HiSOR ACTIVITY REPORT 2024

Research Institute for
Synchrotron Radiation Science
Hiroshima University

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Research Institute for Synchrotron Radiation Science
HiSOR, Hiroshima University

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The annual report is available from

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Preface

The Research Institute for Synchrotron Radiation Science (HiSOR), which was reorganized from the Hiroshima Synchrotron Radiation Center in FY2024, was established in 1996 as part of the academic policies of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan. A compact 700 MeV electron storage ring named HiSOR (our institute is also called HiSOR) produces synchrotron radiation in the ultraviolet and soft X-ray ranges. The mission of HiSOR is to promote advanced research in the field of condensed matter physics, including interdisciplinary fields, using synchrotron radiation and to develop human resources in the international research environment established within the national university. HiSOR has been authorized as a “Joint Usage/Research Center” by MEXT since FY2010. After an evaluation of research activities in the 3rd mid-term goal period, authorization was successfully extended to the 4th mid-term goal period (FY2022–FY2027).

In FY2023, Hiroshima University’s proposal for "Realization of an industrial cluster ecosystem integrating semiconductors, meta matter, and biotechnology with visualization technology using synchrotron radiation" was selected by the MEXT's "J-PEAKS: Program for Forming Japan’s Peak Research Universities". In this program, synchrotron radiation from HiSOR is expected to play an important role in developing interdisciplinary research areas of semiconductors, meta matter, regenerative medicine, cell medicine, and drug discovery.

In FY2024, we obtained funding from the MEXT to reorganize the facility as the Research Institute for Synchrotron Radiation Science. The previous research divisions have been integrated into the Fundamental Research Division (FRD), which will take over the functions of the Joint Usage/Research Center. The Collaborative Research Division (CRD) has been newly established to apply ultraviolet synchrotron radiation to interdisciplinary research fields and to promote industry-academic collaborations, aligned with the J-PEAKS project. The CRD welcomed Specially Appointed Professor Osamu Takahashi and Specially Appointed Associate Professor Kazuki Sumida. In addition, the FRD welcomed Assistant Professor Dr. Yuita Fujisawa from the Okinawa Institute of Science and Technology to advance the research on novel low-dimensional systems.

In 2024, our facility experienced several issues caused by the aging of the synchrotron radiation source, including water leaks from cooling pipes and discharges in the RF acceleration cavities, which required several extensive repairs. Consequently, many approved joint usage/research projects had to be postponed, causing significant inconvenience to our collaborators. Although we resumed joint usage/research activities in March 2025, we anticipate an increasing need to fix such aging-related issues. While we remain committed to maintaining academic and industry-academia collaborative research, we must also promote the upgrade of our synchrotron radiation source, HiSOR-II. The intense synchrotron radiation and high stability of HiSOR-II will significantly benefit advanced research and expand collaboration opportunities.

Finally, I would like to thank all the staff for their great efforts in operating HiSOR and maintaining and advancing the experimental stations. I would also like to thank our students and collaborators for their excellent scientific achievements and for making full use of our facilities. I deeply appreciate the continued support of Hiroshima University and MEXT.

September 2025

Kenya Shimada

Kenya Shimada
Director of the Research Institute for the Synchrotron
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Current Status of HiSOR

Status of the HiSOR Synchrotron Light Source

1. Introduction

HiSOR, established in 1996, is a synchrotron light source belonging to Hiroshima University, Japan. It is a compact racetrack-type electron storage ring having 22 m circumference and 700 MeV beam energy. It has two 180-degree normal-conducting bending magnets which generate a strong magnetic field of 2.7 T. Due to this compact configuration, the emittance of the electron beam is 400 nm-rad, which is much larger than most other operational synchrotron light sources. 150 MeV electron beam is provided by a microtron. After accumulating 300 mA (max. 350 mA), the stored beam energy is ramped up to 700 MeV. The ring has two straight sections, where two insertion devices, a planar undulator and an APPLE-II undulator, are operational. The undulators cover the VUV spectral range. The high field bending magnets produce synchrotron radiation in a wide spectral range including tender X-rays. The main parameters of the storage ring and the undulators at HiSOR are shown in Table 1 and 2, respectively. The photon energy spectra of the SR are shown in Figure 1.

Table 1: Main parameters of the storage ring.

