Armenian Journal of Physics, 2020, vol. 13, issue 3, pp. 180-184

The Dependence of the Absorption Coefficient of X-Rays on the Position of the Vectors of Diffraction and Temperature Gradient

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Received 22 June 2020

Abstract. The behavior of the interference absorption coefficient of *X*-rays in Laue geometry depending upon the disposition of diffraction vector and temperature gradient vector in the perpendicular direction to the reflecting atomic planes family was experimentally studied. The study was carried out for the different thicknesses of quartz single crystal for atomic planes $(10\bar{1}1)$. It was shown that in the case of anti-parallel disposition of the diffraction vector and temperature gradient vector the absorption coefficient of *X*-rays sharply decreases with the increase of temperature gradient and in the case of the parallel disposition of the diffraction vector and the temperature gradient vector the absorption coefficient firstly increases and then decreases. The theoretical calculation corresponding to the experiment conditions have been done. The physical explanation of the obtained experimental results has been made. The obtained results are in good correspondence with the experiment.

Keywords: Absorption coefficient, Laue geometry, reflecting atomic planes, quartz single crystal.

1. Introduction

The investigations in the area of interaction of angstrom waves with distorted single crystals have an essential importance for the modern solid state physics and scientific instrument-making. The observation of the effect of X – ray full pumping from the transmission direction to the reflection direction in Laue geometry [1] in the case $\mu t \geq 1$ (where: t – the crystal thickness, μ – the linear coefficient of absorption) made an essential contribution to this area development. In works [2, 3] it was experimentally studied the behavior of X – ray absorption coefficient in single crystals according to Laue geometry and was shown that the existence of temperature gradient [2] and ultra sound oscillations [3] results in essential decrease of X – beam absorption (in the case of ultrasound up to zero). The behavior of the absorption interference coefficient of X – rays in single crystals according to Laue geometry is theoretically considered in works [4, 5].

In this work the theoretical and experimental studies are carried out for the given process depending on disposition of the diffraction vector and temperature gradient vector perpendicular to the family of reflecting atomic planes in quartz single crystal.

2. Experiment

The experimental investigations were performed in Bragg-Laue geometry by $(n,-n)$ scheme. The used beam $M_0K_{\alpha 1}$ characteristic radiation initially was monochromatized from the reflecting atomic plane $(10\bar{1}1)$ of the quartz single crystal in Bragg geometry. A diffraction reflection in Laue geometry from a number of reflecting atomic plane families of the studied quartz single crystal with $X-$cut is observed. The integral intensity of the reflected beam was registered depending on the temperature gradient perpendicular to the reflecting atomic planes. The described investigations were performed for the temperature gradient vector (**B**) and diffraction vector (**g**) of parallel and anti-parallel dispositions. The experimental investigations showed that at the presence of temperature gradient and its value increase in the case of parallel disposition of vectors **B** and **g**, the integral intensity of the reflected beam firstly decreases (down to the minimal value) and then reaches the saturation monotonically increasing (fig. 1a). Meanwhile, in the case of anti-parallel disposition of **B** and **g** the reflected beam integral intensity depending on the value of the temperature gradient monotonically increases reaching the saturation (fig. 1b). As it is seen in fig. 1, for an arbitrary value of the temperature gradient the absolute value of the reflected beam intensity in the case of the anti-parallel **B** and **g** is always greater than in the parallel case.

The mentioned peculiarities of the reflected beam behavior are experimentally observed for the various thicknesses of the plates and for various reflecting atomic planes of the quartz single crystal.

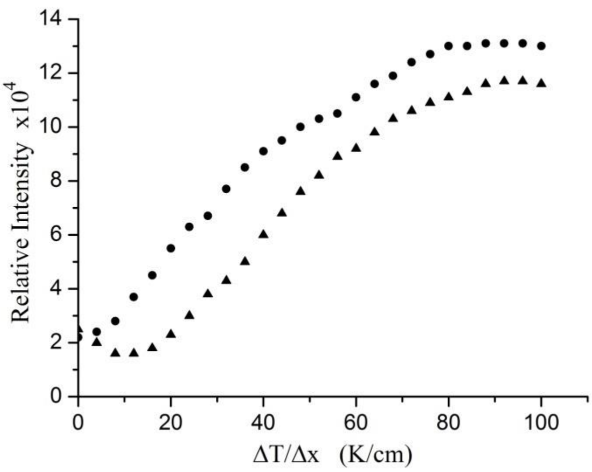

Fig. 1. The integral intensity dependence on the value of the temperature gradient for the beam reflected from reflecting atomic planes $(10\bar{1}1)$ of the quartz single crystal with X-cut and t=2.85mm thickness: a) ***B*** and ***g*** are parallel (Triangle), b) **B** is anti-parallel to ***g*** (Circle).

3. Experiment Analysis and Interpretation

The propagation of X – ray wave fields in a deformed crystal near Bragg condition is usually described by Takagi equations with the spherical and the plane wave approximations. But under the real experiment conditions the falling beam has not only an angular divergence but also a spectral width.

For the purpose of bringing the theory closer to the experiment, the model calculations were made for the process of the coherent scattering for X – rays with the spectral angular distribution of $I(\lambda,\theta)$ intensity falling on the quartz single crystal at the temperature gradient.

