Hard X-ray Imaging Microscopy and Microbeam with Fresnel Zone Plate and Quasi-monochromatic Undulator Radiation

Yoshio Suzuki, Akihisa Takeuchi, Kentaro Uesugi,
Katsuaki Inoue, Hidekazu Takano*, and Toshihiko Oka**

JASRI/SPring-8, Mikazuki, Hyogo 679-5198, Japan
**Univ. Hyogo, Kamigori, Hyogo 678-1297, Japan*
***Keio University, Yokohama, Kanagawa 223-8522, Japan*

Fresnel zone plate (FZP) is widely used for imaging microscopy and for microbeam generation in hard X-ray region. Monochromatic X-ray beam is required for the FZP objective because of its strong chromatic aberration. However, the minimum monochromaticity required for FZP optics is equal to the total number of zone in order to achieve the diffraction-limited resolution. The bandwidth of crystal monochromator is usually around 10^{-4} that is much narrower than the required monochromaticity for FZPs. Undulator coupled with low-emittance storage ring provides quasi-monochromatic radiation with a bandwidth of about 1/100 that is well matched to the FZP optics. So, compared with conventional beamlines with crystal monochromator, the much higher flux is available by using the quasi-monochromatic undulator radiation. When it is applied to imaging microscopy, for example, an very short exposure time is expected.

We have performed imaging microscopy and microbeam experiment with FZP objective using quasi-monochromatic undulator radiation without any monochromators. The experiments were done at SPring-8 helical undulator beamline 40XU where the bandwidth of emitted X-ray beam is 1.2% at an X-ray energy of 8.3 keV. A tantalum FZP with outermost zone width of 0.25 micron and zone number of 100 was used as an objective.

An example of imaging microscopy experiment is shown in Fig. 1. This image was taken at an exposure time of 1.5 ms that is shorter than that in conventional beamlines by a factor of 1000. The spatial resolution of imaging microscope estimated by taking images of resolution test object is better than 0.5 micron [1]. In the microbeam experiment, the spot size of focused beam is measured to be 0.9 micron x 1.0 micron at an X-ray energy of 8.3 keV, and the photon flux density is measured to be 2 x 10^{12} photons/s/micron^2. Typical example of scanning microscopy experiments with this microbeam is shown in Fig. 2. Fine structures up to 0.5 micron are observable in the measured image.

1. Y. Suzuki et al., Rev. Sci. Instrum. **75** (2004) 1155.

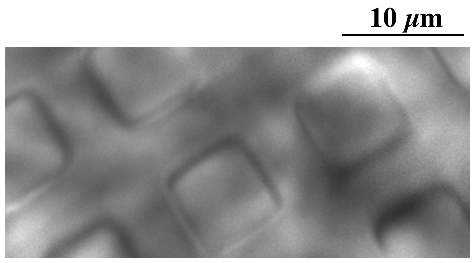

Fig. 1. Result of imaging microscopy.
Sample: copper grid mesh.
X-ray energy: 8.3 keV

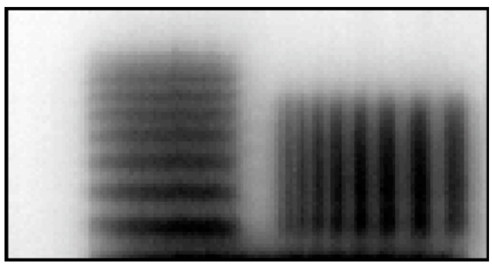

Fig. 2. Result of scanning microscopy experiment with FZP focusing optics.
Filed of view is 12.6 micron x 6.6 micron.
Sample: resolution test patterns.