Circumference	21.95 m
Type	Racetrack
Bending radius	0.87 m
Beam energy at Injection	150 MeV
at Storage	700 MeV
Magnetic field at Injection	0.6 T
at Storage	2.7 T
Injector	150 MeV Racetrack Microtron
Betatron tune (ν_x, ν_y)	(1.72, 1.84)
RF frequency	191.244 MHz
Harmonic number	14
RF voltage	200 kV
Stored current (nominal)	300 mA
Natural emittance	400π nmrad
Beam lifetime	~10 hours@200 mA
Critical wavelength	1.42 nm
Photon intensity (5 keV)	1.2×10^{11} /sec/mr^2/0.1%b.w./300mA

Table 2: Main parameters of the undulators.

Linear undulator (BL-1)	
Total length	2354.2 mm
Periodic length λu	57 mm
Periodic number	41
Pole gap	30-200 mm
Maximum magnetic field	0.41 T
Magnetic material	Nd-Fe-B (NEOMAX-44H)
APPLE-II undulator (BL-9A,B)	
Total length	1845 mm
Periodic length λu	78 mm
Periodic number	23
Pole gap	23-200 mm
Maximum magnetic field	0.86 T (horizontal linear mode) 0.59 T (vertical linear mode) 0.50 T (helical mode)
Magnetic material	Nd-Fe-B (NEOMAX-46H)

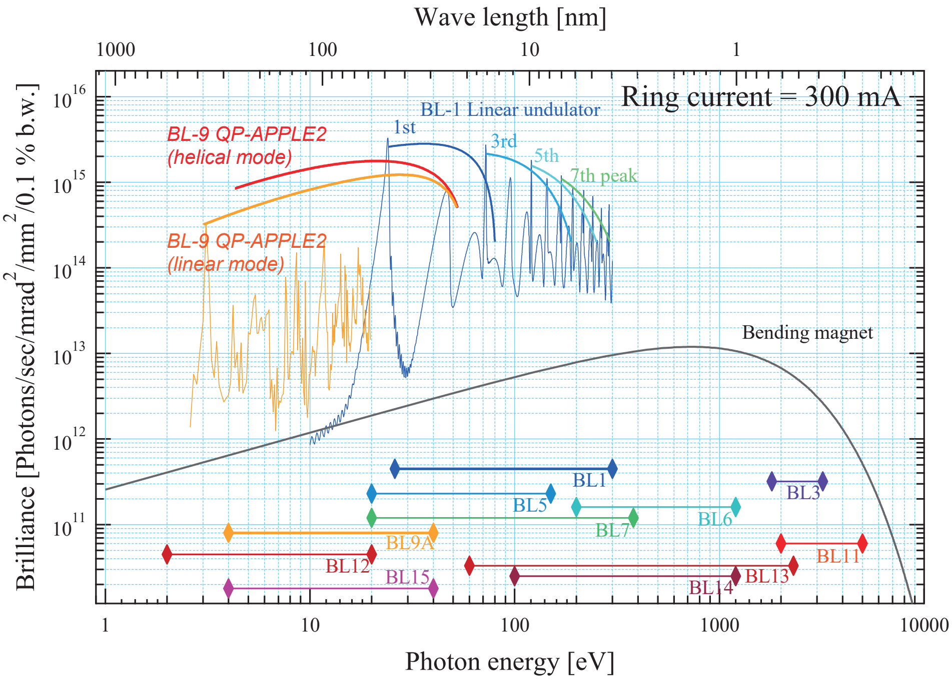


Figure 1: Photon energy spectra of synchrotron radiation from HiSOR.

2. Operational status in FY2024

The synchrotron facility is accessible for users each week from Tuesday to Friday. Figure 2 shows an example of a typical operation pattern for one day. Beam injections had been performed twice a day – at 9:00 and at 14:30, and the operation was stopped at 20:00. However, recently, the injection schedule has been changed for the convenience of the users. So, currently, beam injections are carried out at 9:00 and 15:00, and machine operation is stopped at 21:00, extending the beam time by approximately 10%. Typically, the beam injection can be completed within 30 minutes. The users are requested to evacuate the experimental hall before beam injection occurs. The target beam current is about 300mA, although, lately, the actual beam current was lower because of the machine's present condition as described later. The storage ring is operated for machine conditionings and machine studies every Monday from 9:00 to 17:00.

Figure 3 shows the monthly operation time of the storage ring in FY2024. HiSOR has a yearly shutdown period for maintenance work in August, along with a scheduled electricity outage for maintenance and inspection at the end of August. In FY2023, after the summer shutdown, the beam lifetime was shorter than usual and has not recovered until now. The reason for this is still not clear. In 2024, the machine operation became irregular due to a series of vacuum accidents as described below. As a result, the operation time for users in 2024 was severely limited.

