# Refractive Lens and Zone Plate for Focusing X-ray

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Utilizing a long beam line planned in the SPring-8 project, the subgoup 'Very Small Angle X-ray Scattering (VSAXS)' is going to construct a 1000 m-long SAXS camera which can observe the X-ray scattering in the angle from 10 μrad to 1 rad. Conventional focusing systems such as totally reflecting mirrors or bent crystal monochro-mators are not feasible for this facility with such a long focal length because of the instability of the focal position and of the severe requirement for the flatness of the mirror.

For this reason, we propose the use of refractive lenses for focusing X-rays. The advantages of using a lens system over mirrors and monochromators are (i) the stability of focal position, (ii) the easiness to achieve long focal length, (iii) the straight optical alignment, (iv) the compactness, which allows cooling device to be simpler, and (v) the clear focus with minimum stray radiation.

Refractive lenses for X-ray made of gold can be fabricated by using an ultra-fine lathe developed by Omron Corporation, Nagaoka, Kyoto. Two kinds of concave lenses (radius of curvature: 5 mm; focal length: 100 m for 8-keV X-rays) were made in order to evaluate the accuracy of the shape of lenses fabricated by this method.

A spherically concave lens has been made by directly turning a gold disc of 187 μm in thickness. The profile of the lens was characterized with Form Talysurf S5 (Rank Taylor Hobson). The direct turning of a gold disc gave rise to a large FESS (form error of spherical surface) and an FEFS (form error of flat surface). We developed a new method; sputtering copper of 1 μm thickness onto a beryllium disc and then plating gold on the copper-sputtered beryllium disc. The result was excellent: FESS: 0.8 μm; surface roughness: Ra 0.012 μm.

In order to avoid the severe absorption of X-rays at the off-center part of the lens, a Fresnel lens must be employed. A Fresnel lens with 6 teeth (focal length: 200 m for 8-keV X-rays; diameter: 3 mm) has been fabricated.

The subgroup was recommended by the JAERI-RIKEN SPring-8 Project Team to perform R&D at a 80m-long beam line available in 1998. Hence we have fabricated a new phase-modulating zone plate which is considered to provide a shorter focal length than lenses. The difference of phases between neighboring zones are caused not by the difference between materials, but by that of thicknesses. Fig. 1 shows a SEM photograph of the zone plate. The performance of the zone plate was investigated with a Bonse-Hart camera[2]. X-ray beam transmitted through the zone plate had a wide profile which consisted of the 0th, 1st and 3rd convergent beams (Fig. 2). The 0th beam which gave the strong background is ascribed to the difference in absorption between odd- and even-number zones. We, therefore, proposed absorption-constant phase-modulating zone plates and Fresnel lenses composed of two kinds of materials, e.g., Au and Cu. The thickness profiles of two layers are calculated to give the phase difference and constant absorption [3].

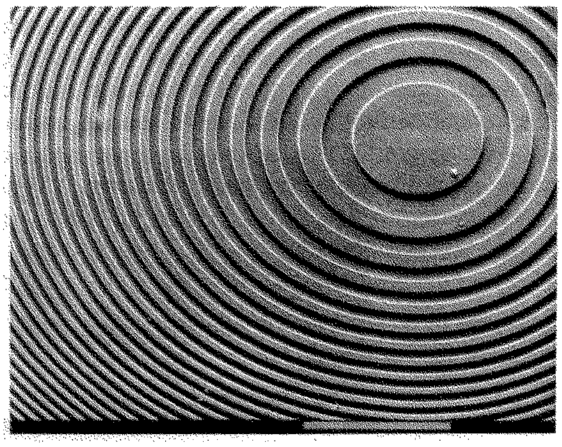

Fig. 1. SEM micrograph of a phase-modulating zone plate. Scale bar is 100 μm.

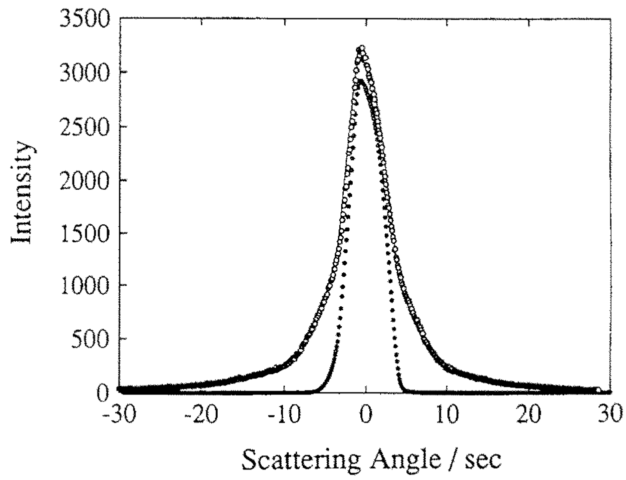


Fig. 2. Line profile of the beam for Cu Kα radiation through the zone plate.

References
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