BL17SU
RIKEN Coherent Soft X-ray Spectroscopy

1. Introduction

As we have noted in the previous SPring-8/SACLA Annual Report FY2021, BL17SU has been operated 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 spectromicroscopes, *i.e.*, the versatile photoemission electron microscope (PEEM) [1] and the scanning soft X-ray (SX) microscope [2], as main equipment, we have been operating the beamline together with advancing the launch of a new scanning SX microscope with high spatial-resolution, and high counting efficiency, and also the sophistication, including the development of an automatic measurement system, for the angle-resolved photoelectron spectroscopy (ARPES) apparatus.

At the end of 2020, it was unfortunate that a water leakage was found in the coil of the electromagnet used in the novel insertion device, ID17, called the multi-polarization-mode undulator [3]. After a shutdown of a few weeks, it was decided to operate ID17 as the vertical undulator using only permanent magnets and no electromagnets. Since then, the operation of BL17SU resumed under the constraints of no polarization-switching capability and a reduction of the energy range as well as the photon flux. At the beginning of 2021, it was decided to build a new insertion device specific to the SX energy region, called a Helical-8 undulator [4], to overcome these constraints. Design work was initiated in early 2021 and the construction of the new ID17 began at the beginning of FY2021. The installation of the new ID17 was carried out during the summer storage-ring shutdown period in FY2022 [5].

2. Recent activities

2.1 Installation of new ID17 Helical-8 undulator

BL17SU, constructed in 2004, is a SX undulator beamline with a multi-polarization-mode undulator composed of electromagnets and permanent magnets. The failure of the electromagnets at the end of 2020 led us to consider installing a new insertion device for possible use at SPring-8 II. The construction of the new insertion device, called a Helical-8 undulator, started in 2021, and the replacement of ID17 was completed in the summer of 2022 [Figs. 1(a) and 1(b)].

The Helical-8 undulator consists of six arrays of permanent magnets, three upper and three lower, as shown in Fig. 1(c). The horizontal and vertical magnetic fields are independently generated by the side arrays A–D and the central arrays E and F, respectively. The central arrays E and F are phase-fixed, whereas the side arrays A–D are phase-variable. The photon energy of synchrotron radiation light can be changed by controlling the undulator gap. The phase control of the side arrays allows switching of the operation mode between the helical undulator and the figure-8 undulator, as shown in Fig. 1(d). In the helical undulator mode, which provides circularly polarized light, it is possible to switch between left and right circular polarization by shifting the side arrays by half a period. At an incident light energy of 710 eV (near

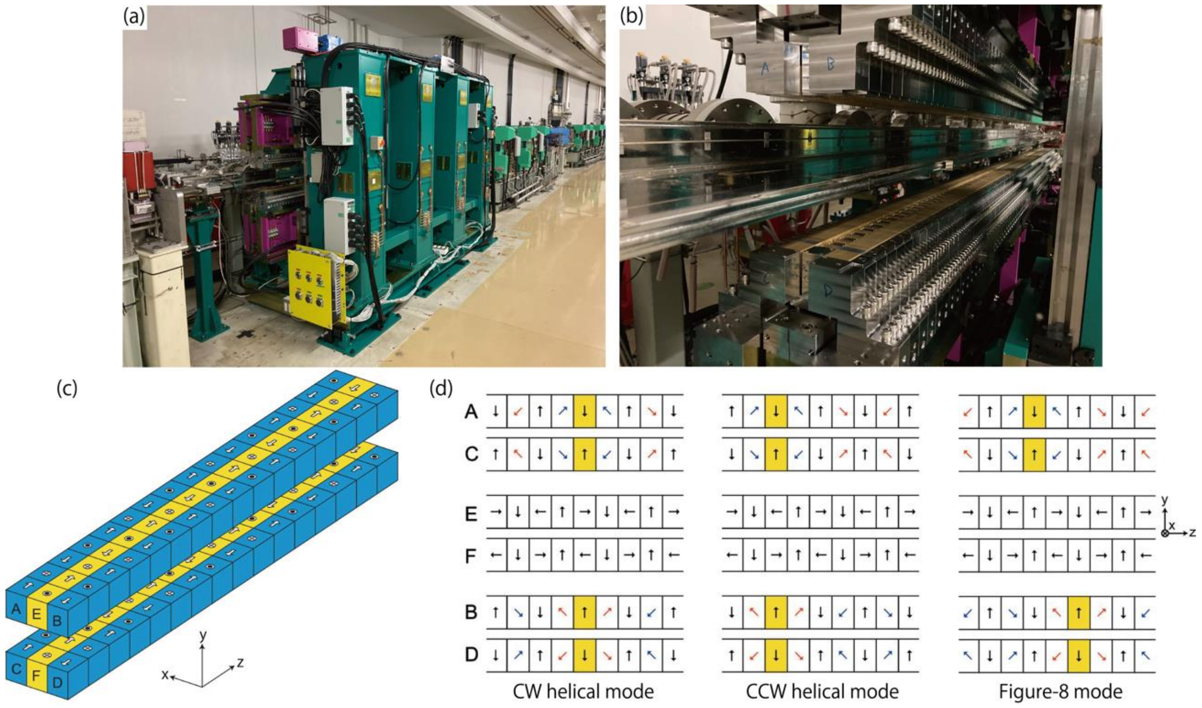

Fig. 1. (a) Photograph of Helical-8 undulator installed at BL17SU. (b) Photograph of magnetic arrays on Helical-8 undulator. (c) Schematic drawing of a helical undulator composed of six Halbach arrays [5]. (d) Operation modes of Helical-8 undulator [5].