The first incidence occurred in the middle of January 2024. Cooling water of a photon absorber, located inside the vacuum chamber near a bending magnet, leaked into the ultra-high vacuum. We recorded a similar accident almost ten years ago, and the absorber was replaced at that time. However, the water leakage occurred again. The absorber was removed from the chamber, the leak point was identified, and subsequently repaired by welding. Then, vacuum conditioning had to be carried out. However, during this process another leakage occurred in April 2024, in which cooling water entered the RF cavity, consequently compromising the ultra-high vacuum section of the storage ring again . The RF cavity features two water-cooled pump ports where RF shields are installed. Surprisingly, leakage occurred at both ports within a few days. The leakage was fixed by replacing the copper cooling water pipe. Then, the vacuum conditioning started again, including baking of the RF cavity. During vacuum conditioning with the beam in June 2024, leakage at the photon absorber occurred again. This time, the leak point was only about 10 cm away from that of the first incident. The absorber was inspected by using an ultrasonic inspection device. It was found that the remaining wall thickness of the water channel was only 1 mm or less, affecting a range of approximately one meter around the leak point. This time, a thin copper plate equal length was welded onto the absorber to support the eroded wall region. After this repairment, the vacuum conditioning had been started again and continued until the middle of August. Then, the system was shut down for the regular annual inspection. In September, machine conditioning started as scheduled and, in October, ordinary user operation resumed. However, the beam lifetime and the stored current did not recover sufficiently. Therefore, beam injection was carried out three times a day at 9:00, 13:00 and 17:00. In November, another incidence took place at the RF cavity. The contact fingers of the RF shield at the tuner were broken, leading to electric discharges. The damaged RF shield was replaced with a new one. Machine conditioning started in January 2025, and regular user operation resumed in mid-February.

As described above, we could not operate the storage ring regularly for almost one year for users. This is evident in the operation statistics shown in Figures 3 and 4.

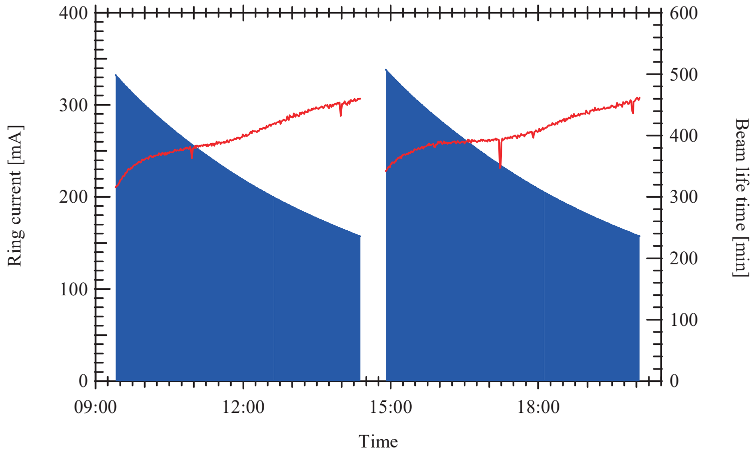
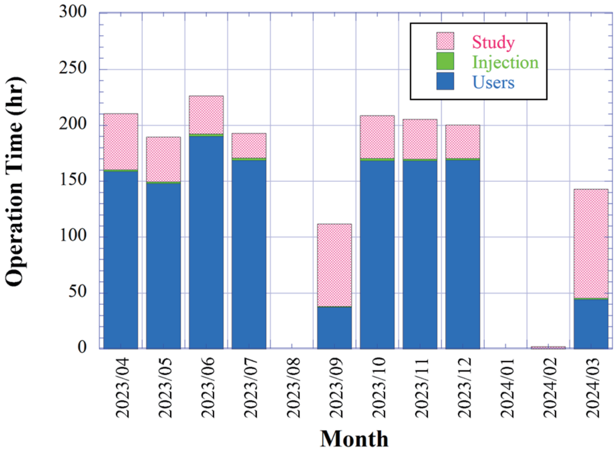


Figure 2: Typical daily operation status.



