X-RAY MICROBEAM AND SCANNING MICROSCOPY WITH MULTILAYER ZONE PLATE

Many types of X-ray focusing devices has been developed to generate micro-focused X-ray beams in the hard X-ray region, and sub-µm spot size has already been achieved. Among those types of optical devices, a sputtered-sliced Fresnel zone plate (FZP) has the advantage of a narrow zone width and thickness; *i.e.*, a high aspect ratio of the zone structure. Therefore, the sputtered-sliced FZP is considered to be useful for focusing high energy X-rays. Evaluation of multilayer FZPs in the X-ray regions shorter than 1.6 Å are now in progress at SPring-8 [1].

Experiment have been performed at beamline **BL47XU**. A schematic diagram of the experimental setup is shown in Fig. 1. Undulator radiation is monochromatized through Si 111 double crystal monochromator, and focused by a multilayer FZP. The FZP consists of alternating multilayer zones constructed with magnetron sputtering. Fifty Al/Cu concentric multilayer structures are deposited onto a Au wire substrate with a diameter 47 µm [2-5]. The gold core of the FZP acts as a central beam stop for the FZP with adequate thickness. We have tested two kinds of FZPs with outermost zone widths of 0.25 µm and 0.15 µm. After the deposition, the wire sample is sliced and thinned down to about 20 - 40 µm. The measured focal length of the FZP with outermost zone width of 0.25 µm and 0.15 µm were found to be about 158 mm at 1.4 Å and 234 mm at 0.45 Å, respectively.

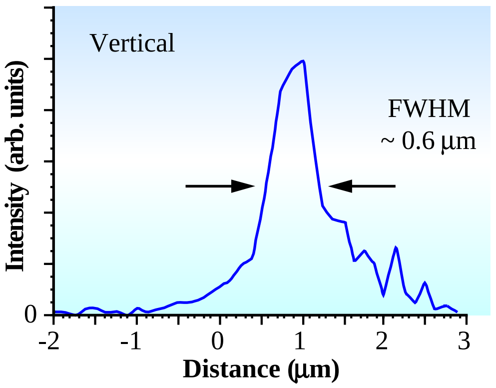

Fig. 2. Focused beam profile measured by edge-scan. X-ray wavelength: 1.4 Å, f ~ 158 mm, pinhole X-ray source (20µm in diameter).

The focused beam profiles measured by edge-scanning for the FZP with an outermost zone width of 0.25 µm are shown in Fig. 2. The thickness of the FZP was estimated to be about 20 µm. The full-width at half maximum of the focused beam was about 0.6 µm at 1.4 Å. This focused beam was generated by using pinhole X-ray source (about 20 µm in diameter) placed 9 m upstream from the FZP. Therefore, the focused beam profile was nearly symmetrical in the vertical and horizontal directions. The present 20 µm thick Cu/Al FZP was expected to operate as a phase-modulation FZP in this X-ray wavelength region, and the efficiency was expected to be higher than 10%, which is the theoretical limit of amplitude-modulated FZP. The actually measured diffraction efficiency at 1.4 Å was about 25%.

The focused beam profile for the FZP with an outermost zone of 0.15 µm is shown in Fig. 3. A focused beam size of 0.7 µm was achieved in the vertical direction. In this experiment the focus spot was generated by demagnification of the undulator light source. Therefore the horizontal spot size (about 4.7 µm) is determined by the source size and the magnification. The FZP was estimated to

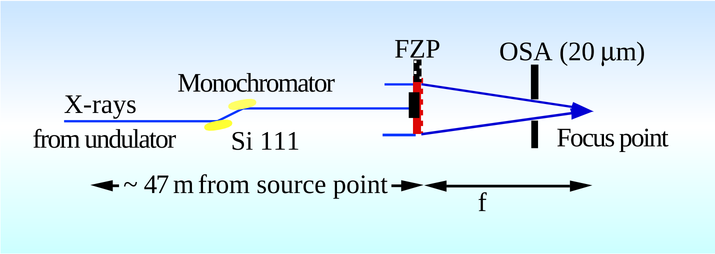

Fig. 1. Schematic diagram of experimental setup.

be about 40 µm thick, with a diffraction efficiency of 15% measured at 0.45 Å. Therefore, this FZP is also considered to be a phase-modulation FZP. The total intensity of the focused beam was found to be 10^{10} photons/s under the focusing conditions shown in Fig. 3. This level of flux of the focused beam should be sufficient for most applications in fluorescent X-ray scanning microscopy. The results of a preliminary experiment in scanning microscopy is shown in Fig. 4. The test sample was a gold mesh, and the Au L-fluorescent X-rays were detected with a scintillation counter.

