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Formation of Parallel X–ray Beams with Controllable Quantity and Distances

T.R. Muradyan[1]*, E.H. Bagdasaryan[1], S.M. Petrosyan[1], H.H. Samsonyan[1], L.R. Aloyan[2], A.V. Shahverdyan[1], V.R. Kocharyan[1]

Institute of Applied Problems of Physics NAS of the Republic of Armenia
25 Hrachya Nersissian Str., 0014, Yerevan, Republic of Armenia
[2]Yerevan State University, 1 Al. Manoogian Str., Yerevan, Republic of Armenia, 0025
*E – Mail: tigran.muradyan.86@mail.ru

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Abstract. The possibility of obtaining parallel X-ray beams and controlling their quantity and distances in a wide range has been experimentally considered. To implement this experiment, a three-crystal scheme was assembled. The first crystal is set to monochromatize an X-ray beam, which provides high resolution. The second quartz crystal with AT - cut is used to obtain parallel X-ray beams with different distances and quantities using the effect of bulk acoustic waves with different frequencies. And the third quartz crystal with asymmetric reflection is used to control the distances of parallel beams in a wide range (from 50 μm to 1 mm). Thus it is shown that, using such a three-crystal scheme, it is possible to obtain any number of parallel X-ray beams and control their distances in wide ranges.

Keywords: X-ray radiation, quartz single crystal, volume acoustic waves.

1. Introduction

The requirement for creation of more sensitive and universal research methods in different fields of science and technique stimulates the development of new methods for obtaining monochromatic beams of $X-$rays with parameters controlled in space and time, as, e. g., the angular divergence, spatial distribution and monochromaticity. $X-$ray diffractometry in the presence of external influences is one of such methods. For instance, the presence of external acoustic fields or temperature gradient in crystal monochromators enables one to control the parameters of diffracted $X-$rays in space and time [1–3]. The possibilities of controlling the parameters of reflected $X-$rays from different atomic planes $(10\bar{1}1)$ of single quartz crystal with different bends in the presence of volume acoustic waves up to $10\,MHz$ have studied in [4-10]. The phenomenon of the full transfer of $X-$rays from the transition direction to the reflection direction in quartz single crystal in the Laue geometry under the influence of ultrasonic oscillations was first observed in [4]. Since the dependence of the intensity of the reflected $X-$ray radiation on the parameters of the external acoustic fields or temperature gradient it possible to obtain controllable $X-$ray beams both in time and space, numerous studies were subsequently carried out to study the various characteristics (angular divergence, spatial distribution, energy dispersion) of the reflected $X-$rays [5-7]. In [8, 9], the diffraction of $X-$ray radiation on various reflecting atomic planes of a quartz single crystal with an AT cut in the Laue geometry was experimentally studied when volume acoustic waves were excited in the crystal. Certain reflecting atomic planes are curved and have periodicity along the thickness of the crystal, which is equal to $n\times\lambda/2$, where n is an odd number and corresponds to the order of the resonant frequency, and λ is the wavelength of acoustic waves. It is shown that volume acoustic waves lead to spatial modulation of diffracted beams, that is, bands appear in the frontal section, which perpendicular to the diffraction vector. The number of bands depends on the order of the harmonic of the excited acoustic field. The intensity of the emerging bands depends on the amplitude of the acoustic waves excited in the crystal. It was shown in [10] that a spatially modulated beam formed from the quartz single crystal with an AT cut of excited acoustic waves can be completely pumped in the direction of reflection at a certain value of the temperature gradient applied to the second crystal while preserving the spatial distribution of the beam.

In this work, the possibility of controlling the distances of the obtained parallel $X-$ray beams in a wide range has been experimentally considered.

