-nematic transition[7] it is naturally to assume that this temperature region is optimum for display of thermomechanical effect.

The manifestation of spatial inhomogeneity of order paremeter (order-electric effect[8]) at conditions of our experiment is hardly probable since smectic-nematic transition is weakly first order[9] and is not accompanied by large change of order paremeter.

CONCLUSIONS.

We believe that experimental results, concerning light beam interaction with LC 8CB, being in the region of smectic-nematic phase transition, are the first observation of thermomechanical effect.

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