# INVESTIGATION OF EXTERNAL INHOMOGENEITY EFFECTS ON THE X-RAY AND OPTICAL PARAMETERS OF $LiNbO_3$ AND SBN CRYSTALS

**V.N. Trushin, A.A. Zholudev, Y.V. Chuprunov, M.A. Faddeyev, A.F. Khokhlov**

*Nizhny Novgorod State University, Physics Department,*
*http://phys.unn.runnet.ru, E-mail: zhol@phys.unn.runnet.ru*

Creating some elements of spatial and temporal modulation of X-ray radiation is one of current problems in X-ray optics. There may be various ways for solving this problem. For instance, high-frequency time modulation of X-ray radiation can be implemented in the process of X-ray diffraction with the use of surface acoustic waves [1-3]. An attempt to transmit an image in X-rays was made in [4] using the dynamic focussing effect. Practical application of the proposed schemes is limited by a small angular aperture of lenses and their low aperture ratio. That is why such schemes can be implemented with synchronous radiation.

This paper describes the results of a research into the influence of weak external inhomogeneous thermal effects on X-ray diffraction parameters (XDP) and optical properties of crystals. The aim of the research was to study the possibility of formation of X-ray images (XI), i.e. X-ray beams with the given spatial - temporary structure.

In [5] it was shown that the external influences can lead to significant changes in the intensity of X-ray diffraction maxima (XDM) of crystals. It was established experimentally in [6] that the effect of reversible change of crystal parameters under the influence of crystal surface illumination by optical radiation can be used to form an X-ray image. It was shown that the spatial structure of XDM under certain conditions can correspond to the structure of the external influence, i.e. it can represent an X-ray image functionally related to the optical image (OI), used as a template.

The experiments were carried out on a two-crystal X-ray spectrometer ($CuK_{\alpha 1}$- radiation). Figure 1 shows the layout of experiments (a) and the topograms 3 (b,c) of $LiNbO_3$ and SBN crystals illuminated by a spatially modulated laser beam ($\lambda$ = 1.06 mm, 20 $mWcm^{-2}$). On the surface of crystal 1 an optical image was formed with the help of transparency 2. In the case when the optical radiation was poorly absorbed by the crystal, the illuminated surface of the crystal had to be blackened. The illuminated surface of the crystal represented a Y-section of a $LiNbO_3$ crystal or a Z-section of a SBN crystal. One can see from the figures that the structure of XDM corresponds to the structure of the optical image generated on the surface of the crystal. The formed XI are inverse in relation to the optical image , i.e. the illuminated sites on the crystal surface correspond to the areas of lowered intensity in the topograms. In XI of $LiNbO_3$ and SBN a contour effect is observed.

The areas corresponding to illuminated sites of the surface have a lower intensity and are surrounded with areas of increased intensity in the field of the geometrical shadow (contour effect). Unlike in the images obtained with the help of $LiNbO_3$ (see Fig. 2b, curves 1 and 2) and SBN crystals, in the images generated with the help of KDP crystals areas with an increased level of diffraction are not observed (see Fig. 2b curves 3 and 4). The dependencies of the photoinduced change of the nigrescence degree $\Delta I =(I - I_o)/I_o$ of photographic plates of topograms for $LiNbO_3$ (reflection $0\bar{4}2$, $2\Theta \approx 93^o$) KDP (008, $2\Theta \approx 62^o$) crystals are shown in Fig. 2. Intensities $I_o$, $I$ – correspond to the unilluminated and illuminated crystal, respectively. One can see from the figures that the intensity maximum is increased in the geometrical shadow area (contour effect) in $LiNbO_3$ crystals (see Fig. 2b, curves 1 and 2) and it is absent in KDP crystals (see Fig. 2b, curves 3 and 4).

