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Diffraction of Modulated X-Ray Beams from Quartz Crystal at the Presence of Temperature Gradient

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Abstract. The two-crystal diffraction of X-ray radiation from the reflecting $(10\overline{1}1)$ atomic planes of a quartz single crystal in the Laue geometry is studied experimentally when the first crystal is in the field of volume acoustic waves and the second crystal is under the influence of a temperature gradient. It is shown that a spatially modulated beam formed from the first crystal can be completely pumped to 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.

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

1. Introduction

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 a temperature gradient or ultrasonic oscillations was first observed in refs [1, 2]. Since the dependence of the intensity of the reflected X-ray radiation on the parameters of the external influence 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 [3-5].

In [6, 7], 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. 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 AC voltage applied to the crystal.

In this paper, we consider the possibility of transfer spatially modulated beams from the reflecting atomic planes $(10\overline{1}1)$ of quartz single crystal with the condition of conservation of the angular aperture and spatial distribution with the help of a second crystal under presence an external temperature gradient.

2. Experiment

The experimental study was carried out on an X-ray DRON-3 installation with an anodic molybdenum tube BSV-25, the voltage on the tube was fed 30 kV at the anode current of 10 mA. (The size of the focal spot of the source is 0.2×10 mm^2). A two-crystal (n; -n) diffraction scheme was used (Fig. 1).

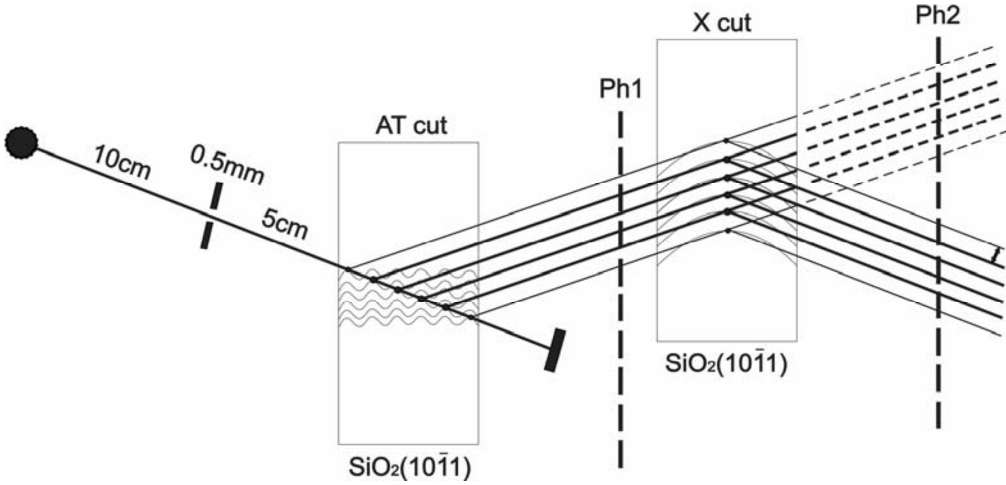

Fig. 1. The experimental scheme

At a distance of 10 cm from the source, a slit with a width of 0.5 mm was installed. Passing through the slit, the beam falls on a quartz single crystal, which is placed at 5 cm from the gap in the Laue geometry. The collimation of the beam is chosen so that only the radiation of MoKα_1 (Bragg angle 6°6') is reflected from the atomic planes ($10\bar{1}1$). After the first sample, in the direction of the reflected beam, a second single crystal of quartz was identically installed at a distance of 18 cm. The X-ray beam was registered with the detector at a distance of 20 cm from the second crystal. The cross sections (Ph1, Ph2) of the reflected beams from the first and second crystal were recorded at a distance of 10 cm using an X-ray film. The first crystal (the shaper of the modulated beams) was a plate in the form of a 1.7 mm thick washer made of an AT-cut quartz single crystal whose surfaces were covered with contacts of an aluminum layer with a thickness of less than 10 µm. Excitation of volume acoustic waves in the crystal was carried out with an electromagnetic waves generator, which was connected to the contacts of the crystal [6]. The second sample-crystal was a rectangular plate with dimensions of 2.4×2.9 cm^2, 2 mm thick, made of quartz single crystal of X-cut. The temperature gradient was created with the help of a spiral heater which was placed in parallel with the reflecting atomic planes ($10\bar{1}1$) at one of the edges of the crystal, where the temperature gradient vector and the diffraction vector were antiparallel [11].

A spatially modulated beam was formed from the first quartz crystal with an AT-cut at an external acoustic field. As is known [6-10], the bands are formed from a certain value of the amplitude of an alternating electric field, and the number of which depends on the order of the resonance frequency. Applied to the first crystal AC voltage is 40 V and at frequencies of 2.936 MHz, 4.888 MHz, 6.843 MHz, i.e. the number of bands in the formed beam (incident on the second sample crystal) was 4, 6, and 8, respectively. Without excitation of the first crystal, the intensity of the reflected radiation was 14000 pulses/sec. The intensity of the reflected radiation from the first quartz crystal at the excitation frequency of 2.936 MHz, 4.888 MHz and 6.843 MHz at an AC voltage of 40 V was 113000 pulse/sec. Under these conditions, the intensity of the passing modulated beam from the second crystal was 37000 pulses per second, and the intensity of the reflected beam was 2300 pulse/sec. After 13 V voltage was applied to the spiral heater of the second sample, the intensity of the transmitted beam was 7200 pulse/sec, and the reflected intensity from the second sample was 29400 pulse/sec.

