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Compound Refractive Lens Optics for Microbeam X-ray Diffraction Measurements at BL13XU in SPring-8

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X-ray diffraction techniques using X-ray microbeam is a powerful tool to investigate local structure of crystals such as lattice distortion and inclination. At beamline BL13XU in SPring-8, we have used a Fresnel zone plate (FZP) as a focusing device for microdiffraction experiments so far [1, 2]. However, FZP has disadvantages as its low efficiency for high-energy X-rays over 20 keV and the degradation by radiation damage and contamination. Compound refractive lens (CRL) is one of the promising devices to overcome these problems. CRL has high efficiency for high-energy X-rays, robustness, and easy on-axis alignment. Recently, we have developed a transition system between FZP and CRL optics at BL13XU. In this paper, we describe the CRL optics and its performance for microdiffraction at BL13XU.

Figure 1 shows the details of the transition stage. On the upper terrace, an alignment stage of two CRLs is arranged, which enables us two-dimensional focusing in both horizontal and vertical direction in a crossed geometry. A stage for FZP including a center beam stop is mounted on the lower terrace. The transition is performed by a manual Z-stage. The position of the Z-stage is precisely adjusted by micrometers with a resolution better than 1 μm.

X-rays from an in-vacuum undulator are limited by several slit in the transport channel, which act as secondary sources. The X-ray energy is tuned from 8 to 30 keV by a Si(111) double crystal monochromator, followed by total reflection mirrors to remove higher order harmonics. The FZP unit and CRL unit are selected as the X-ray energy. A pair of CRLs is aligned in a crossed geometry to focus X-rays in both horizontal and vertical direction. A small aperture is arranged at the downstream of the focusing device to reduce background.

For focusing high-energy X-rays, we use CRLs made of quartz glass [3]. Quartz has suitable properties for the lens material such as high uniformity, relatively low density similar to silicon crystal, high affinity for microfabrication process, and amorphous structure without cleavage. We successfully applied 100-μm-deep etching for the fabrication of the lens, which realize high-efficient microfocusing. The optical microscopic image of the lens is depicted in Fig. 2. We prepared CRLs made of quartz glass for X-ray energy of 20, 25, and 30 keV. Rectangular regions on the side of the lens, which corresponds to the phase variation between the lens material and air by the multiple of 2π within the lens thickness, were removed for reducing the absorption of X-rays [4, 5]. We designed pairs of the lenses with focal distances of 100 and 200 mm for focusing both horizontally and vertically.

The focused beam sizes and photon fluxes are summarized in Table 1. At each energy, we successfully obtained the beam sizes less than 3.2 μm in both horizontal and vertical direction. At 30 keV, the beam size was large compared with the sizes at the other energies. For high-energy X-rays, the radius of the lens paraboloid is quite small, thus it is considered that the shape error which was introduced in the fabrication process largely influenced the focused beam size. By careful investigation of the focusing performance of the lens, we found that the focal position fluctuated along the beam axis as the illuminated position on the lens moved. This indicates that the radius of the paraboloid changes as the illuminated position. For further improvement of the performance of the lens, the refinement of the fabrication process is necessary.

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References:

[1] Y. Imai et al, AIP Conf. Proc. CP1221 (2010) p. 30.
[2] Y. Imai et al, Proceedings of the 7th International Symposium on Advanced Science and Technology of Silicon Materials (2016) p. 31.
[3] S. Kimura et al, Jpn. J. Appl. Phys. **55** (2016) 038001.
[4] V. Aristov et al, Appl. Phys. Lett. **77** (2000) p. 4058.
[5] V. Aristov et al, Optics Communications **177** (2000) p. 33.

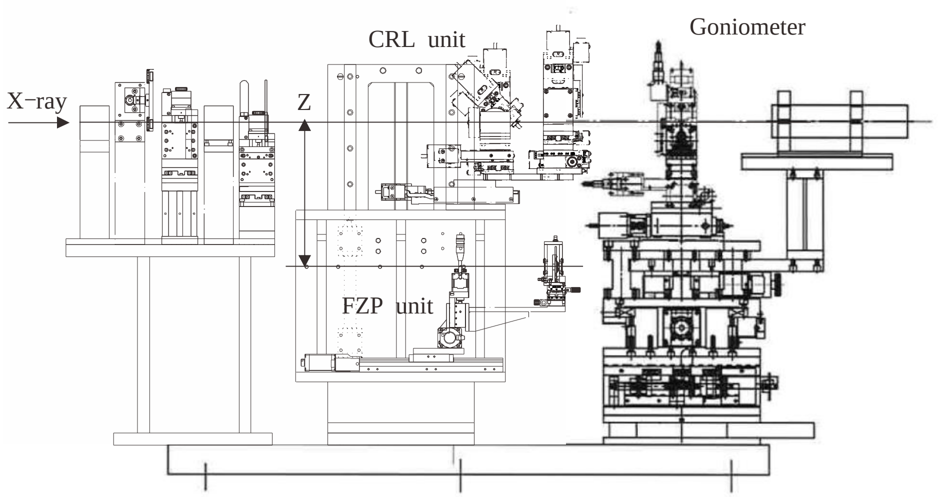

Figure. 1. Transition system between FZP and CRL optics. The vertical position of the unit is adjusted by a manual Z stage so that the appropriate unit is aligned on the optical axis.

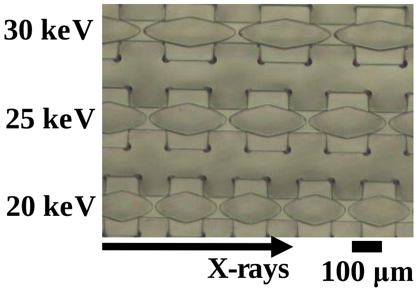

Figure. 2. Optical microscopic image of the CRLs made of quartz glass for 20, 25, and 30 keV.

Energy (keV)	Device	Beam size (µm)		Photon flux (photon/sec)
		Horizontal	Vertical	
8	FZP	0.24	0.31	1.34×10^9
20	CRLs	0.77	2.49	1.29×10^9
25	CRLs	1.11	1.7	3.06×10^9
30	CRLs	2.33	3.2	8.02×10^8

Table. 1. Summary of the beam sizes and photon fluxes.