To estimate the characteristics of the formed images, oscillation curves of a $LiNbO_3$ crystal (Y- section, reflection $0\bar{4}2$) were studied for different positions between the

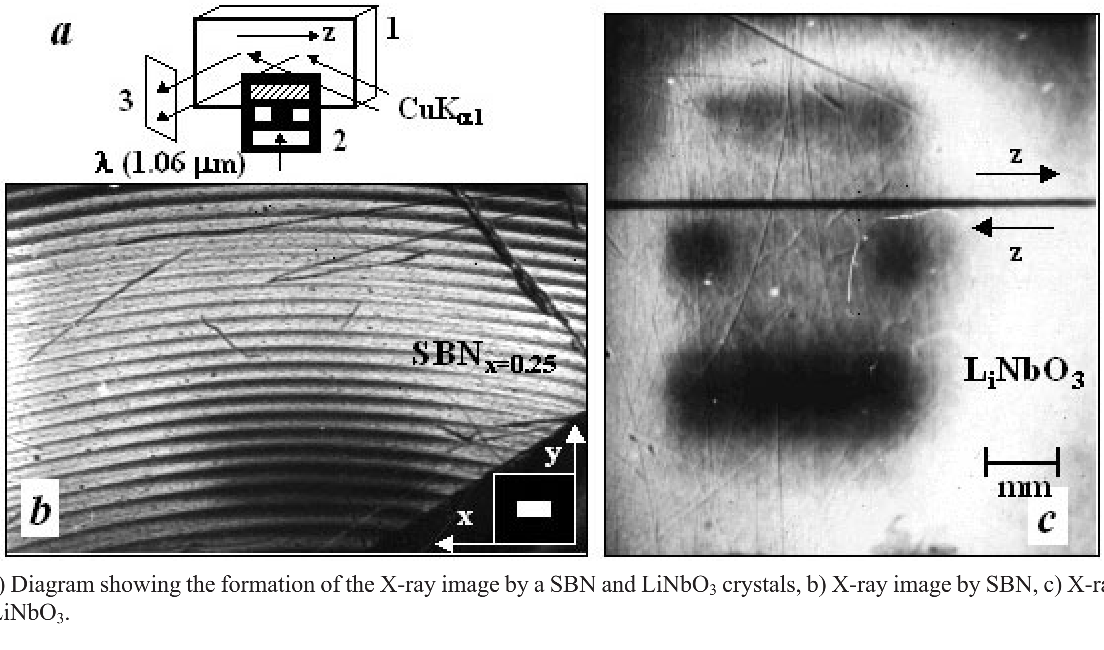


**Fig. 1.** a) Diagram showing the formation of the X-ray image by a SBN and $LiNbO_3$ crystals, b) X-ray image by SBN, c) X-ray image by $LiNbO_3$.

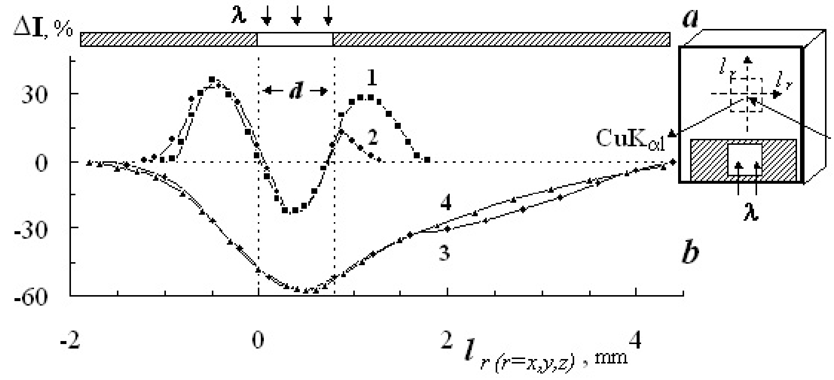


**Fig. 2.** Sections of topograms passing through the area, corresponding to a square light spot (1 x 1 mm$^2$) on a surface of $LiNbO_3$ crystals and KDP. The curves 1, 2 show the dependence ΔI for $LiNbO_3$ along the X and Z axes, and curves 3, 4 show ΔI for KDP along the Y and X axes. The shaped lines show the contours of the square light spot are show by dashed lines.

area of light influence on the blackened surface of the crystal relative to the area of X–ray diffraction. Diffraction areas of an X-ray beam and of the light spot had the size 2 × 4 mm$^2$ and 2× 6 mm$^2$, respectively. The family of oscillation curves and the respective changes of XDP of the $LiNbO_3$ crystal are shown in Fig. 3.