The efficiency of the 40 µm thick Al/Cu multilayer FZP was expected to be highest at 0.15 Å. The focussed spot image at 0.15 Å taken by the image sensor is shown in Fig. 5. The focal spot appears to be in the center of the image. The spot size was less than 1 pixel (6 µm) wide vertically, and 2 pixels wide (12 µm) horizontal. Although the measured spot size was limited by the spatial resolution of the detector, it was confirmed that the sputtered-sliced FZP with adequate thickness can function as a focusing element for X-rays as short as 0.15 Å.

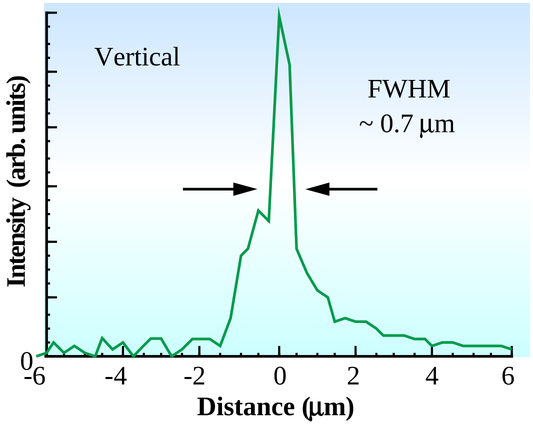

Fig. 3. Focused beam profile measured by edge-scan. X-ray wavelength: 0.45 Å (27.8 keV), f ~ 234 mm.

Yoshio Suzuki

SPring-8 / JASRI

E-mail: yoshio@spring8.or.jp

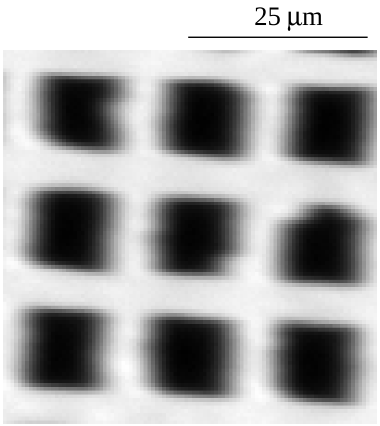

Fig. 4. Scanning X-ray microscopic image.

Sample : #1500 gold mesh (1500 lines/inch)
Image size : 101 × 101 pixel
Pixel size : 0.5 µm × 0.5 µm
X-ray wavelength : 0.45 Å
Integration time : 1 s/pixel
Au L-fluorescent X-ray yield.

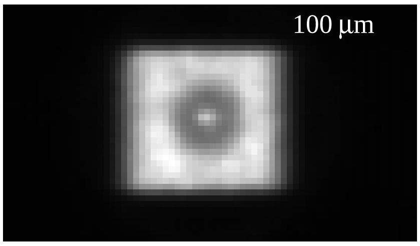

Fig. 5. Focused spot image taken by image sensor. X-ray wavelength: 0.15 Å (82.7 keV), f ~ 690 mm.

References

[1] Y. Suzuki, M. Awaji, Y. Kohmura, A. Takeuchi, N. Kamijo, S. Tamura, and K. Handa, 6th International Conference on X-ray Microscopy Proc., to be published.

[2] Y. Suzuki *et al.*, X-ray Microscopy and Spectromicroscopy **III** (1998) 117.

[3] Y. Suzuki *et al.* , J. Synchrotron Rad. **4** (1997) 60.

[4] N. Kamijo *et al.*, Rev. Sci. Instrum. **68** (1997) 14.

[5] S. Tamura *et al.*, Mat. Res. Soc. Proc. **524** (1998) 31.