

INVESTIGATION OF THE INFLUENCE OF ELECTRIC FIELD ON THE ANISOTROPY OF NEMATIC LIQUID CRYSTALS BY MEANS OF X-RAY INTERFEROMETRIC METHOD

L. G. GASPARYAN¹*, V. P. MKRTCHYAN¹, T. K. DADALYAN²

¹Chair of Solid State Physics YSU, Armenia

²Chair of Optics YSU, Armenia

The refractive index of nematic liquid crystal (NLC) E7 in the X-ray spectral range using the X-ray interferometric method, was measured experimentally. It was shown that NLC E7 is anisotropic medium for X-rays. This method is sensitive to reorientation of the molecules of liquid crystals and allows to measure the refractive index of homogeneously aligned NLC layer, when the molecules are reoriented under the influence of external electric field.

Keywords: nematic liquid crystal, LLL spectroscopy.

Introduction. The development of new methods for investigation of the anisotropy of liquid crystals (LC) is an interesting problem. In this paper we propose a new method for studying anisotropy of refractive index of LC under the influence of external electric field.

One of the mesophases of LCs are nematic liquid crystals (NLC), which exhibit the property of orientational ordering and large optical anisotropy. The molecules of NLC have preferred orientation, which is described by means of vector called director \vec{n} [1, 2]. The alignment of NLC molecules is sensitive to such external factors as electromagnetic fields, light, vibrations, chemical additives, which allowed creation of optical components for controlling the parameters of the light beams [3].

The alignment of NLC molecules could be controlled by means of external electric field [2]. Depending on the type of NLC the dielectric anisotropy could be positive or negative. In the first case the molecules of NLC tend to align parallel to the electric field, while in the latter case they align perpendicular [3]. Such reorientation of the NLC molecules leads to refractive index change and affects the state of the polarization of the light beam propagating through NLC layer. This could be easily observed in the visible part of the spectrum by means of crossed polarizers. There are many studies devoted to investigation of optical anisotropy of NLC in optics. More detailed study of LC structure is possible to implement by means of rheo-Nuclear Magnetic Resonance spectroscopy [4] or by means of diffraction of X-ray [5].

The anisotropy of refractive index of LC could be studied by means of X-ray LLL interferometer. This method was successfully applied for investigation of the anisotropy of NLC 5CB and polyethylene film [6–9], but it was not applied for studies of the anisotropy of NLC in the presence of external field, which tends to reorient the molecules of NLC. The

* E-mail: laura@ysu.am

aim of this work is to investigate the variation of the refractive index of NLC E7 under the influence of external electric field by means of LLL interferometer.

Experimental Part. We have experimentally studied anisotropy of NLC E7 layer with thickness $20\ \mu\text{m}$. The NLC layer was formed in the LC cell, which was made of two transparent glass substrates with $1\ \text{mm}$ thickness coated with conductive layers of indium tin oxide, which have served as electrodes for application of external electric field. The thickness of the NLC layer was defined by the gap between two glass substrates, which was provided by insulator films with $20\ \mu\text{m}$ thickness. For obtaining homogenous planar alignment of NLC molecules the substrates were coated by poly vinyl alcohol and rubbed in antiparallel directions. The cell was filled by capillary method. The molecules of NLC were reoriented by means of electric field with frequency $1\ \text{kHz}$ and amplitude $11\ \text{V}$ provided by the signal generator. During the experiment we have used NLC E7. The ordinary and extraordinary refractive indices of which for light with wavelength $587\ \text{nm}$ are respectively $n_o = 1.52$ and $n_e = 1.74$ [10].

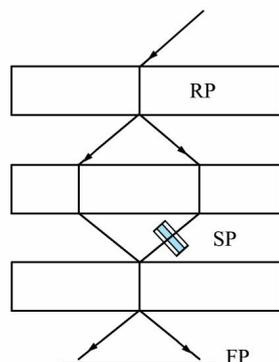


Fig. 1. Propagation of X-ray beams in LLL interferometer.

RP – reflection planes, SP – sample, FP – photographic film.

The anisotropy of NLC layer was studied by registration of phase shift of X-ray waves with different polarizations passing through the medium. For this purpose, a three block LLL interferometer was used [8], which consists of three silicone crystalline blocks (Fig. 1). Reflection planes of the blocks for $\text{MoK}\alpha$ emission are perpendicular to the surface (110). The thickness of the blocks satisfied to Bormann condition $\mu t \gg 1$, where μ is the linear absorption coefficient and t is the thickness of the block. After passing through the block of interferometer, only component with σ -polarization of unpolarized X-ray wave remains. The plane of polarization of σ -polarized X-ray wave is perpendicular to the plane of diffraction. In X-ray interferometer the beams are interfering on the third block-analyzer and, as a consequence, in two beams emerging from the block-analyzer, interferometric Moiré pattern is observed. If one of interfering beams is let through the sample, the shift of Moiré lines compared to their initial position will allow to calculate refractive index of the sample (Fig. 1). This method is described in [8, 9].