The interval -2mm < $Z$ < 2mm corresponds to the overlapping of the X-ray diffraction and the light spot areas. In the area of partial overlapping of X-ray and laser beams ($Z$ ≈ 3 mm) a salutatory change of XDM integrated intensity is observed. This change has both positive and negative values. The maximum value corresponds to the area of their full overlapping.

To explain the contour effect, the equation of thermal conductivity for the $LiNbO_3$ crystal was solved numerically. For the area around the “light – darkness”interface the results are shown in Fig.4.

A significant gradient of the thermal field is observed in the field of the geometrical shadow with the illumination of a crystal near the “light - darkness” interface. The contour effect is inherent in this area. Such gradients of temperature cause significant deformations of the crystal lattice. The distribution of deformations is determined by the spatial and temporal structure of the optical image. In the homogeneously illuminated area on the crystal surface, contrast variation on the topograms is determined by its deviation from the Bragg angle related to the area’s temperature and fault structure as well as to the thermoelastic parameters of the crystal. The existence of areas with the increased intensity of XDM is explained by the weakening of the extinctional attenuation of intensity.

This allows to explain the contour effect by local thermally and optically induced changes in the conditions of dynamic diffraction of X-ray beams on the $LiNbO_3$ crystal. In $LiNbO_3$:Cu having a more faulty structure (about 10 μm thick), the contour effect was absent. This also shows that the contour effect has a dynamic nature and is explained by extinction effect in perfect crystals.

Structural distortions leading to significant changes of parameters should have an effect on the optical parameters of crystals. We have investigated experimentally the behaviour of optical properties of LiNbO3 crystals in non--uniform temperature fields. Thermoinduced changes of intensity of the linearly polarized laser radiation (λ = 0.63 mm) passing through the system polarizer-crystal-analyzer (PSA) were investigated. It was also established, that

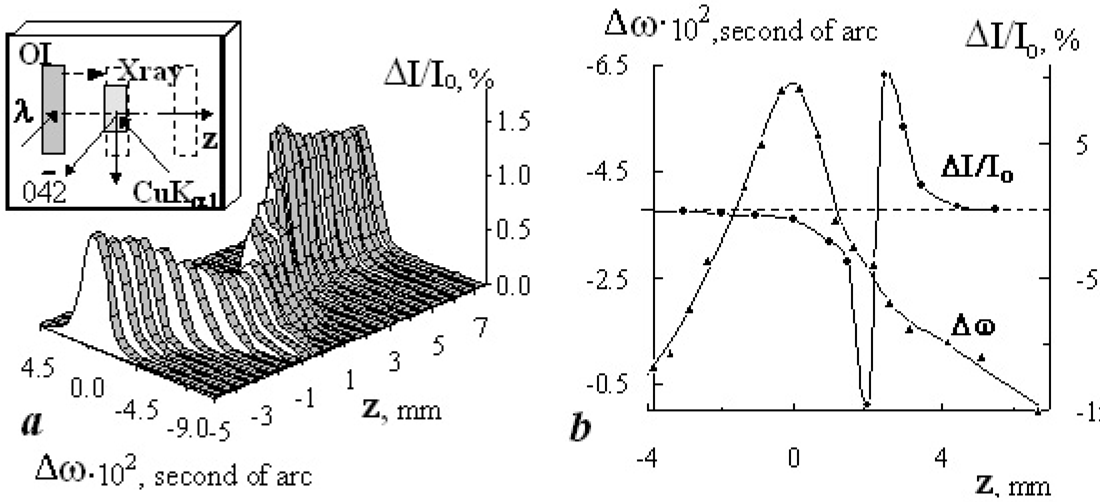


**Fig. 3.** a) Oscillation curves of $LiNbO_3$ for varions positions of the light spot (OI) (1 ×3 mm$^2$) and of the X-ray diffraction area Xray (1 × 1 mm$^2$), b) Changes of parameters of the oscillation curves: $\Delta I/I_0$ -relative change of integrated intensity, Δω - change of Bragg angle.