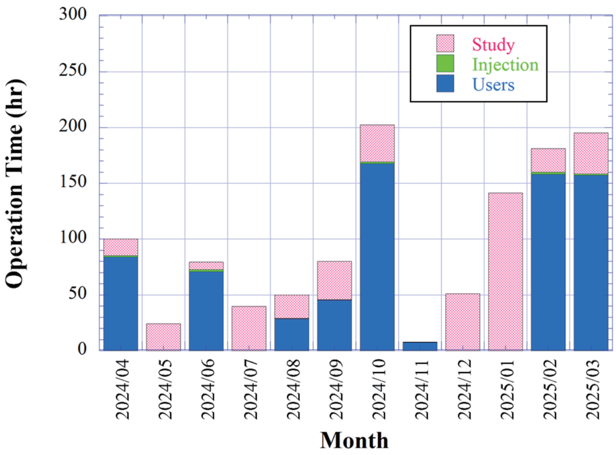


Figure 3: Monthly operation time in FY2023 (upper chart) and FY2024 (lower chart).

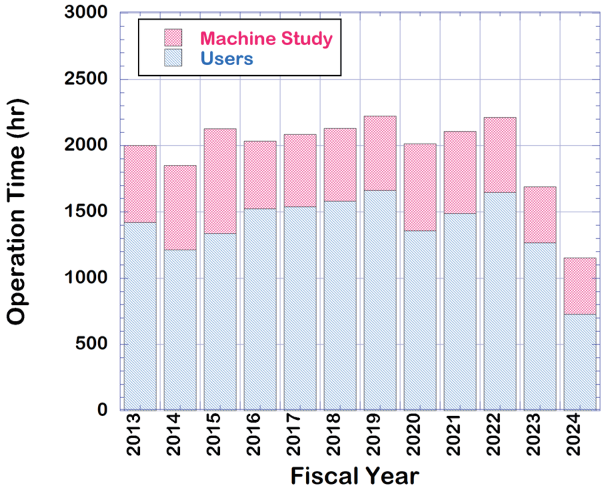


Figure 4: Operation time in FY2013-FY2024.

3. Improvements and future developments

The HiSOR accelerator system was constructed in the 1990's. Most of the accelerator components have aged and some of them are becoming more and more difficult to procure for maintenance. The photon beam absorber which caused serious failures should be replaced as soon as possible, because the repairments made last year were temporal. In addition, the absorber installed in the other bending magnet has the same structure and same risk of failure. The pulse magnet system is another serious issue because its key device, the thyratron, has already been discontinued. We have started preparing for the replacement of the power supply system which utilizes semiconductor switching devices.

For the future plan of HiSOR, we are designing a compact novel storage ring. Various lattice designs have been investigated and a variety of accelerator layouts have been considered. The most recent target parameters are as follows: 600 MeV beam energy, 44 m circumference, and utilization of four insertion devices. Furthermore, the use of combined-function magnets in a hexagonal storage ring shape could allow for compact beam steering and focusing, potentially achieving a competitive emittance of less than 15 nm. The ring should be operated in the top-up mode in order to provide continuously high beam brightness. Therefore, a full energy injector is required. These characteristics should be realized with minimal construction costs. To make this undertaking feasible, the efficient use of existing infrastructure, as well as the re-use of equipment, is indispensable. For example, the current storage ring could be modified to serve as a high-energy injector, a common method when upgrading such accelerator systems. The running costs should be kept as low as possible, for example by using long-lasting permanent magnets with specialized iron yoke and weak electromagnetic excitation, which require low power and few movable parts, thus making maintenance highly cost-efficient. We are continuing our collaborations with KEK, UVSOR and NuSR on the development of ring components for future sustainable synchrotron light sources.

Beamlines

A total of 13 beamlines has been constructed so far; three normal-incidence monochromators, seven grazing-incidence monochromators, two double crystal monochromators and apparatus for white beam irradiation (Fig. 1). Table 1 lists the beamlines at present together with the main subject, energy range and monochromators.

Table 1: List of Beamlines

Beamline	Source	Monochromator	Subject	Energy range (eV)	Status
BL-1	LU	GIM	Polarization dependent high-resolution ARPES	22-300	In use
BL-3	BM	DCM	Surface XAFS	1800-3200	In use
BL-4	BM		White beam irradiation		Closed
BL-5	BM	GIM	ARPES and PEEM	40-220	In use
BL-6	BM	GIM	Gas-phase photochemistry	200-1200	In use
BL-7	BM	GIM	ARPES	20-380	In use
BL-8	BM		Beam diagnosis		In use
BL-9A	HU/LU	NIM	High-resolution ARPES	5-35	In use
BL-9B	HU/LU	GIM	High-resolution spin-resolved ARPES	16-300	In use
BL-11	BM	DCM	XAFS	2000-5000	In use
BL-12	BM	NIM	VUV-CD of biomaterials	2-10	In use
BL-13	BM	GIM	Surface photochemistry	60-1200	In use
BL-14	BM	GIM	Soft-XMCD of nano-materials	400-1200	In use
BL-15	BM	NIM	VUV-CD of biomaterials	4-40	Closed
BL-16	BM		Beam profile monitor		In use

