

Focusing Effects in Parabolic Shaped Multi-plate Crystal Cavity for X-rays

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The Fabry-Perot type multi-plate crystal cavities consisting of compound refractive lenses (CRL) on silicon wafers are prepared by using micro-electronic lithographic techniques. Each refractive lens is a parabolic shaped concave lens. The crystal orientation of this X-ray optical device is the same as that of the two-plate x-ray resonators reported. Experimentally, the transmitted X-ray beam size of the (12 4 0) back diffraction through these monolithic silicon crystal devices is measured with a fine knife-edge.

The incident radiation was monochromatized first by a Si (111) double-crystal and then by a four-crystal ultra-high resolution monochromator, to give the energy

resolution $\Delta E = 0.36$ meV at 14.4388 keV. Schematic of

compound refractive lenses with the (12 4 0) satisfying back reflection is shown in Fig.1. Each hole serves as a crystal cavity of a Fabry-Perot type. The crystal between two adjacent holes serves as an x-ray lens. Diffraction experiments from these devices with successive forward transmission and backward reflection are then performed and the beam size of the transmitted beam through the devices is measured to investigate possible focusing effects.

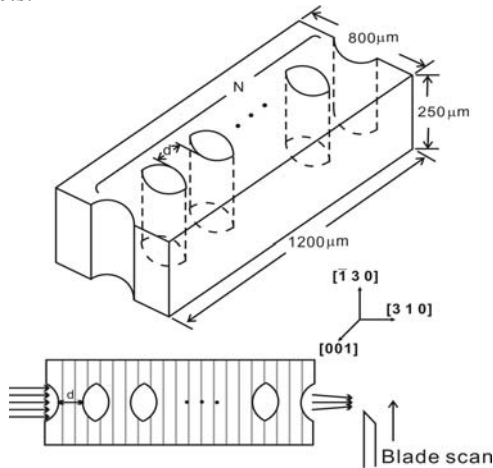
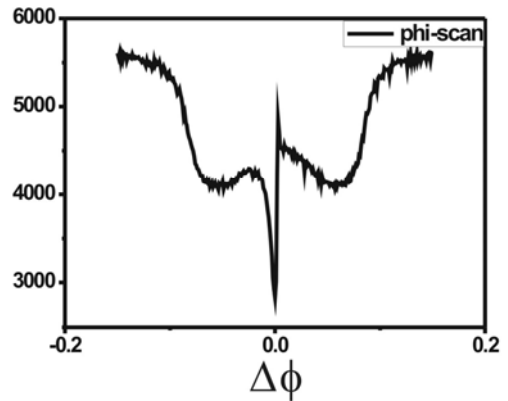


Fig. 1

The lens formula, $F = R/2N\delta$, was used to device the crystal cavity with the CRL by considering mainly the refractive focus. The surface of the concave lens was in parabolic shape. The focal length of our design is 715 mm. An 8-circle diffractometer was used to align the (12 4 0) back diffraction. The horizontal tilt of the crystal device, $\Delta\phi$, shows the intensity dip at $\Delta\phi = 0$

in Fig. 2(a), indicating that the photon energy is 14.4388 keV. The beam size of the transmitted beam through the crystal devices was then measured by using a knife edge across the beam at different positions along the beam direction. The red curve of Fig. 2(b) shows the optical refractive focusing. As can be seen, the transmitted beam was focused to the point 750 mm from the end of the cavity. And the focused beam size $\sim 9 \mu\text{m}$. The optical result agrees with the theoretical calculation. The black curve of Fig. 2(b) shows the diffractive focusing. The transmitted beam was focused to 360 mm and the focused beam size $\sim 6.5 \mu\text{m}$. The focal length is reduced by nearly a factor of 2.

(a)



(b)

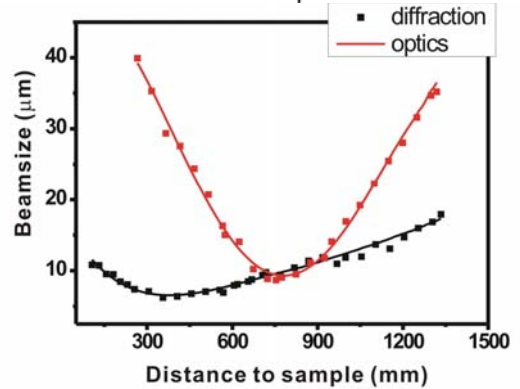


Fig. 2

In conclusion, we have observed unusual optical effects in curved multi-plate x-ray crystal cavities consisting of compound refractive lenses. Thus, a small sized x-ray beam is produced. This enhanced beam-focusing, governed by the curvature of the curved CRL, is due to the change of the direction of the wavevector of the transmitted beam during the excitation of the dispersion surface of the back reflection. This focusing mechanism may find usage in producing small sized x-ray beams in very low-emittance synchrotron facilities.