The shift of Moiré stripes depends on the orientation of σ -polarization of X-ray beam and the optical axis of the sample. When the latter is perpendicular to the plane of the diffraction and to the normal of the wave front of the X-ray beam the polarization plane of σ -polarized X-ray (\vec{N}) beam will be parallel to the optical axis of the sample ($\vec{n} \parallel \vec{N}$). The X-ray wave will behave as extraordinary wave with refractive index n_e . When the sample is rotated by 90° with respect to the wave front of the beam ($\vec{n} \perp \vec{N}$), the optical axis of the sample will be in the same plane as the plane of the diffraction. The X-ray wave will behave as ordinary wave with refractive index n_o [8, 9].

Results and Discussion. In the work applying the external electric field the molecules of NLC were reoriented parallel to the vector of the electric field and the shift of Moiré stripes for ordinary and extraordinary waves was registered with respect to their initial positions in absence of the electric field. During the experiment we were registering the positions of Moiré stripes without samples. Then the positions of Moiré stripes were registered, when empty LC cell was placed on the path of one of the interfering beams to ensure that there is no shift of the Moiré stripes. After filling the LC cell with NLC E7, we have recorded the Moiré stripe positions for the case ($\vec{n} \perp \vec{N}$) without electric field and when the electric field is on. The results are shown on the Fig. 2.

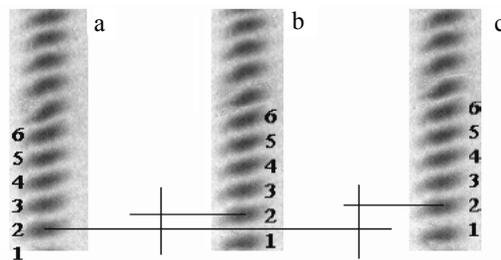


Fig. 2. Moiré stripes of LC cell for case $\vec{n} \perp \vec{N}$, for:
 a – empty cell; b – cell filled with NLC, without electric field;
 c – cell filled with NLC, with switched electric field 11 V;
 $\Delta_{ba}\Lambda=0.28 \text{ mm}$, $\Delta_{cb}\Lambda=0.48 \text{ mm}$.

From Fig. 2, b and 2, c one can see that Moiré stripes are experiencing different shift compared to the Fig. 2, a, which shows the positions of Moiré stripes of empty cell. These results demonstrate that NLC E7 is anisotropic medium for X-ray, and LLL interferometer is sensitive to the structural changes occurring in the LC under the influence of the electric field of 11 V. By measuring the period and the shift of Moiré stripes and using the formula in [9] it is possible to calculate the decrement (δ) of NLC E7. The wavelength of MoK α emission is $\lambda = 0.709 \text{ \AA}$, $\Delta\Lambda$ is relative shift of Moiré stripes, $\Lambda = 700 \mu\text{m}$ is the period of the Moiré pattern, $t = 20 \mu\text{m}$ is the thickness of the layer. For values of decrement we obtain: $\delta n_e = 0.85 \cdot 10^{-6}$, $\delta n_e^{el} = 2.4 \cdot 10^{-6}$. Here δn_e is the decrement of NLC layer without electric field for the case ($\vec{n} \perp \vec{N}$) and δn_e^{el} is the decrement of the NLC layer with electric field.

Conclusion. In conclusion we have experimentally studied the influence of the external electric field on the refractive index of the NLC E7 layer. It was shown that NLC E7 is anisotropic medium for X-rays and can be effectively studied by means of X-ray interferometer. The refractive index of the NLC layer for X-ray region of the spectrum could be measured using three block Laue interferometer which allows to study the anisotropy of the medium. This interferometer is sensitive to reorientation of the NLC molecules and we were able to measure the decrements of the NLC layer when it is exposed to external electric field. For the values of the decrement of unperturbed NLC and for the same initial alignment with electric field on respectively $\delta n_e = 0.85 \cdot 10^{-6}$, $\delta n_e^{el} = 2.4 \cdot 10^{-6}$. Further studies are necessary to explain such big difference of the values of the decrements.

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