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Beam suppression and focusing in multi-plate crystal cavity with compound refractive lenses

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Fabry-Perot type multi-plate crystal cavities consisting of compound refractive lenses were prepared on silicon wafers by micro-electronic lithographic techniques. The crystal orientation of this X-ray optical device is the same as that of the two-plate x-ray resonators reported (Phys. Rev. Lett. 94, 174801, 2005). Experimentally, X-ray (12 4 0) back diffraction from these monolithic silicon crystal devices for various photon energies showed interference fringes as a function of photon energy due to cavity resonance, but with less pronounced amplitudes. The expected focusing effect from the CRL is observed and energy-dependent focal length is detected. Detailed analysis on cavity interference and beam focusing will be discussed.

Keywords: focus, compound refractive lens, cavity

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Beam conditioning by diffractive-refractive crystal monochromators in Bragg and Laue geometries

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Beam shape conditioning and high-resolution monochromatization for laboratory and synchrotron sources is achieved by crystal monochromators with flat surfaces. In coplanar geometries, Bragg reflection geometry is used for single flat diffractors, double diffractor arrangements and Bartels monochromators working in parallel beam set-up. On the other hand, diffractive-refractive optical devices involve non-coplanar geometry arrangement. Devices with V-shape arrangement of flat diffractors or with cylindrical or parabolic grooves set in Bragg non-coplanar geometry focus the incident beam into a distant focal spot. Their focusing properties and their aberrations were studied in the past. Recently, we have extended studies of the diffractive-refractive devices into the Laue geometry. Then both the transmitted and the diffracted beams pass through the device. Therefore, these devices can be prepared as a flat thin plate or as a shaped plate-parabolic, double-parabolic or double-tunnel crystals. Theoretical predictions and the first experiments by synchrotron radiation show focusing properties as well. We will present results of the beam propagation and focusing properties resulting from aligning a sequence of these devices with crystal diffractors with high asymmetry.

Keywords: X-ray optics, monochromators, synchrotron radiation

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Study of complete transfer phenomenon for media with various thermal conductivity

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In this work the effect of complete transfer (from diffracted-transmitted direction to the diffracted-reflected direction) of x-rays for the media with different thermal conductivity is considered in presence of temperature gradient (TG). The media with different conductivities were experimentally realized by simply changing the pressure of the same medium. It has been found experimentally in a quartz monocrystal that the relative intensity of the beam depending from the TG is increasing and at the certain values is saturating. It is seen that with decreasing the pressure from 760 Torr until 10 Torr, decreasing also the corresponding to the complete transfer the magnitude of the TG. The consequent decreasing of the pressure results to increasing the magnitude of the corresponding TG. No saturation is taking place at the smallest pressure (0.03 Torr). We have to mention that for the transmitted beam taking place the contrary scenario. With the increasing the TG the intensity of the beam is decreasing practically until the zero. In order to explain the obtained results it has been solved the thermal conductivity equation with the boundary conditions corresponding to the experiment. We have obtained the expression for the displacement function $U_x(x,z)$. It is shown that $U_x(x,z)$ is solution of Takagi equations only in case of condition of the complete transfer and that solution is unique. In that case the behavior of the relative intensity of the diffracted beam is well matching with the results of the experiment. In fact we have found the relation in between wave and corpuscular processes in case of condition of the complete transfer. Method for measuring the thermal conductivity coefficient is proposed based on obtained results.

Keywords: dynamical X-ray diffraction theory, heat transfer, crystal lattice distortion

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Observation of rocking curves in Bragg-Laue case

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High resolution rocking curves of X-rays in Bragg-Laue case diffracting have been measured by using synchrotron radiation at KEK-PF in Japan. The measured rocking curves are shown in Fig. 1. The used X-ray energy was 11100 ± 0.5 eV and its angular resolution was about 0.3 arcsec. The distance (L) from incident point of X-ray to the side edge of the sample was 143 μm. P_h is the intensity of diffracted beam from the incident surface, P_h' and P_t' are those of the diffracted and transmitted beams from the side surface, respectively. The peak heights of the three rocking curves are normalized so as to show the same height. The abscissa is the angle deviation from the exact Bragg condition. It is noted that the intensities of P_h' and P_t' are approximately ten times smaller than that of P_h, and the FWHM

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of P_h' is about three times narrower than that of P_h. Fig.2 shows the calculated rocking curves by using Wagner's dynamical theory (Wagner, H. (1956) *Z. Phys.* **146**, 127). The measured rocking curves show excellent agreement with the calculated one. Consequently, the characteristics of P_h, P_h' and P_t' in Bragg-Laue case are reproduced by using the theory.