In Fig. 2(a,b,c) are shown the cross-sections of the reflected (formed) beams at a distance of 10 cm from the first sample, when the first sample is excited at a frequency of 2.936 MHz, 4.888 MHz and 6.843 MHz, respectively (the exposure of the photographs was 5 minutes). In Fig. 2(d,e,f) are shown the cross sections of the reflected beams at a distance of 10 cm from the second sample in the presence of a temperature gradient with a voltage of 13 V applied to the spiral heater (the exposure of the photographs was 10 minutes), with the corresponding incident (formed) beams.

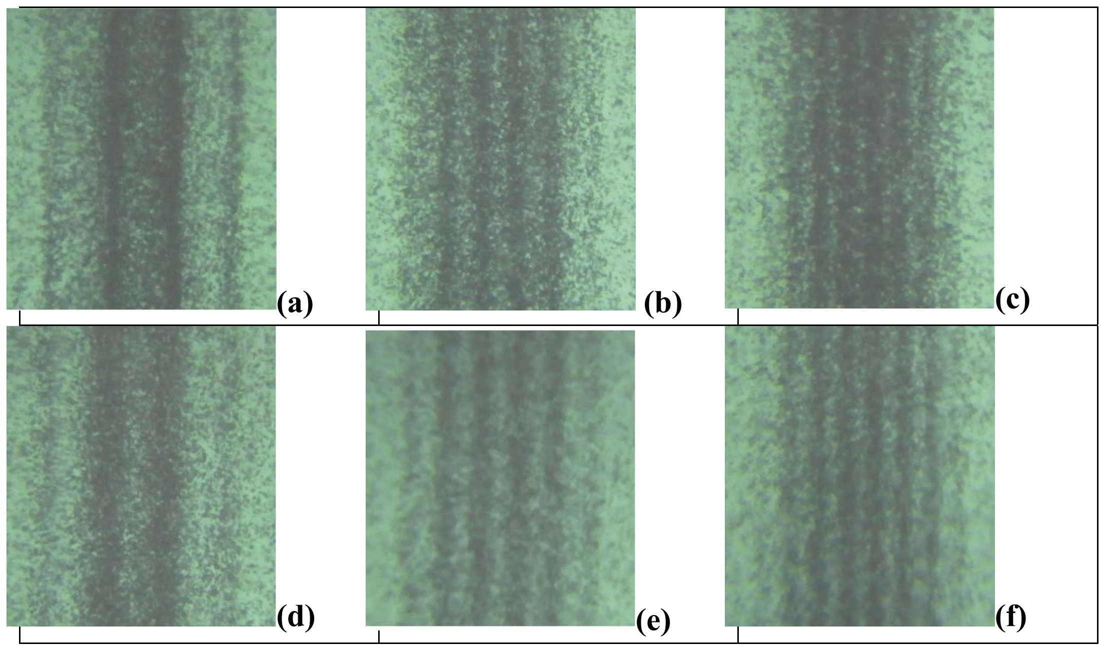

Fig. 2. The cross sections of the formed beam (a, b, c) in the presence of acoustic waves in the first crystal with the frequency of 2.936 MHz, 4.888 MHz, 6.843 MHz and the cross sections of the reflected beam (d, e, f) from the second crystal, when a voltage of 13V was fed to a spiral heater, respectively.

3. The discussion of the results

It is known that the bands are formed from the antinodes of a standing acoustic wave. Consequently, they propagate from each other at distances $\Delta x = \lambda_a \sin\theta \cos^2\theta$, where λ_a – the length of acoustic waves and θ – the Bragg angle [10]. That is, in the presence of acoustic waves, when a narrow collimated beam falls on the first crystal at a Bragg angle we have reflected X-ray beams (bands) with a number corresponding to the condition m = n + 1, where n is the order of the harmonic and takes odd values [7]. Thus, n+1 parallel X-ray beams fall at the second crystal at a distance Δx from each other (Fig. 1). As a result, the shaped (spatially modulated) beam incident on the second crystal, when there is a certain value of the temperature gradient (voltage on the spiral heater is 13 V), is transferred from the transition direction to the reflection direction, without changing the characteristic of the formed beam from the first crystal.

4. Conclusion

Thus, it was experimentally shown that when using a two-crystal X-ray diffraction scheme from the reflecting atomic planes $(10\bar{1}1)$ of a single crystal of quartz in Laue geometry, when the first crystal is under the field of volume acoustic waves and the second crystal is under the influence of a temperature gradient, it is possible for a certain value of the temperature gradient applied to the second crystal completely transfer to the direction of reflection the generated modulated beams obtained from the first crystal, with securing the spatial distribution of the beam.

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