BL17SU
RIKEN Coherent Soft X-ray Spectroscopy

1. Introduction

As noted in the previous SPring-8/SACLA Annual Report FY2022, the BL17SU has been operating as a beamline dedicated mainly to spectromicroscopic studies in the last few years. Nowadays, more than 70% of the total user time of BL17SU, including public use, is devoted to spectromicroscopic experiments. While utilizing two existing spectromicroscopes, *i.e.*, the versatile photoemission electron microscope (PEEM) [1,2] and the prototype apparatus of the scanning soft X-ray (SX) fluorescence spectromicroscope [3–9], as the main equipment, we have been operating the beamline together with launching the construction of a new scanning SX spectromicroscope with submicron spatial resolution and high counting efficiency. We have also been making efforts to realize a sophisticated angle-resolved photoelectron spectroscopy (ARPES) apparatus by incorporating the development of an automatic measurement system.

2. Recent activities

2.1 Development of high-speed scanning SX spectromicroscope

As described in SPring-8/SACLA Annual Report FY2022, we have been developing a scanning SX fluorescence spectromicroscope with submicron spatial resolution and high counting efficiency by utilizing a monolithic Wolter mirror as a focusing component and multiple silicon drift detectors (SDDs) for the detection of the fluorescence emitted from the sample surface. The previous version, *i.e.*, the prototype apparatus, utilized the Fresnel zone plate (FZP) as a focusing component. Thus, the resultant available energy range and the focused SX-beam intensity were limited. In that case, we had to change the FZP and its diffraction order to cover a wide energy range, as summarized in Table 1. We also needed to adjust the focusing optics every time after changing the FZP.

The spatial resolution of the new apparatus, on the other hand, is easily adjustable in the submicron to sub-100 μm range by moving the sample position along the axis of the photon beam, *i.e.*, from the focusing condition to the defocusing condition, without readjustment of the focusing optics. The new apparatus can be used for spectromicroscopic observations on various materials under vacuum conditions. In response, the prototype apparatus's role will be changed to be specialized for observing wet samples that require a He-atmosphere environment, where the vacuum and atmospheric-pressure regions are separated using a SiC membrane as a partitioning window.

A scanning microscope with an excessively focused beam has the disadvantage that too many measurement points are required when observing a wide region, *e.g.*, sub-millimeter to a few millimeters, which increases the total measurement time. If the scanning step is set larger than the beam size to reduce the number of measurement points, there is a possibility that the target material will be missed between measurement points. We began designing and developing a new spectromicroscope in early FY2022 with the goal of realizing a scanning SX fluorescence spectromicroscope that can rapidly map a wide region.

Figure 1 shows a schematic drawing of the new scanning SX spectromicroscope. Figure 2(a) shows a photograph of the outer view of the high-speed scanning soft X-ray fluorescence spectromicroscope under development. This fiscal year, we are installing a monolithic Wolter mirror as a focusing component. In Fig. 2(b), we show the Wolter mirror mounted on the gyro, which has adjustment capabilities for pitching, yawing, and rolling the mirror block. Notably, up to six SDDs can be installed to detect fluorescent X-rays emitted from the sample. Increasing the number of SDDs can increase the solid angle, allowing for high-counting-efficiency measurements. Compared with the previous scanning SX spectromicroscope [3] operated with a single SDD, the spectromicroscope currently under development has a solid angle of about 4.5 times larger. The reason why the solid angle does not increase more than sixfold is that the tips of the SDDs interfere with each other, preventing them from being placed too close together. Fluorescent X-rays emitted from the sample are detected by SDDs placed at 45° from the incident light, and elemental mapping and X-ray absorption spectroscopy (XAS) in the partial fluorescence yield mode can be performed.

Various software applications for a quick scan, based on the on-the-fly measurement scheme, are under development using LabVIEW. The step scan will also be available.

Table 1. Parameters of the focusing optics

	FZP-1	FZP-2
Membrane	SiC, 100 nm	
Zone	Au, 260 nm	
Outer diameter (μm)	910	1250
Outer zone width (nm)	153	175
CBS[*1] diameter (μm)	364	500
OSA[*2] diameter (μm)	100	
Focusing distance (mm)	44.9 〜 84.9	
Energy range (eV)	designed	
1^{st} order	400 〜 756	260 〜 450
3^{rd} order	1200 〜 2268	780 〜 1350
Focused beam size (nm)	designed	
S2a[*3]=100 μm, E/ΔE[*4]〜5,000	351〜516	416〜551
S2a=20 μm, E/ΔE〜15,000	306〜487	343〜499
Diffraction efficiency	Photon flux (ph/s) (measured)	
1^{st} order 〜10.1%	8.1x10^{8} @ 750 eV	1.2x10^{9} @ 420 eV
3^{rd} order 〜1.1%	9.7x10^{8} @ 1860 eV	6.8x10^{8} @ 1000 eV

