HiSOR

ACTIVITY REPORT

2023

Hiroshima Synchrotron Radiation Center, HiSOR
Hiroshima University

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The annual report is available from

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Preface

The Hiroshima Synchrotron Radiation Center was inaugurated in 1996 as part of the academic policy of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan. A compact 700 MeV electron-storage ring named HiSOR (our center is also often called HiSOR) produces synchrotron radiation in the ultraviolet and soft X-ray range. The mission of HiSOR is to promote advanced research in the field of condensed matter physics, including interdisciplinary fields, using synchrotron radiation and develop human resources in the international research environment established inside the national university. HiSOR has been authorized as a “Joint Usage/Research Center” by the MEXT since FY2010. After an evaluation of the 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 proposal, synchrotron radiation is expected to play an important role in developing interdisciplinary research areas of semiconductors, meta matter, regenerative medicine, cell medicine, and drug discovery.

In addition, to promote interdisciplinary research by strengthening collaboration with the priority research fields of Hiroshima University (semiconductors, meta matter, drug discovery, and regenerative medicine), we obtained funding from the MEXT to reorganize the facility as the Research Institute for Synchrotron Radiation Science in FY2024. The previous research divisions have been integrated into the core research division which will take over the functions of the Joint Usage/Research Center. The collaborative research division has been newly established to apply ultraviolet synchrotron radiation to various research fields. In addition, we will promote the upgrade project of the high brilliance compact electron storage ring (HiSOR-II) through the expansion of stakeholders.

The number of accepted proposals in FY2023 was 104, including 40 overseas proposals. We accepted 169 (real number) researchers and students, including 37 from abroad. We published 33 peer-reviewed papers in 2023. Among them, 17 papers (52% of the peer-reviewed papers) were published under international collaborations. The number of the top 10% most cited papers amounted to 13% for the 2017–2022 period, indicating the quality of our publications.

The 28th Hiroshima International Symposium on Synchrotron Radiation (62 participants, including 12 overseas participants) was held on-site, combined with online sessions, on Mar. 14–15, 2024. During the symposium, an international external review was conducted. We also hosted the 19th

International Conference on Chiroptical Spectroscopy (CD2023) (Hiroshima, Sep. 17-21, 2023) chaired by Assoc. Prof. Matsuo.

In FY2023, Dr. Amit Kumar moved to the Max Planck Institute in Germany and Dr. Kazuki Sumida joined as a specially appointed assistant professor to develop advanced spin-resolved photoemission spectroscopy.

We have accepted visitors including junior and senior high school students to introduce our facilities. We also accepted a Ph.D. student from the Julius-Maximilians-Universität Würzburg in Germany on the 2023 JSPS summer program.

Finally, I would like to thank all the staff for their great effort 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 the MEXT.

September 2024

Kenya Shimada
Director of the Research Institute for the Synchrotron
Radiation Science (HiSOR), Hiroshima University

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Current Status of HiSOR

Status of the HiSOR storage ring

1. Introduction

The HiSOR is a synchrotron light source in Hiroshima University, established in 1996. It is a compact racetrack-type storage ring having 21.95 m circumference and 700MeV electron 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 natural emittance of the electron beam is 400 nm-rad, which is much larger than most of other operational synchrotron light sources. It has two straight sections, where two insertion devices, a planar undulator and an APPLE-II undulator, are operational, which cover the VUV spectral range. The high field bending magnets produce synchrotron radiation in wide spectral range including tender X-rays. The principal parameters of HiSOR are shown in Table 1. Major parameters of the undulators are listed in Table 2. The photon energy spectra of the SR from HiSOR are shown in Figure 1.