the Fe L_3 edge), circular polarization switching takes about 7 minutes. The figure-8 undulator mode provides horizontally and vertically linearly polarized light. In the figure-8 undulator mode, the synchrotron radiation light of integer order is horizontally linearly polarized and that of half-integer order is vertically linearly polarized, so the horizontal/vertical polarization switching can be performed by controlling the undulator gap.

2.2 Development of high-speed scanning SX spectromicroscope

As described in last year's SPring-8/SACLA Annual Report, we have been developing a scanning SX fluorescence spectromicroscope with high spatial resolution. The spatial resolution reaches from submicron to sub-100 nm and has been used for spectromicroscopic observations on various materials [6–10]. On the other hand, a scanning microscope with an excessively focused beam has the disadvantage that too many measurement points are required when observing a wide region, 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 microscope that can rapidly map wide regions.

Figure 2(a) shows a photograph of the outer view of the high-speed scanning SX fluorescence spectromicroscope under development. The size of the light incident on the sample is controlled by a pinhole upstream of the measurement chamber. The pinhole can be selected from four different pinhole sizes: 2, 5, 10, and 20 µm. Notably, up to six silicon drift detectors (SDDs) can be installed to detect fluorescence light from the sample. By increasing the number of SDDs, the detectable angle can be increased, allowing for highly efficient measurements. Compared with the previous scanning SX spectromicroscope [2] operated with a single SDD, the spectromicroscope currently under development has a detectable angle range of about 4.5 times. Figure 2(b) shows a photograph of the interior of the measurement chamber of the high-speed scanning SX fluorescence spectromicroscope. The measurement chamber and the upstream pinhole chamber are separated by a SiC window, and synchrotron radiation light transmits through the SiC window and is incident to the sample. Fluorescence emitted from the sample is 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. The SiC window makes it possible to measure samples in a He atmosphere, which allows the measurement of liquid samples. In the future, we will develop an automatic sample position control system so that elemental mapping and local XAS can be measured automatically. In order to increase the intensity of the incident light, we are planning to install a Wolter mirror to focus the light.

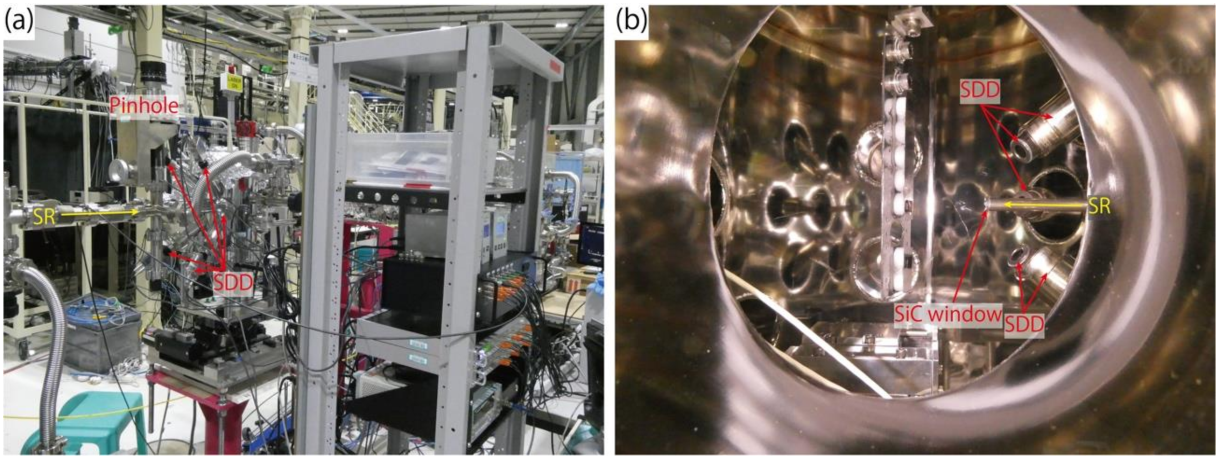

Fig. 2. (a) Photograph of the exterior of the high-speed scanning SX fluorescence spectromicroscope. (b) Photograph of the interior of the measurement chamber of the high-speed scanning SX fluorescence spectromicroscope.

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