2. Experiment

In experiment the spectrum of $X-$rays produced from Mo БСВ-29 $X-$ray tube under voltage of $30kV$ and $10mA$ anode current was used. The size of the focal spot of the source is $0.2\times10mm^2$. The three-crystal scheme was used to control the distances of the obtained parallel $X-$ray beams in a wide range (Fig. 1). The first quartz crystal was located in a reflective position of atomic planes $(10\bar{1}1)$ Bragg geometry for monochromatization of $X-$ray radiation with an energy of $17.48keV\,(MoK\alpha1),$ which provides high resolution. The second quartz crystal with AT - cut was located in a reflective position of atomic planes $(10\bar{1}1)$ Laue geometry for the obtained of parallel $X-$ray beams with different distances and quantities using the effect of bulk acoustic waves with different frequencies. Acoustic vibrations with frequencies of $2.979, 4.890, 6.933$ and $8.836MHz$ were excited to the second quartz crystal, and $X-$ray parallel beams were recorded using photographic film (Ph1). And the third quartz crystal with $X-$cut was located in a reflective position of atomic planes $(11\bar{2}0)$ Bragg geometry with asymmetric reflection is used to control the distances of parallel beams in a wide range (from $50\mu m$ to $1mm$). After third crystal the $X-$ray parallel beams were recorded using photographic film (Ph2).

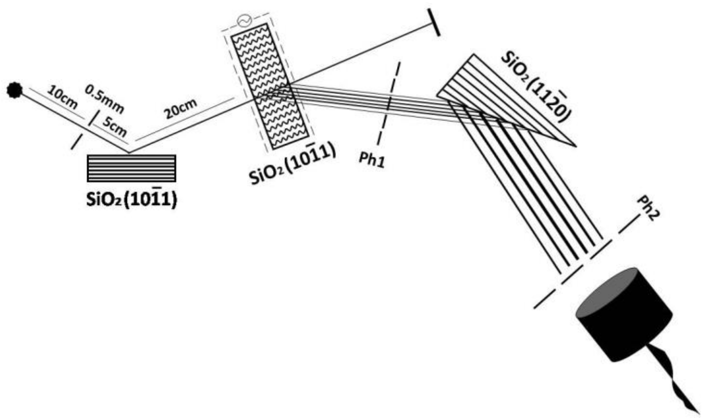

Fig.1. Experimental scheme.

The experiments showed that the intensity of the reflected beam increases with the increase of the amplitude of the electromagnetic field applied to the second crystal with a resonant frequency (fig.2).

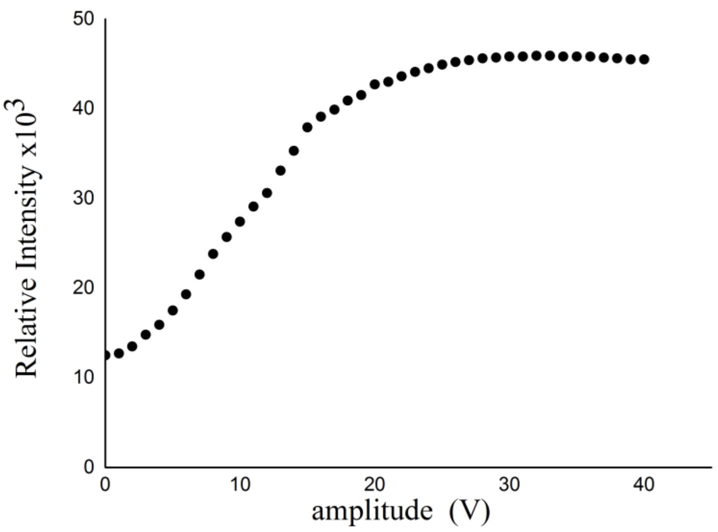

Fig. 2. The intensity of the reflected beam depending of the amplitude of the electromagnetic field applied to the crystal with a resonant frequency of 4.89MHz.

Increasing amplitude of the electromagnetic field, applied to the crystal with a resonant frequency, means that the amplitude of the acoustic wave exciting in the crystal increases. Acoustic wave leads to the curvature of the reflecting atomic planes $(10\bar{1}1)$ of the crystal. The experiments showed that starting at a certain value of the amplitude of the acoustic waves (the curvature of the reflecting atomic planes) at the nodes of the standing wave, the Bragg condition is violated. However, from antinodes the intense reflected X – rays are formed. As a result, the reflected X – ray beam splits, and narrow beams are visible in the cross section of the reflected beam (fig.3), the number of which is equal to the number of antinodes of the standing acoustic wave.