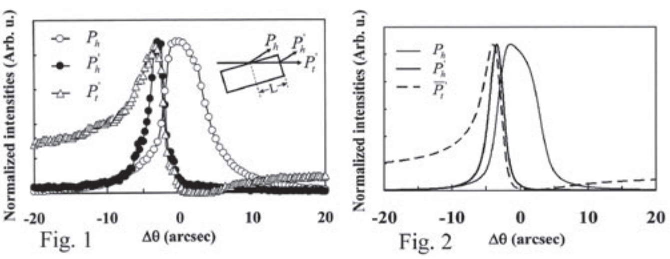

Fig. 1 Fig. 2

Keywords: Bragg-Laue case, dynamical diffraction, dynamical X-ray diffraction theory

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Interference fringe in Bragg-(Bragg)^m-Laue case

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The interference fringes of the diffraction from the side surface on the finite thin plane parallel crystal have been observed [1]. This diffraction scheme as shown in Fig.1 may be called as Bragg-(Bragg)^m-Laue case, where the first Bragg means the Bragg case and the second (Bragg) a sequence of "m" times diffractions in the crystal and the last Laue the last diffraction on the side surface. The measured interference fringes of the diffracted X-rays from the side surface are shown by the solid line in Fig.2. We tried to analyze the origin of the interference fringes using the Wagner's dynamical theory [2]. In Fig.1, the X-ray beams from the two courses of S1 and S3 are overlapped each other at $x=b$. The calculated interference fringes shown by the broken lines in Fig.2 excellent agree with the measured one's except the peek at $x=H$. Since the peek at $x=H$ can not produce the interference between two beams of S1 and S3, it peek seems to be obtained by the X-ray confinement effect as pointed out by the reference [3].

[1] Fukamachi, T. et al. (2004,5). JJAP. **43**, L865-867.and **44**, L787-L789.
[2] Wagner, H. (1956). Z. Phys. **146**, 127-168.
[3] Fukamachi, T. et al. (2006). JJAP. **45**, 2830-2832.

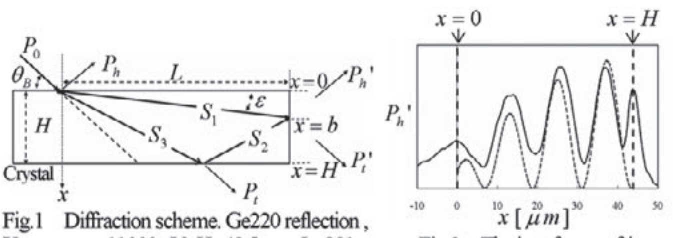

Fig.1 Diffraction scheme. Ge220 reflection, X-ray enagy:11000 eV ,H=43.5 μm ,L=891 μm. Fig.2 The interference fringes.

Keywords: interference fringe, Bragg case, X-ray confinement effect

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Observation of in-phase interference fringes

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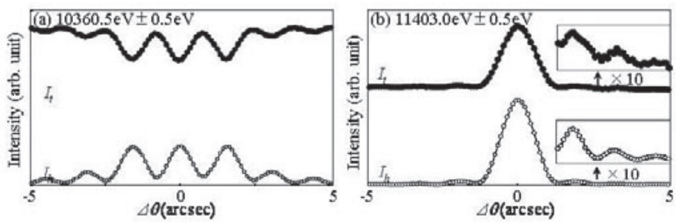
By using X-rays of high angular and energy resolution, we have measured the diffracted and transmitted rocking curves of GaAs 200 reflection near the K-absorption edge of As [1]. X-rays from synchrotron radiation are monochromated by a Si 111 double-crystal monochromator and by an asymmetric GaAs 200 monochromator. The angular resolution of the X-rays after passing the monochromators is 0.23 arcsec. In the figures are shown the diffracted Ih (open circles) and transmitted It (filled circles) rocking curves when the X-ray energy is 10360.5 eV (a) and 11403.0 eV (b), respectively. In (a), well-known Pendellosung fringes that are anti-phase with each other in the diffracted and transmitted waves are observed. In contrast, in (b), the interference fringes are in phase with each other, which is not expected according to conventional theory of diffraction. The insets of (b) show the magnifications of the tail, which show three peaks of the in-phase oscillations. The origin of the in-phase interference fringe is analyzed to be characteristic to the diffraction only by the imaginary part of the atomic scattering factor.

[1] Negishi, R., et al., J. Phys. Soc. Jpn., 2008, 77, 023709.



Keywords: interference fringe, resonant dynamical theory, anomalous scattering factor

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Anomalously large dispersion angle of refracted wave in Bragg case

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X-rays transmitted from a Ge thin crystal in Bragg case have been observed on a nuclear plate as shown in Fig (b), when the beam intensities from the side surface become maximum. Fig. (a) shows an illustration of geometry in the experiment. The dispersion angle $\delta\theta$ of the incident beam is 0.25 arcsec, and the beam width along the dispersion angle is 20 μm. The width of the observed transmitted beam is 143 μm. Using Wagner`s dynamical theory of diffraction [Wagner H. (1956), Z. Phys. **146**, 120-168.], we have studied why the width of the transmitted beam is so wide. If we choose ε as the angle between the directions of the refracted beam and of the crystal surface as shown in Fig. (a), ε changes from zero to approximately Bragg angle within the angle of $\delta\theta$ in the experiment. When the refracted beams reach at the bottom surface, a part of them come out and are