Table 1: Main parameters of the HiSOR 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)

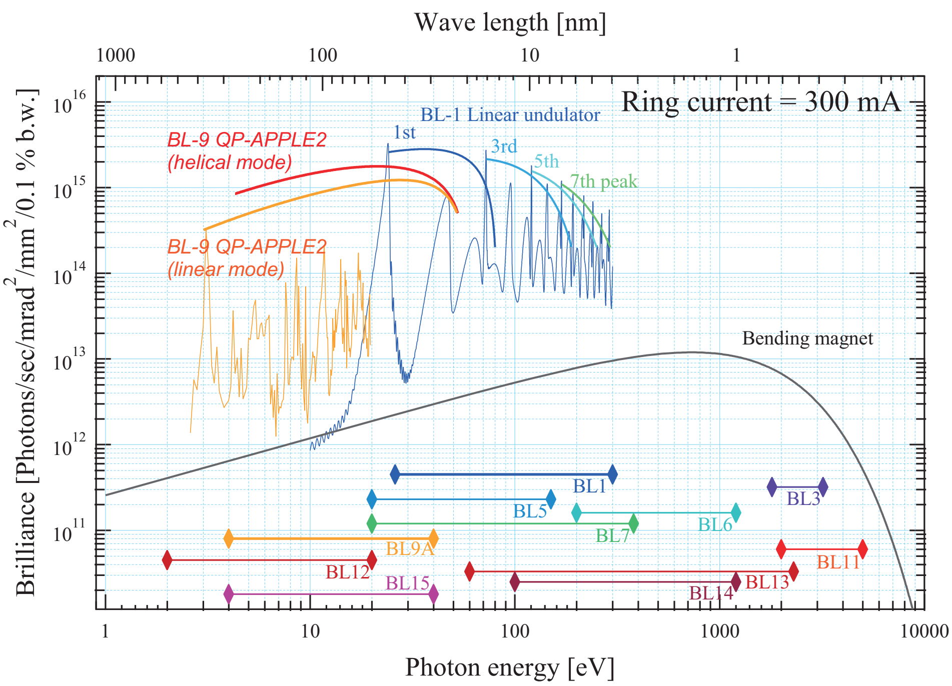

Figure 1: Photon energy spectra of the SR from HiSOR.

2. Operation status in FY2023

The ring is operated for users from Tuesday to Friday. Figure 2 shows an example of typical users' operation for one day. Beam injection for HiSOR is executed twice a day, at 9:00 and 14:30. The beam injection is normally completed within 30 minutes. The users are requested to evacuate from the experimental hall during the injection. The filling beam current is about 300mA. Machine is operated for machine conditionings and studies on Monday.

Figure 3 shows monthly operation time of HiSOR storage ring in FY2023. HiSOR regularly has a long-term shutdown period for maintenance works in every summer. One of the reasons is the planned electricity outage for maintenance and inspection, which is regularly set at the end of August. In FY2023, after the summer shutdown, the beam lifetime was shorter than usual and did not recover. The reason of this is still not clear. However, the machine had been operated as scheduled until the end of December. After January, 2024, the machine operation became irregular because of the several vacuum accidents as described below. As the result, the operation time for users from January to March, 2024 was very limited.

After the short shutdown during the new year holidays, a serious vacuum trouble happened in the middle of January. It was found that the cooling water of the photon absorber, which was installed inside of the vacuum chamber at one of two bending magnets, was leaking out to the ultra-high vacuum. Similar accident took place almost ten years ago and the absorber was replaced at that time. However, it happened again. The absorber was removed from the chamber and the leaking spot was identified and repaired by welding. Then, the vacuum conditioning was started. However, during the vacuum conditioning with the beam in April, the cooling water leakage into the ultra-high vacuum happened at the RF cavity. This was repaired quickly and the vacuum conditioning was carried out including the baking of the cavity. Surprisingly, during the vacuum conditioning with the beam in June, the leakage at the absorber happened again. This time, the leaking spot was only about 10cm away from that of first accident. The absorber was inspected by using an ultrasonic inspection machine. It was found that the thickness of the wall of water channel was only 1mm or less for about 1m range around the leaking spot. This time a thin copper plate was welded to the absorber for the 1m range. After this repairment, the vacuum conditioning was started and continued until the middle of August. Then, the machine was shutdown for the annual regular inspection. Consequently, we could not operate the machine for about a half of the year, for users with the normal operation condition.