At present, nine beamlines BL1, BL3, BL6, B7, BL9A, BL9B, BL11, BL12, BL13 and BL14 are opened for users. Furthermore, three offline systems, resonant inverse photoemission spectrometer (RIPES), low-temperature scanning tunneling microscope (LT-STM) system, high-resolution angle-resolved photoemission spectrometer using ultraviolet laser (Laser ARPES) are in operation (Fig. 2).

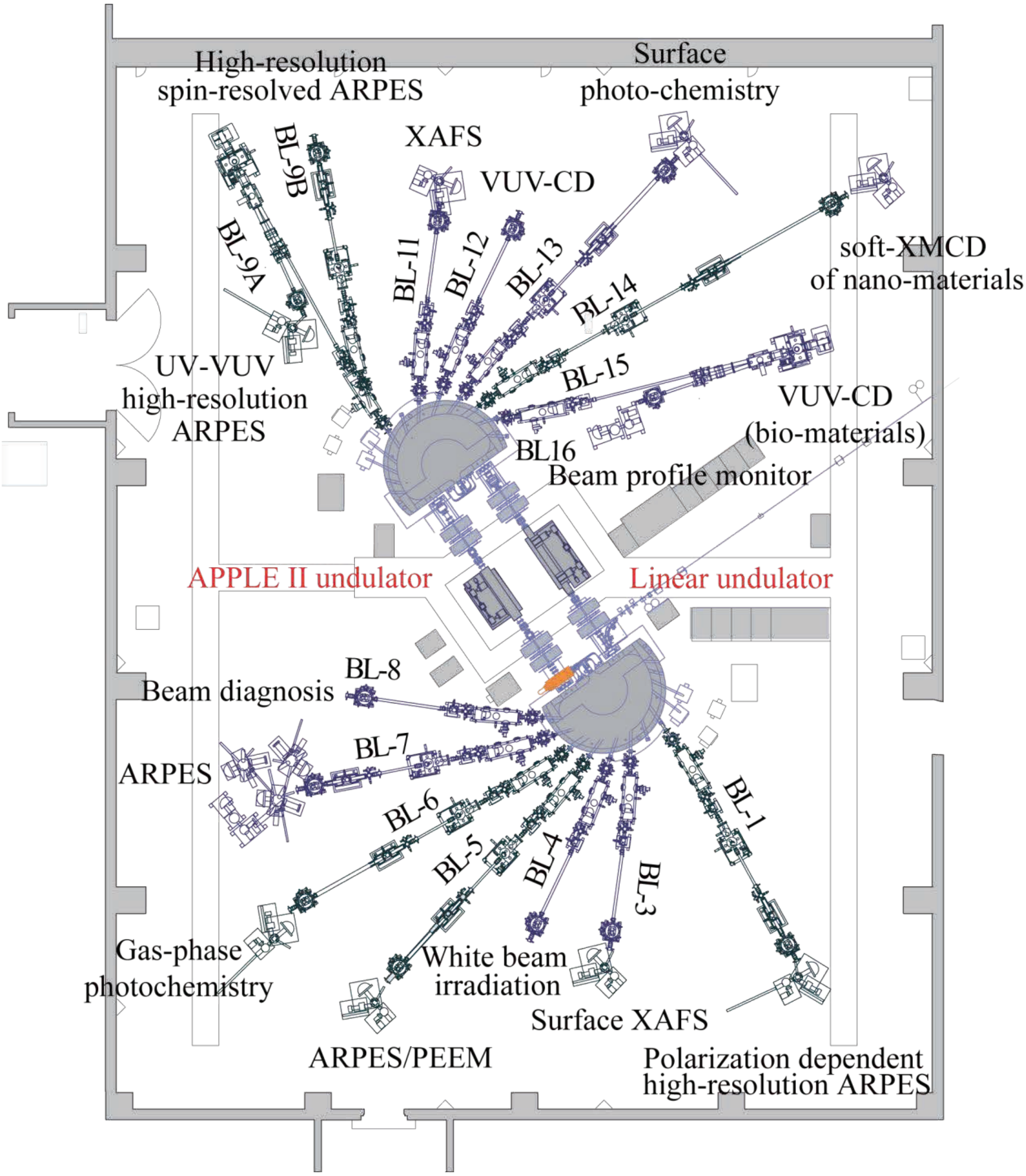


Fig. 1: Schematic view of the experimental hall.