In the model calculations it is considered that: the X – ray beam falling on the crystal has divergence and spectral width and the aggregate of plane waves with different wave-lengths propagates in each direction. Each of them is scattered in correspondence to the dynamic theory with the plane wave approximation. After that in the detector plane integration by the spectral and angular parameters takes place. In calculations, for each transmission and reflected monochromatic plane waves the solutions obtained in work [5] were used.

The model calculations were made for the scattering of characteristic X – ray $MoK_{\alpha 1}$ radiation with different spectra-angular widths. In fig. 2 the calculations for reflecting atomic planes $(10\overline{1}1)$ of quartz single crystal with X – cut are presented for the integral intensity of reflected, transmission and summed up X – ray depending on the value of the deformation induced by the temperature gradient [5]. In the figure the calculations are presented both for the anti parallel (fig. 3a,b,e) and the parallel (fig. 3c,d,e) dispositions of the diffraction vector and temperature gradient vector.

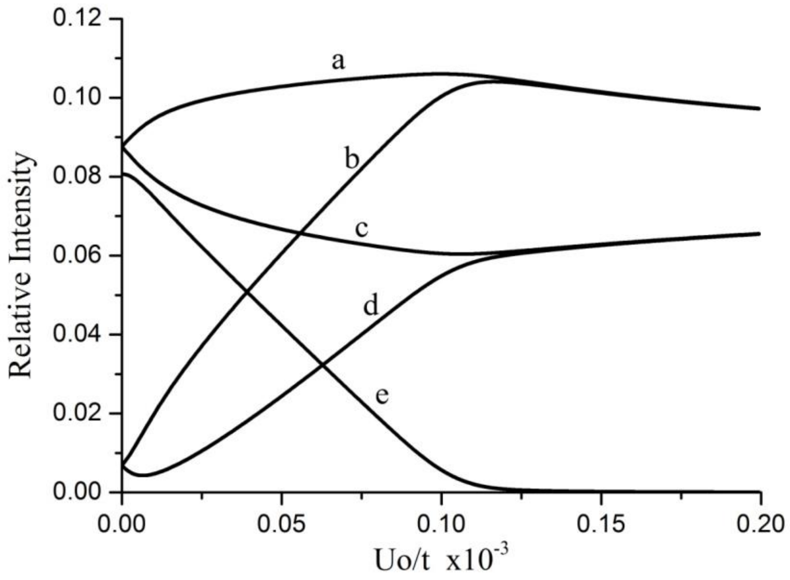

Fig.2. Calculations of integral intensity of X-rays for the reflecting atomic planes $(10\overline{1}1)$ of the quartz single crystal with X-cut and t=2.85mm thickness depending on the value of the relative deformation Uo/t. a) Summed up beam when **B** is anti-parallel to ***g***, b) reflected beam when **B** is anti-parallel to ***g***, c) summed up beam when **B** is parallel to ***g***, d) reflected beam when **B** is parallel to ***g*** and e) booth transmission beams when **B** is anti-parallel or parallel to ***g***.

The calculation analysis shows that in the case anti-parallel disposition of $\mathbf{g}$ and $\mathbf{B}$ with the increase of the temperature gradient value the amplitude of the reflected weakly absorbing field increases (fig. 3b) due to the simultaneous decrease of the amplitude of the reflected strongly absorbing field and the amplitude of the transmission field in which the both summands decrease (fig. 3e). For a certain curvature the whole energy is pumped into this field, i.e. the other fields come down to zero. As a result of this, the crystal interference absorption coefficient essentially decreases (fig. 3a). The further curvature increase leads to the decrease of the energy pumped into reflected weakly absorbing field (the interference absorption coefficient again increases).

In the case parallel disposition of $\mathbf{g}$ and $\mathbf{B}$ the reverse behavior of the interference absorption coefficient of the crystal is observed. Viz. with the gradient value increase the amplitude of the reflected strongly absorbing field increases (fig. 3d) due to the simultaneous decrease of the amplitude of the reflected weakly absorbing field and the amplitude of transmission in which the both summands decrease (fig. 3e). For a certain curvature the whole energy is pumped into this field, i.e. the other fields come down to zero. As a consequence the crystal interference absorption coefficient essentially increases (fig. 3c). The further curvature increase leads to the decrease of energy pumped into the reflected strongly absorbing field (the interference coefficient again decreases).

The theoretical calculations were made for a number of reflecting atomic plane families of the quartz single crystal. However the above mentioned effect is mostly obvious for reflecting plane families $(10\bar{1}1)$.

4. Conclusion

Thus it was show that with the increase of the temperature gradient anti parallel to the diffraction vector of the reflecting atomic planes of the quartz single crystal, the interference absorption coefficient of $X-$rays sharply decreases and reaches its minimal value. And in the case of parallel disposition of the diffraction vector and the temperature gradient vector, the reverse behavior of the interference absorption coefficient of the crystal is observed.

Funding

This work was supported by the RA MES Science Committee, in the frames of the research project №18T–1C395.

Conflict of Interest

There is no conflict of interest.

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