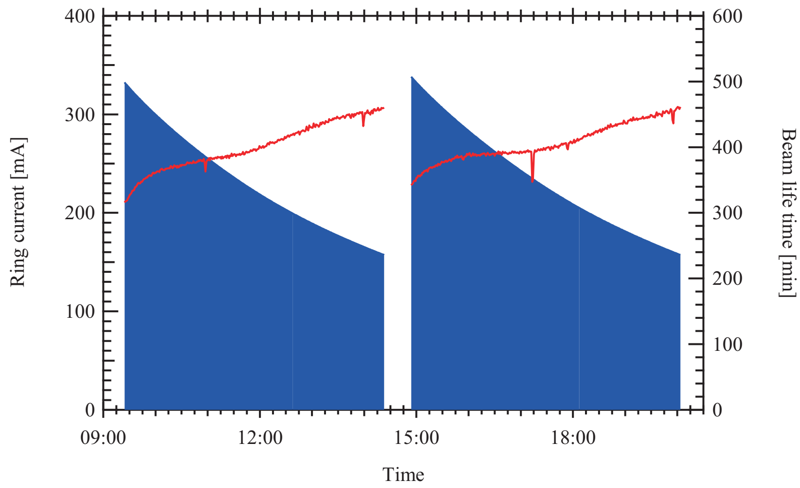

Figure 2: Typical daily operation status.

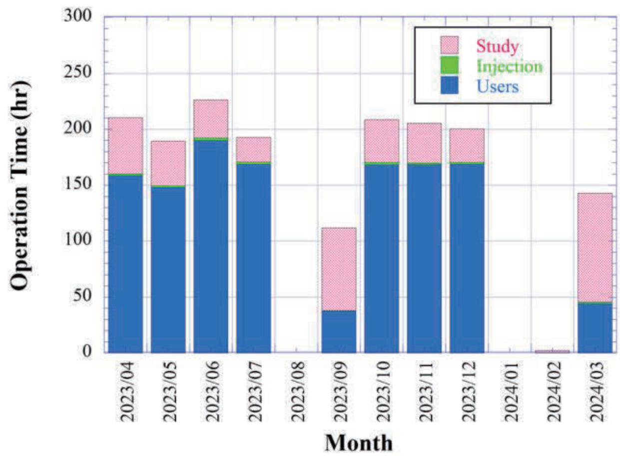

Figure 3: Monthly operation time in FY 2022.

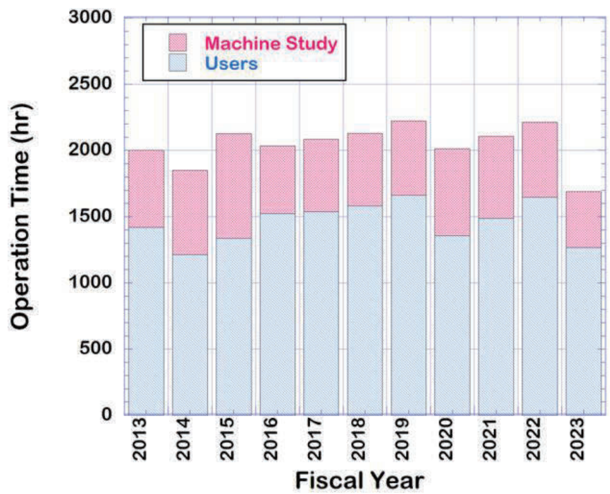

Figure 4: Operation time in FY 2013-2021.

3. Improvements and Developments

The HiSOR accelerator system was constructed in 1990's. Many of the accelerator components have been aging and some of them are becoming difficult to procure for maintenance. The photon beam absorber which caused the serious troubles should be replaced soon, because the repairment made so far was temporal. In addition, another absorber installed in another bending magnet has the same structure and same failure may occur soon. 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 storage ring. Various lattice designs are under investigations. Also, the accelerator layout is under consideration. The target parameters are as follows; the beam energy around 500 MeV, the circumference smaller than 50 m, the numbers of insertion devices larger than 4. The ring will be operated in the top-up mode. Therefore, a full energy injector is required. All these should be realized with a construction cost as low as possible. Also, the running cost should be as low as possible. We have started a collaboration with KEK, UVSOR and NuSR on the element technology development 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).