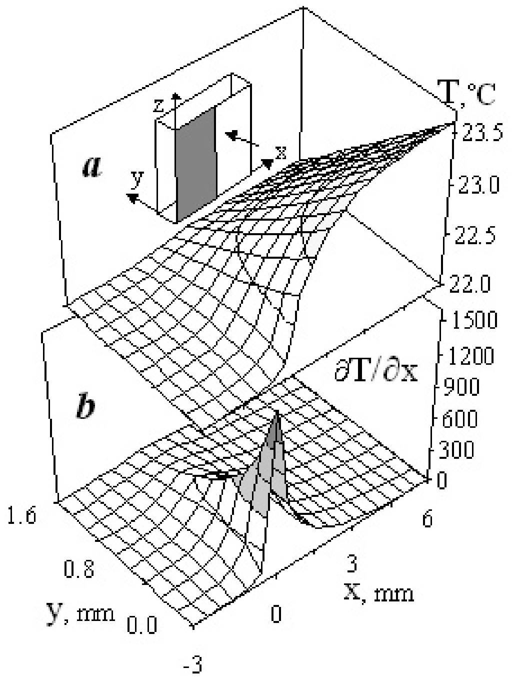


**Fig. 4.** a) Distribution of temperature fields T, b) Distribution of the temperature gradient in the bulk of the crystal $LiNbO_3$ along the axis Y. The fields are generated by the illumination of the blackened surface XZ by the light image (20 mW × $cm^{-2}$) as a "light - darkness" interface during 5 sec.

inhomogeneous temperature (∇T) deformations lead to changes of optical parameters of crystals, in particular, to changes of absorption factors of a crystal. Fig.5 shows the thermoinduced changes of absorption factors $\alpha_o$ obtained by means of processing the experimental data in the approximation of a single-axis optically inactive crystal.

In $LiNbO_3$ both an increase and a decrease in absorption coefficients were discovered that were related to the value and the direction of the temperature gradient, to the direction of the light beam and the optical axis of the crystal.

The contour effect in the X-ray image and the effect of changes of absorption in a crystal are both related to the formation of inhomogeneous fields of thermoinduced deformations in a crystal. Such effects are not observed in the presence of homogeneous temperature fields in a crystal.

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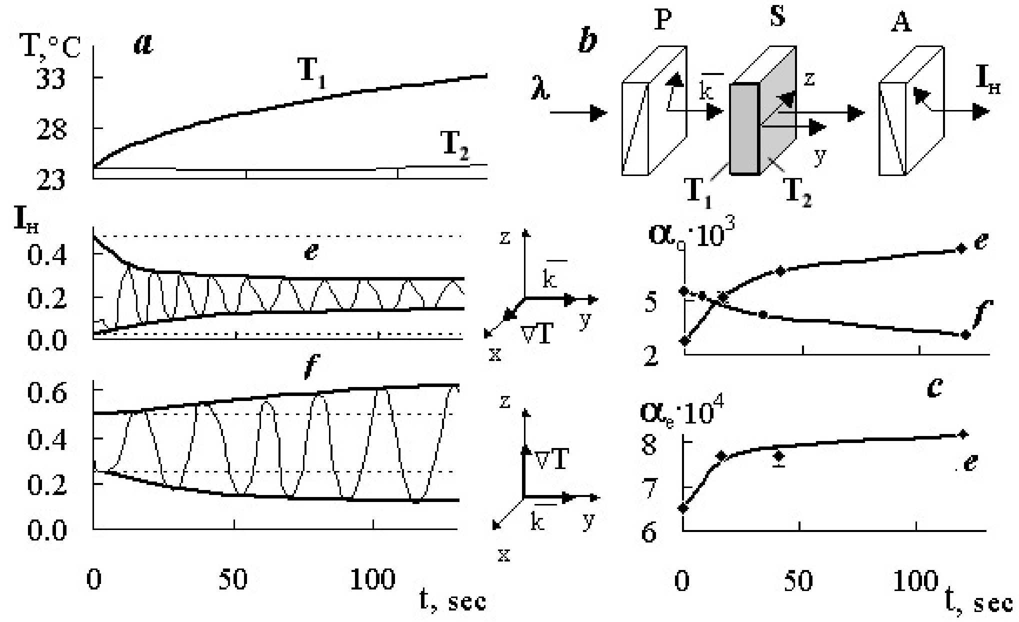


**Fig. 5.** Thermoinduced changes of intensity of the laser radiation $I_i$ and of absorption factors $\alpha_{o,e}$.