# BL25SU
# Soft X-ray Spectroscopy of Solid

## 1. Introduction

BL25SU is utilized for soft X-ray spectroscopic studies on electronic/magnetic states and surface structures of solid materials. Owing to substantial upgrades implemented in FY2014, the beamline consists of two branch lines. The A-branch boasts of high-energy-resolution X-rays that are suitable for electron spectroscopy experiments, whereas the B-branch is optimized for providing nano-focused beams with small angle divergence [1–3] and is mainly used for X-ray magnetic circular dichroism (XMCD) experiments.

In FY2021, there were some modifications in the beamline apparatuses, which are as follows: (i) the installation of a spectroscopic low-energy electron microscope (SPELEEM), (ii) the removal of the display-type spherical mirror analyzer (DIANA), and (iii) the repair of the twin-helical undulator. Although the machine trouble in the undulator, which occurred in FY2020, has created a difficult environment for XMCD experiments owing to the lack of a quick helicity switching system, the repair was completed in the summer of FY2021, and the twin undulator has been normally operating. In the next section, the current status of each end-station is explained in detail.

## 2. Status of experimental apparatuses

### 2-1. A-branch beamline

In FY2021, a beam monitor for evaluating the beam property was newly installed on the upper reach of the experimental stations. The beam monitor consists of SiC membrane substrates for monitoring beam flux, together with standard oxide powders (MnO, $Sr_3Fe_5O_{12}$, and CuO) cast on carbon tapes for photon energy calibration. They are attached to the same metallic plate that is connected to a linear feed-through and an X-Y stage, allowing the target material to be selected (Fig. 1(a)). In addition, a retractable photodiode was installed just behind the beam monitor to facilitate quantitative photon intensity monitoring (Fig. 1(b)). Performance tests of these instruments have been conducted and they are ready for routine operation.

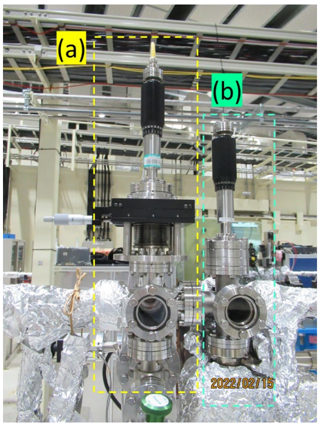


Fig. 1. (a) Beam monitor and (b) photodiode installed at A-branch.

### 2-2. Spectroscopic low-energy electron microscope (SPELEEM) (A-branch first station)

The SPELEEM (LEEM III with an energy analyzer, ELMITEC GmbH), which had been operated at BL17SU [4], was moved to BL25SU in August 2021 (Fig. 2). After an initial performance check, it will be opened for normal operation from the beginning of FY2022. This apparatus is a full-field imaging tool that is useful for various nano-spectroscopic studies, including magnetism research.

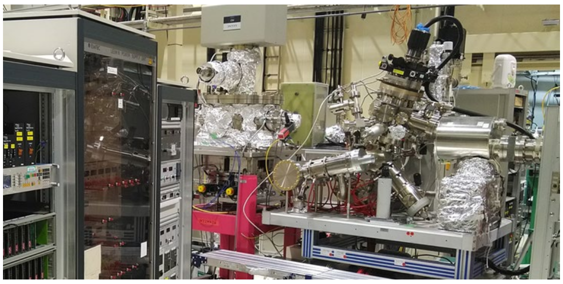

Fig. 2. SPELEEM installed at BL25SU.

**2-3. Retarding field analyzer (RFA) (A-branch second station)**

Photoelectron diffraction and holography allow nonperiodic local structures with multiple chemical states to be studied [5]. These methods require wide-range photoelectron angular distribution patterns measured with a sufficiently high energy resolution to resolve core-level chemical shifts. To perform such measurements, a display-type retarding field analyzer (RFA) with a high resolving power ($E/\Delta E$) of 1100 was developed [6]. Further improvements were made in FY2020, such as the replacement of the wire-meshed grid with a mechanically holed grid (Fig. 3), and now it is in good shape with $E/\Delta E$ of about 2000 [7]. Since the DIANA that had been used in this beamline ended its operation and was demolished in FY2021, the RFA has been playing its roles.

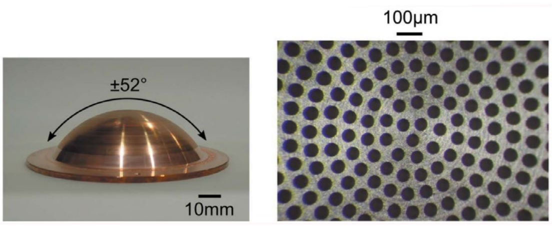


Fig. 3. Retarding grid made of mechanically holed spherical dome.

**2-4. Microbeam angle-resolved photoemission spectroscopy (ARPES) (A-branch third station)**

The ability to select flatly cleaved areas (which are in many cases microscopic) from poorly cleaved sample surfaces is valuable for ARPES [8]. To enhance this capability, a micro-ARPES end-station equipped with a DA30 analyzer of Scienta Omicron and a microfocusing mirror was developed [9,10]. The typical focusing size is 0.4 μm (vertical) × 4 μm (horizontal). The beam spot size on the sample surface is as small as 5 μm even at a glancing angle of 5 degrees. This end-station has been opened for public use since FY2018. Although there was a problem in some high-voltage modules at the end of FY2021, they will be repaired by the beginning of FY2022.

**2-5. Electromagnet-type XMCD spectroscopy (B-branch second station)**

This is a versatile XMCD apparatus that provides various experimental conditions. There are three types of sample holder, that for low temperature, that for high temperature, and that for measurements under current flow or applied electric field. We attach one of them to the manipulator of this apparatus, according to the experimental conditions. The method of signal detection can also be selected from the total electron yield (TEY), partial fluorescence yield (PFY), and transmission modes. A high-precision manipulator introduced in FY2020 allows measurements of microscopic areas. As mentioned in Introduction, single-undulator operation during the repair considerably degraded the accuracy of the spectra in which the detection limit of the XMCD signal was several percent of the absorption intensity. It is now restored to the conventional performance, which is in the order of 0.1%.

**2-6. Scanning soft X-ray microscope (nano-**

**XMCD) (B-branch third station)**

A scanning soft X-ray microscope was developed with the support of the Elements Strategy Initiative Center for Magnetic Materials (ESICMM) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan [11,12]. This unique apparatus features nanoscale XMCD imaging under high magnetic fields up to 8 T. The total electron yield method, which converts X-ray absorption from sample current, cannot be used to observe insulating samples or voltage-applied devices. Furthermore, the morphological information of the sample surface hinders the quantitative analysis of electrical and magnetic properties. To overcome these problems, in FY2021, we developed a sample-current-independent X-ray absorption imaging method. By arithmetically specifying the emission direction of photoelectrons, a three-dimensional image of the sample was constructed. This study enabled simultaneous *in situ* measurements of the surface 3D morphology and XMCD of the sample surface.

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