Major upgrade of BL25SU for soft X-ray imaging and spectroscopy using nano- and micro-focused beams

Here we report a recent major upgrade of beamline **BL25SU** for soft X-ray spectroscopy of solid. The upgrade project started in 2012 for the purpose to optimize the beamline optics and experimental stations for advanced soft X-ray imaging and spectroscopy using nano- and micro-focused beams. Particularly, magnetic imaging with soft X-ray magnetic circular dichroism (XMCD) using a nano-focused beam (<ϕ100 nm) is highly required in accordance with the element strategy project of permanent magnets, initiated by Ministry of Education, Culture, Sports, Science & Technology in Japan.

The original beamline was one of the first ten beamlines constructed at SPring-8 in 1998 [1]. BL25SU has mainly been dedicated to soft X-ray photoemission spectroscopy (PES) and absorption spectroscopy for studies on the electronic and magnetic properties of solid-state materials. A helicity switching technique using a twin helical undulator light source [2] has been advantageous when measuring soft XMCD precisely. To promote high-energy-resolution PES, the beamline was designed to achieve high energy resolution of about $E/\Delta E$>10,000 at a photon energy of 1 keV.

During reconstruction, every optical component at the original beamline was replaced with new components. Installation of the new beamline started in Jan. 2014, and was completed in three months. After the half-year commissioning during the 2014A experimental period, the beamline has been available to users since 2014B. The new beamline consists of two branches: a microbeam with high-energy-resolution branch (branch-a) and a nanobeam with small angular divergence branch (branch-b). These can be switched using the pre-focusing mirrors (M0) shown in Fig. 1. Downstream of M0 for vertical focusing, each branch has its own horizontal focusing mirror (M1). A monochromator based on the Hettrick Underwood type [3] is composed of an entrance slit (S1), spherical mirrors (M2n), varied line spacing plane gratings (Gn), and an exit slit (S2). The specifications of each branch are listed in Table 1.

The beam performance of branch-a is almost the same as the original one in terms of its energy resolution, energy range, and photon flux. This branch has three experimental stations, ST1a: two-dimensional photoelectron spectroscopy

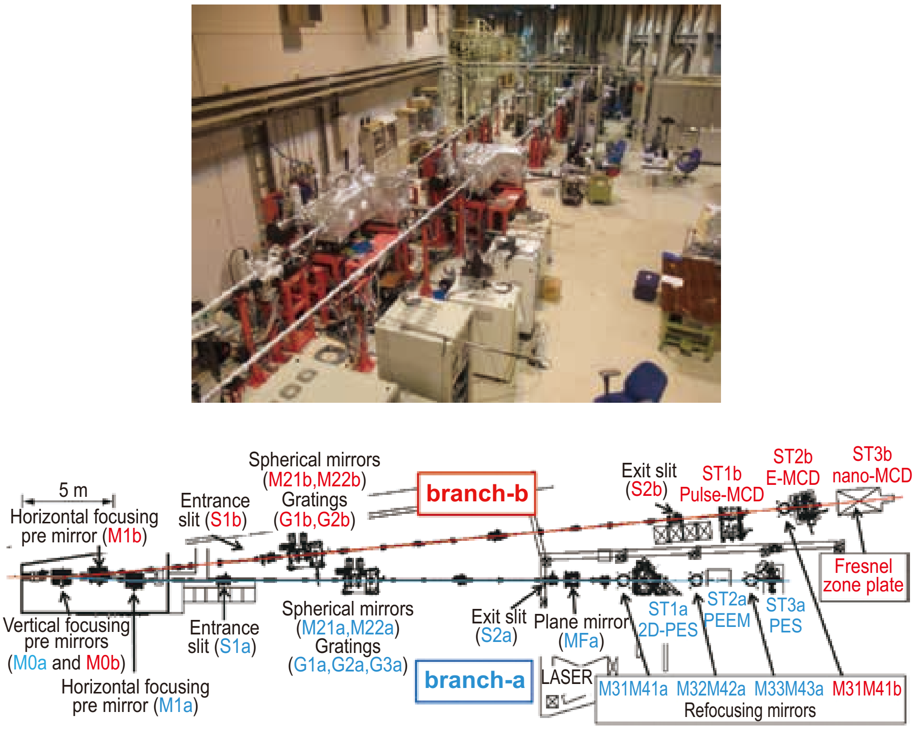

Fig. 1. Photograph and schematic view of upgraded BL25SU.

Table 1. Design specifications of each branch of upgraded BL25SU.

	Branch-a High energy resolution	Branch-b Small angular divergence
Energy range	120 – 2000 eV	200 – 2000 eV
Resolving power	$E/\Delta E > 10{,}000$	$E/\Delta E > 3{,}000$
Photon flux	10^{11} ph/sec	10^{12} ph/sec 10^{10} ph/sec @nano-MCD
Beam Size	10 – 100 μm	10 – 100 μm ϕ100 nm @nano-MCD

(2D-PES) apparatus, ST2a: photoemission electron microscope (PEEM), and ST3a: photoemission electron spectroscopy (PES) apparatus. In order to obtain a micro-focused beam, refocusing mirror systems (M3n, M4na) are installed upstream of each experimental station. A high resolving power ($E/\Delta E$) of above 10,000 is confirmed by the photoemission profile at the Fermi edge of Au. The photon flux of the monochromatized beam is measured to be 10^{11} photons/sec/0.01%BW using a Si photodiode. The focused beam sizes at three end stations are typically better than 10 μm (V) × 170 μm (H).

The optical layout of branch-b is optimized for nanofocusing using a Fresnel zone plate (FZP). To increase the acceptance of FZP, the divergence angle after the exit slit is suppressed by the asymmetrical layout of the monochromator components. The divergence in a vertical direction at branch-b is about 1/10 of that at branch-a, as shown in Fig. 2. There are three experimental stations, ST1b: pulse-magnet-type XMCD apparatus (Pulse-MCD), ST2b: electromagnet-type XMCD apparatus (E-MCD), and ST3b: XMCD apparatus equipped with the FZP (nano-MCD). A refocusing mirror system (M31, M41b) is installed upstream of E-MCD. The resolving power and photon flux after the exit slit are 4,000 and 6×10^{11} photons/sec/0.03%BW, respectively. The estimated focused beam sizes are 10 μm (V) × 100 μm (H) at E-MCD and ϕ 100 nm at nano-MCD.

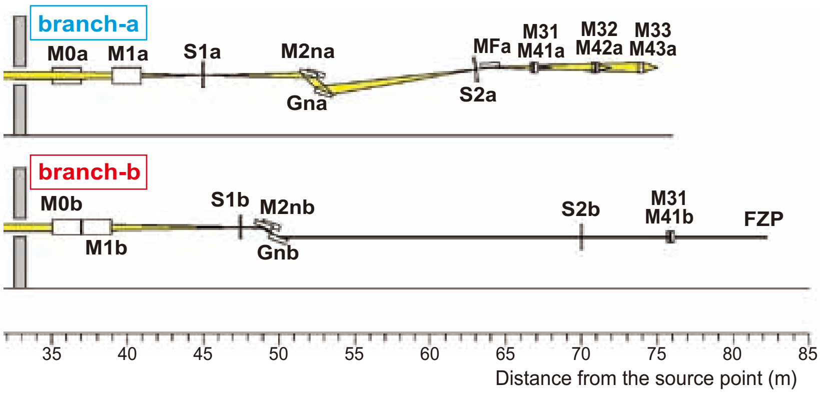

Fig. 2. Optical layout (side view) of upgraded BL25SU.

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