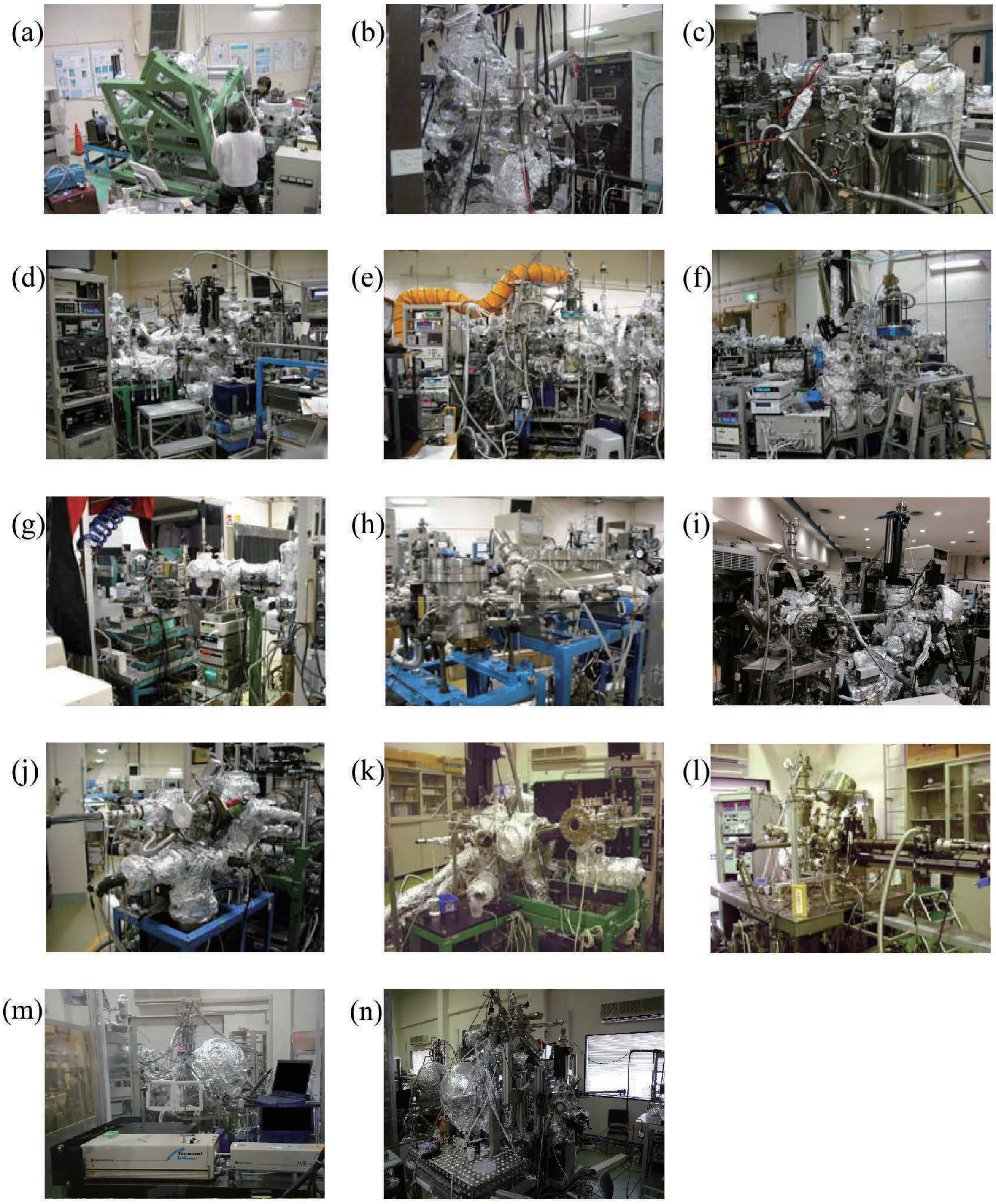


Fig. 2: Experimental stations on the beamline and offline: (a) BL-1, (b) BL-3, (c) BL-6, (d) BL-7, (e) BL-9A, (f) BL-9B, (g) BL-11, (h) BL-12, (i) BL-13, (j) BL-14, (k) RIPES (offline), (l) LT-STM (offline), (m) Laser ARPES (offline), (n) Laser spin-ARPES (offline).