BL47XU
Micro-CT

1. Introduction

BL47XU, which is an X-ray undulator beamline, is dedicated to micro/nano-CT and high-speed X-ray imaging. These experiments need a high-flux-density monochromatic beam. To handle the high heat load of the undulator, a liquid-nitrogen (LN_2) cooling system is used to cool the monochromator crystals. The available energy range is between 6 and 37.7 keV with a Si (111) reflection of the monochromator. To eliminate higher harmonics, a set of reflection mirrors (double bounce in the vertical direction) can be inserted.

The beamline has two experimental hutches (EH1 and EH2) located just after the optics hutch. EH1 contains experimental tables for X-ray micro/nano-CT, while EH2 contains some X-ray optics and X-ray image detectors for nano imaging. Half of EH2 can be used as an open hutch for users who bring their own special equipment. Recently, a chamber for a condenser zone plate (CZP) and a micro-loading system were installed and used for user’s experiments. The details and some results are described here.

2. Developments and Evaluation of Half-transparent X-ray Image Detector

Although X-ray imaging is a useful technique for observing the interior of materials, the information obtained is often insufficient on its own. Therefore, there is a need for multimodal measurement methods that provide complementary information that cannot be obtained by imaging alone with other measurement techniques such as X-ray diffraction and scattering. However, it has been difficult to measure them simultaneously with existing equipment owing to physical limitations between devices.

Recently, the speed of X-ray measurements has increased, enabling in situ observations of material changes at more than tens of hertz. In many cases, the intermediate reaction products that form during the process can affect the reaction; however, they disappear or transform into completely different states at the final stage. Therefore, simply observing the initial and final states makes it difficult to understand the full reaction process. To overcome this, it is necessary to perform multiple simultaneous measurements. In this study, we have developed and evaluated a half-transparent X-ray image detector.

Concepts and appearance of the half-transparent X-ray image detector

The proposed half-transparent X-ray image detector has been developed to enable the simultaneous acquisition of transmission images in conjunction with small-angle scattering measurements (Fig. 1).

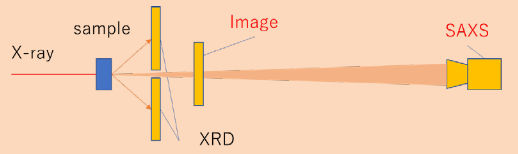

Fig. 1. Illustration of the basic concept of simultaneous measurement.

The detector allows the visualization of X-ray transmission images with a spatial resolution corresponding to a pixel size of approximately 1 μm. Owing to its design, most of the incident X-rays are transmitted through the detector without significant absorption or scattering, thereby minimizing interference with downstream measurements. Furthermore, the detector exhibits high robustness against large irradiation doses, which renders the visible-light conversion-type detector particularly suitable for such applications.

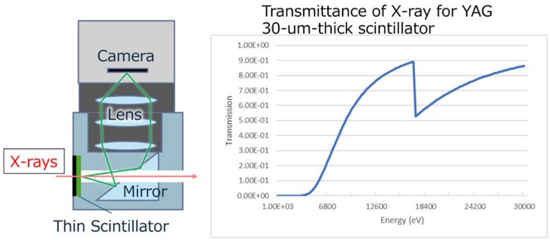

Fig. 2. Left: Schematic illustration of the developed detector. Right: Transmittance of X-ray for the YAG 30-um-thick scintillator.

Evaluation of the detector

The performance of the detector was evaluated by assessing its spatial resolution and conversion gain under conditions with and without the presence of holes on the prism mirror. The modulation transfer function (MTF) exhibited no significant difference between the two configurations. However, the conversion gain was reduced to nearly half in the presence of holes on the prism mirror. Despite this reduction, the detector remains advantageous in practical applications, as it enables in situ beam diagnostics during ongoing experiments and supports one-shot holotomography, which typically requires multiple distance measurements.

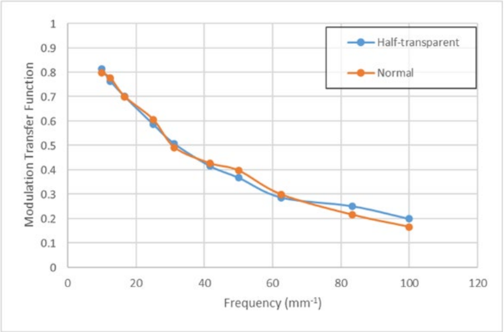

Fig. 3. Modulation transfer functions obtained from test chart images. The hole does not affect the MTF.

