Hard X-ray Micro-imaging Beamlines at SPring-8
-Present status and some applications-

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There are four public beamlines used for micro-imaging in SPring-8, BL20XU, BL20B2, BL37XU, and BL47XU. Although, these beamlines are not exclusively used for micro-imaging, most of micro-imaging activities can be covered by combining these four beamlines. Details of these beamlines and some experimental results will be presented.

BL20XU is a medium-length (248 m) beamline with undulator light source [1,2]. Although, at the beginning, BL20XU was proposed as a medical imaging beamline, the present major fields in 20XU are R&D of optical systems and optical elements in hard X-ray region (8-110 keV), and coherent optics (holography, speckle, etc.), because its unique property is high-brilliance and high spatial-coherence by utilizing the undulator X-ray source and long beam-transport channel. An example of experimental results is shown in Fig. 1. Hard X-ray microbeam with 100 nm-resolution is attained with a FZP optics [2,3]. The optical devices and optics developed at BL20XU are transferred to other beamlines, and supplied to user experiments. Adding to them, a phase-contrast CT with Bonse-Hart type interferometer is now opened to public use at BL20XU, and 3-dimensional phase-contrast images can be taken with a spatial resolution of 10 μm [4].

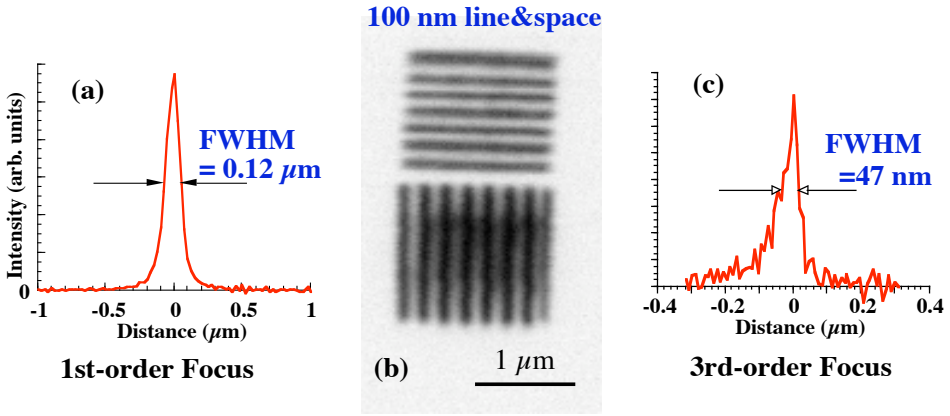

Fig. 1. X-ray microbeam and scanning microscopy experiment at BL20XU.
Outermost zone width of FZP is 100 nm, and focal length is100 mm at 8 keV. (a) focused beam profile of 1st-order diffraction, (b) scanning microscopy image of test patterns, (c) focused beam profile of 3rd-order diffraction. Spatial resolution near to the diffraction-limit is achieved.

BL20B2 is a medium length (215 m) beamline with bending magnet light source[5]. This beamline is used in many fields of imaging techniques; micro-CT with spatial resolution of 10-100 μm, refraction-enhanced imaging, diffraction topography, micro-angiography, etc. The experimental setup for these application is routinely used by many user groups. Majority of the users in BL20B2 is micro-CT for material sciences, planetary sciences, and biomedical applications. The unique feature of BL20B2 is wide beam-cross-section. The beam width at the end station is 300 mm. A single-shot X-ray topography of 12-inches diameter Si wafer can be taken, as shown in Fig. 3. The high spatial-coherence and wide beam size is also appropriate for characterization of X-ray optical element with a large aperture, i.e. X-ray telescope. The 15 m-long experimental hutch at the end station is also significant for this purpose. Characterization (imaging properties and efficiency, etc.) of a hard X-ray telescope with 400 mm-aperture and 8 m-focal length is now being done at BL20B2.

BL37XU is a new public beamline constructed for X-ray fluorescence (XRF) analysis [6]. The BL37XU is designed to be a user-friendly beamline for spectro-microscopy, and high energy XRF experiment up to 75 keV can be done. Microbeam and scanning microscopy with spatial resolution of about 1 μm is routinely performed using the FZP objectives and/or total-reflection mirror optics in the energy region around 15 keV. The microbeam is now used by most of user groups at BL37XU.