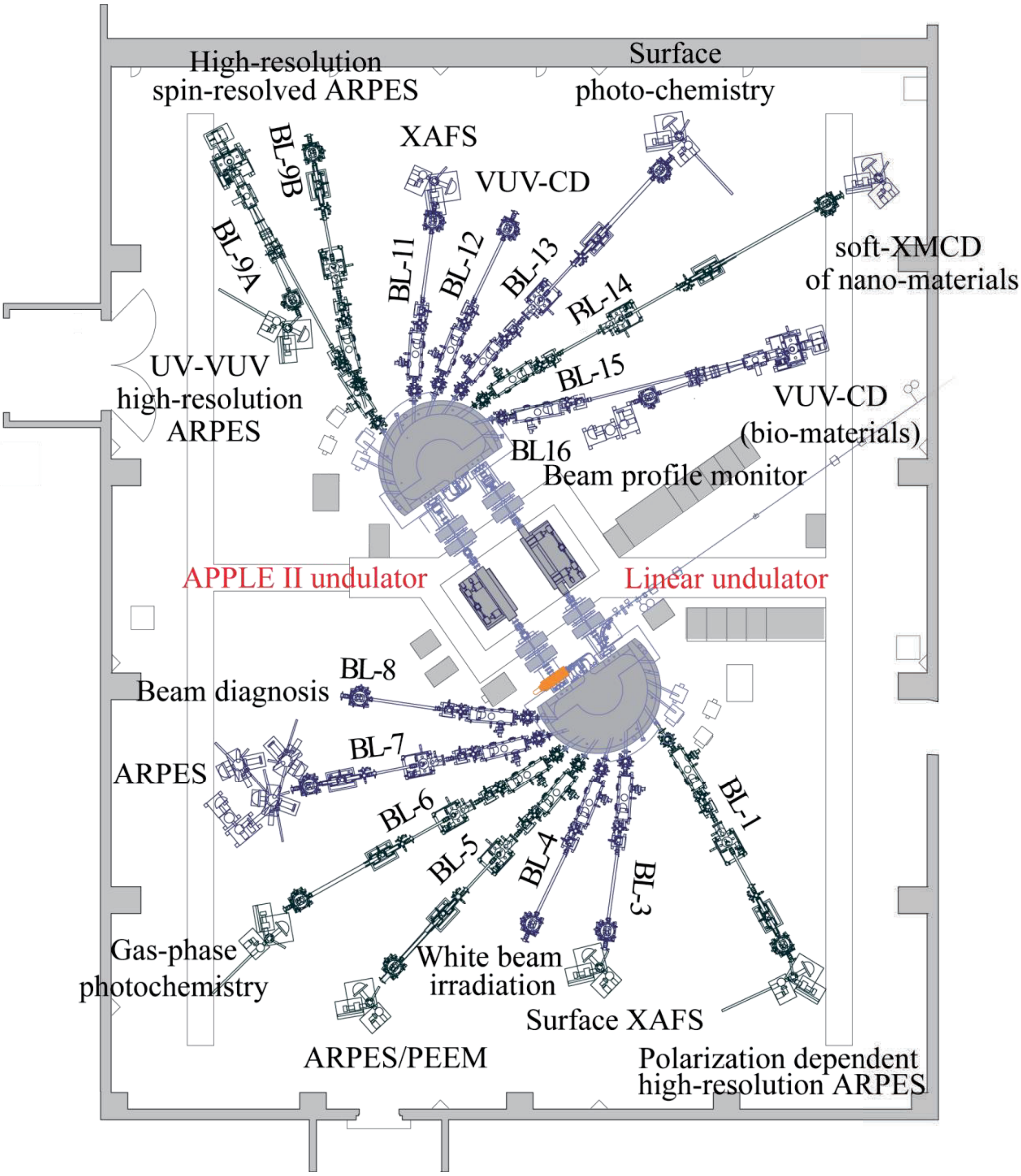

Fig. 1: Schematic view of the experimental hall.

