Active quartz monochromator

A.S. Gogolev, Yu.A. Popov, A.R. Wagner, A.P. Potylitsyn
Tomsk Polytechnic University, 30, Lenin Avenue, Tomsk, 634050, Russia
E-mail: alextpuftf@tpu.ru

Abstract. The experimental results of the active X-ray monochromator research based on quartz crystal with ultrasonic waves are reported in the paper. At frequency of \( f = 5.46 \) MHz the intensity increasing of diffracted L\( \beta_1 \) line tungsten beam by 100% was detected. The tension amplitude of variable electric field causing acoustic excitement was equal to 10 V. The relationship between external impact parameters and diffracted beam intensity were studied.

1. Introduction

Many experiments demonstrate the advantages of using monochromatic X-ray radiation of high intensity for different applications in science, technology and medicine (see, for example [1]). As a rule, in such tasks monochromatization bremsstrahlung or synchrotron radiation (SR) by crystal monochromator is used. SR beam parameters received in electronic storage is undoubtedly exceed parameters of other monochromatic sources. However, due to the high cost of such facilities it remains unavailable for public use, for example, in medical diagnosis. On the other hand X-ray tubes are commercially available and easy to use but the intensity of the monochromatized beam for most tasks is below the required values [2].

In the works [3, 4] the authors demonstrated the possibility to increase the intensity of the diffracted beam when on the piezo-electric crystal monochromator to influence by acoustic or non-uniform temperature field. The authors of [5-7] have shown the possibility to control spatiotemporal characteristics of the diffracted radiation by means of surface acoustic waves. As an alternative way to increase the intensity, listed in the cited works, in the article [8] the piezoquasimosaic effect is proposed to use.

In this paper we investigate the possibility of creating active elements of the X-ray optics based on piezo-electric crystals with the external deformation fields.

2. Experiment

The experimental setup is shown in Fig. 1. As X-ray source a pulsed X-ray tube with a tungsten anode RAP 160-5 was used. All measurements were performed with the same parameters of the tube, the voltage and average current were 60 kV and 1 mA, respectively. X-ray machine was placed in a lead house with a wall thickness of 5 cm. Radiation was formed by collimator with diameter 3 mm located at a distance of 90 mm from the output window of X-ray tube, and then fall onto a quartz crystal mounted in a remotely controlled goniometer at a distance of 215 mm from the collimator.
Goniometer has three translational and three rotational freedom degrees with an accuracy of orientation not worse than 0.5 mm and 10 \( \mu \)rad, respectively. It is possible to install the crystal at the Bragg angle for any families of reflecting atomic planes, so that a detector located in the horizontal plane could register only beams propagating in this plane. In the experiment the X-cut quartz crystal with diameter of 15 mm and thickness of 0.5 mm with a silver sputtering was used. The reflection from atomic planes oriented perpendicular to the large surface of the sample (10-11) with interplanar distance \( d = 3.3429 \) Å is studied. Radiation was registered in the Laue geometry by scintillation detector (NaI) working in current mode at a distance of 620 mm from the crystal monochromator. The diameter of the sensitive volume was equal to 30 mm with a beryllium output window thickness of 20 \( \mu \)m which provides to register x-ray radiation in the range from 8.5 to 50 keV with the efficiency of not less than 60\%. Slit collimator with a 30×3 mm before detector was placed for decrease background radiation. L\( \mu \)l-line of tungsten with an energy of 9.671 keV for which the Bragg angle is \( \theta_B = 11.09^\circ \) for quartz reflection (10-11) was observed. For the ultrasound excitation in the quartz a generator of sinusoidal electrical pulses with smooth changes of amplitude from 0 to 10 V and frequencies from 1 Hz to 25 MHz was used.

To find the reflex (10-11) the angles of \( \theta \) and \( \phi \) were scanned, and then orientation angles corresponding to the maximum yield of the diffracted radiation were selected.

Fig. 2 shows the study results of the diffracted beam intensity dependence on the excitation frequency. The piezo-electric resonance frequency is determined by the formula \( f_n = n c/(2l) \), where \( n \) - odd integers, \( l \) - thickness of the crystal, \( c \) - ultrasonic waves velocity in quartz by about 5700 m/s [9].

As seen from Fig. 2 at frequencies of 5.46 and 16.42 MHz, corresponding to the first and second piezo-electric resonance, the increasing of diffracted beam intensity was observed, whereas at a frequency of 10.92 MHz increasing the intensity of the radiation was not observed. The FWHM of the resonances was 28 kHz in both cases.
The following figure shows the study results of the diffracted beam intensity dependence on the amplitude of the external electromagnetic influence on the crystal-monochromator. The radiation intensity increases linearly in the diffraction direction to increasing voltage electromagnetic oscillations.

Fig. 3 shows the orientational dependence of the diffracted radiation yield at a voltage $U = 10$ V for the first resonance and the absence of external field. On the fig. 4 zero corresponds to the angle orientation of the crystal 11.09° relative to the initial direction of radiation. The figure shows that the diffracted radiation intensity is more than without external influence in two times, with the width of the rocking curves differing slightly. Rocking curve width is determined primarily with the beam divergence and an angular capture detector $\Delta\theta = 4.9$ mrad which corresponds to the deviation from the Bragg angle $\Delta\theta_B = 2.5$ mrad.
3. Conclusion
Experiments showed the possibility of creating active X-ray monochromators based on quartz crystals with ultrasonic vibrations. With the help of external influence on the crystal monochromator the control change and increase the intensity of the diffracted X-ray beam were carried out.

Based on the effects of the deformation fields influence on the X-rays scattering can be constructed the new elements of X-ray optics. In particular, active monochromators with acoustic waves will increase the luminosity of the monochromatic sources and transport of intense monochromatic X-ray beams without loss. In [4] the possibility of strengthening the diffracted radiation on the order of magnitude when increasing the voltage field was indicated.

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