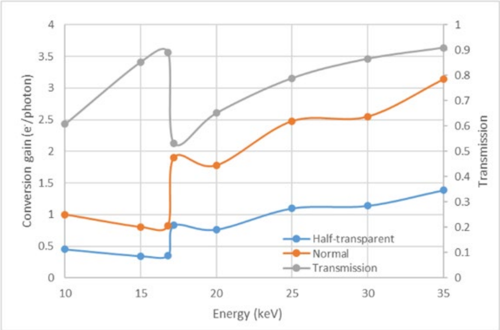

Fig. 4. The conversion gain of the half-transparent detector is almost half that of the normal detector.

3. Diffractometer for XFH and AXS

To encourage users to realize element-specific measurements, we developed a diffractometer using a combination of X-ray fluorescence holography (XFH) and anomalous X-ray scattering (AXS) [1]. Figure 5 shows a photo of the diffractometer. The usual 2θ axis (hereafter, δ axis) in the vertical scattering plane was designed for AXS measurements using a crystal analyzer to observe a large scattering angle above 120 deg. A detector system in the horizontal scattering plane was used in the inverse mode for XFH. The combination of an open χ circle with the δ axis was used to determine the crystal orientation of a sample by observing the Bragg reflections without detecting emission lines by a standing wave in a hologram, which is a notable advantage of our diffractometer.

Figure 6(a) shows typical results of XFH in the inverse mode for a scolecite single crystal. Atomic images corresponding to the surrounding Ca atoms are clearly observed, confirming the ability of our system to visualize local atoms with holograms. Figure 2(b) shows the total pair-distribution function g(r) and the difference pair-distribution function Δg(r) obtained from 15Ag$_2$O–15ZnO–70B$_2$O$_3$ glass by AXS. The total g(r) shows peaks corresponding to B–-O, Zn–O, and Ag–O, whereas Δg(r) greatly enhanced the Ag–O bond length, depicting element-specific features.

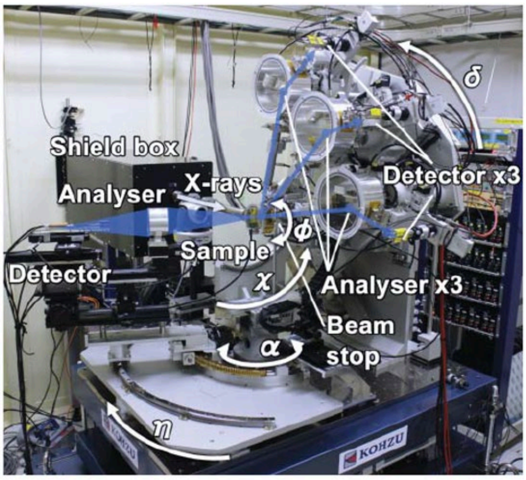

Fig. 5. Photo of diffractometer for XFH/AXS [1].

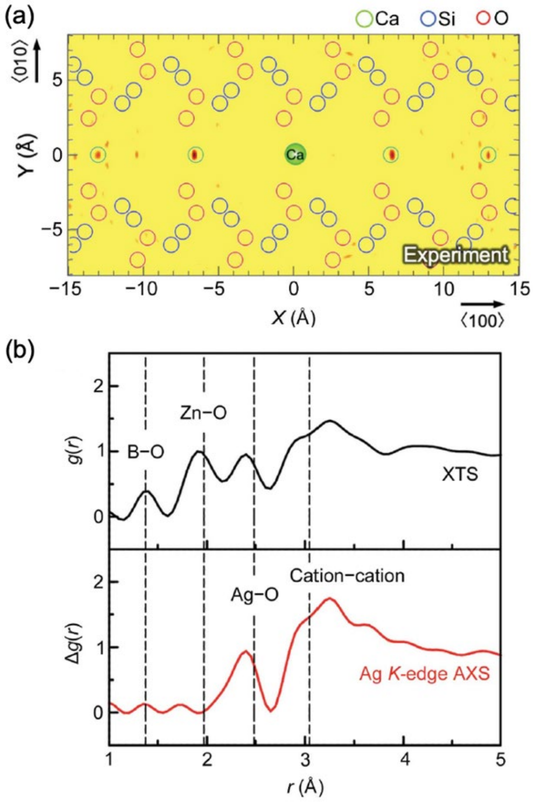

Fig. 6. Typical results of (a) XFH and (b) AXS using the diffractometer shown in Fig. 1 [1].

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References:

[1] H. Tajiri et al. (2025). *J. Synchrotron Rad.* **32**, 125.