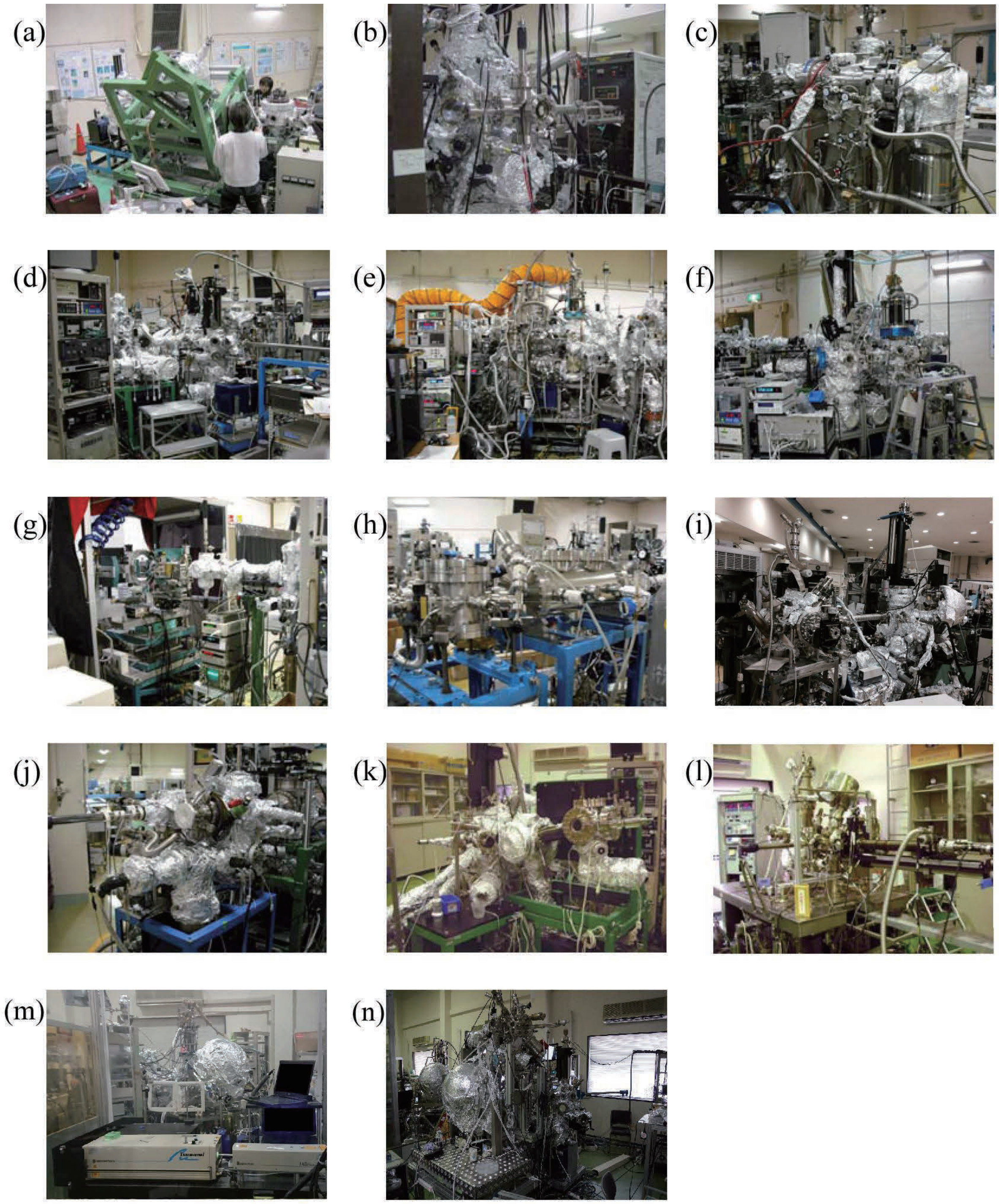

Fig. 2: Experimental stations on the beamline and offline: (a) BL-1, (b) BL-3, (c) BL-6, (d) BL-7, (e) BL-9A, (f) BL-9B, (g) BL-11, (h) BL-12, (i) BL-13, (j) BL-14, (k) RIPES (offline), (l) LT-STM (offline), (m) Laser ARPES (offline), (n) Laser spin-ARPES (offline).