[*1]Center Beam Stop, [*2]Order Sorting Aperture, [*3]Exit slit, [*4]Energy resolution

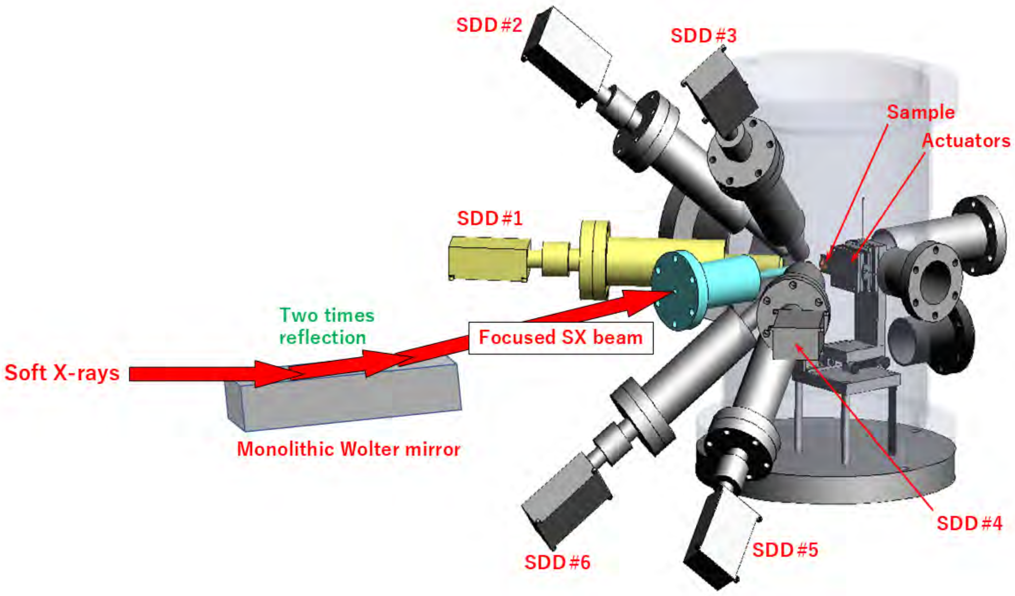

Fig. 1. Schematic drawing of the new scanning SX spectromicroscope.

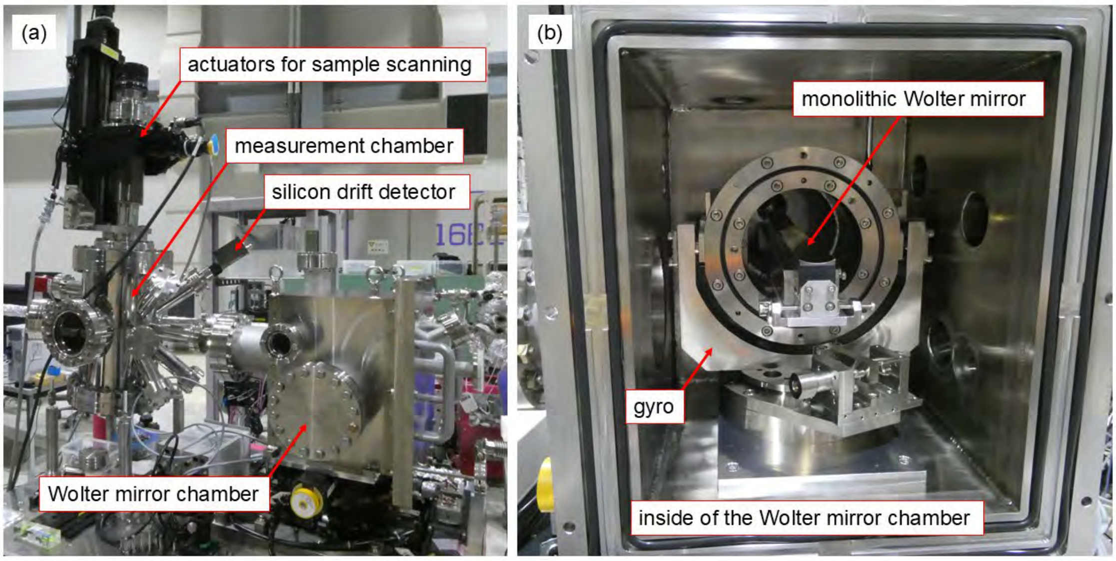

Fig. 2. (a) Photograph of the exterior view of the high-speed scanning SX fluorescence spectromicroscope. (b) Photograph of the interior view of the Wolter mirror chamber. The monolithic Wolter mirror is mounted on the gyro.

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