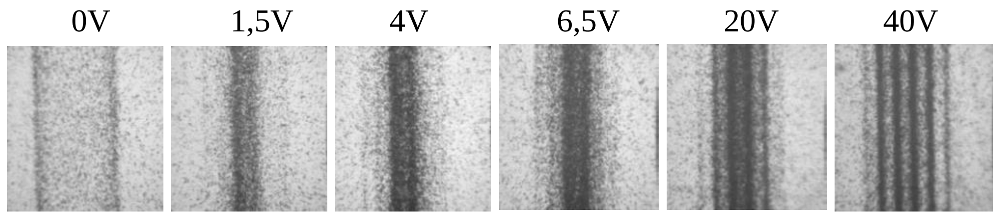

Fig. 3. The formation of narrow x-ray beams from a crystal under the excitation of the standing acoustic wave at a fifth-order resonant frequency.

Experiments show that with an increase in the order of the resonant frequency, the number of narrow X – ray beams also increases (fig.4).

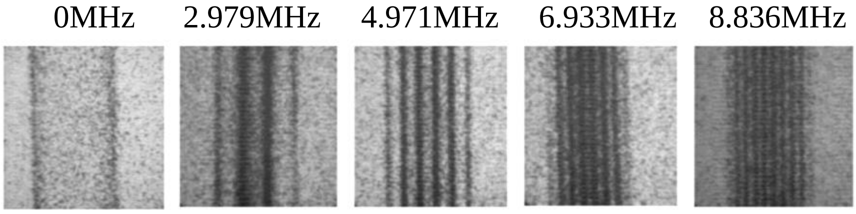

Fig.4. Narrow X-ray beams formed from a crystal under excitation of a standing acoustic wave with the different order of resonant frequency.

The formation of parallel X – ray beams in the frontal section from the second “splitter” crystal, falling on an asymmetric crystal, is reflected and their distance increases more than 20 times (fig.5).

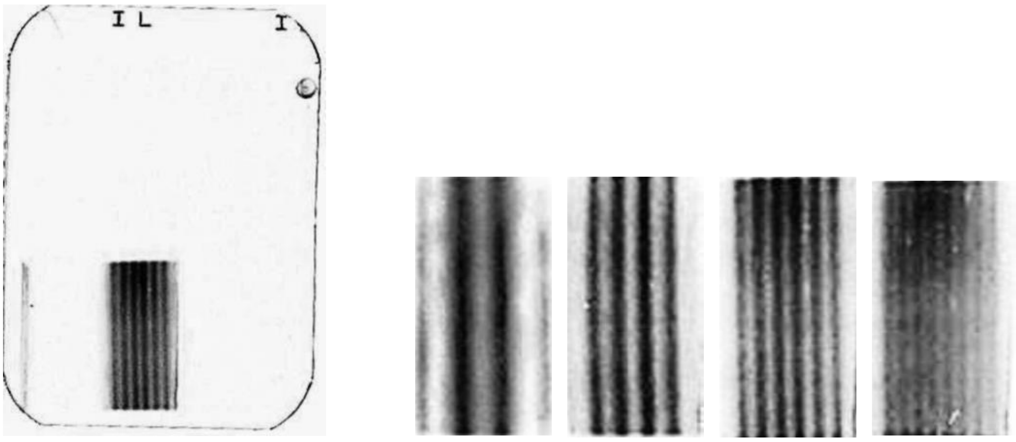

Fig.5. Parallel x-ray beams after an asymmetric crystal

3. Conclusion

Thus it is shown that, using such a three-crystal scheme, it is possible to obtain any number of parallel X – ray beams and control their distances in wide ranges.

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Conflict of Interest

There is no conflict of interest.

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