BL47XU is named "R&D" beamline, and was designed as a pilot beamline in SPring-8. Now, about 40 % of total machine time of BL47XU is opened for general users, as a multipurpose beamline.

Major activity of public users is micro-CT and microbeam applications. Projection-type micro-CT with 1 μm-resolution is now routinely used for material science and geophysics [7], and imaging-type CT with sub-μm resolution is also achieved using a FZP objective, as shown in Fig. 3 [8]. Micro-beam diffraction is also performed with 0.3 μm-probe size, and now applied to material science [9].

We consider that nondestructive measurement by the combination of micro-CT and microbeam analysis (scanning microscopy, fluorescent X-ray spectroscopy, and micro-diffraction) will be an important tool for material sciences, planetary sciences, and biology.

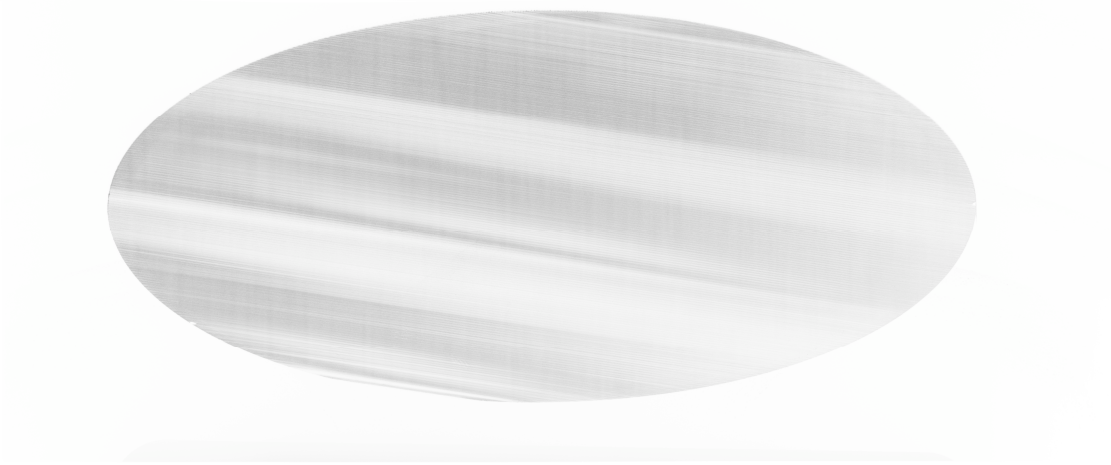

Fig. 2. X-ray Topography of 300 mm-diameter Si wafer taken at BL20B2
X-ray energy: 21 keV

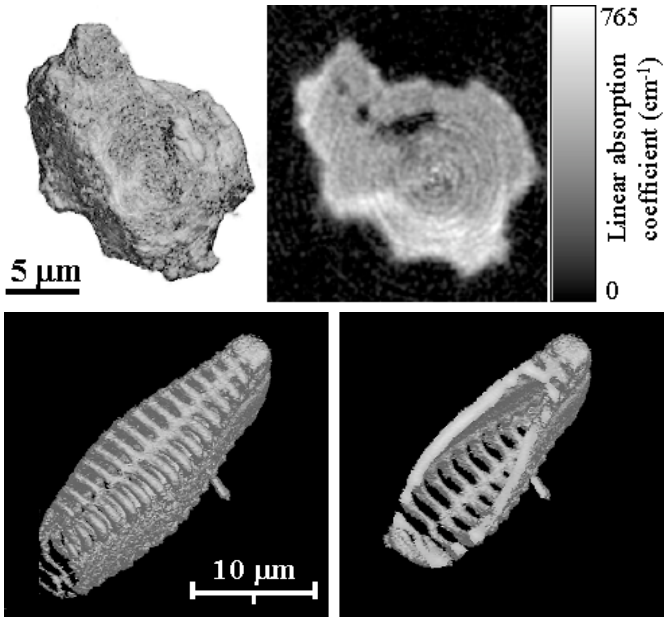

Fig. 3. X-ray microtomography using Fresnel zone plate objective at BL47XU
Sample: stony meteorite Allende (top), and diatom (bottom). X-ray energy: 8 keV,

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