HiSOR

ACTIVITY REPORT

2022

Hiroshima Synchrotron Radiation Center, HiSOR
Hiroshima University

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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 FY2022, Dr. Shiv Kumar moved to the Institute of Microelectronics, Agency for Science, Technology and Research in Singapore. We hope to start collaborative research with his institute in the future. To promote research in the priority area and nurture young scientists, we have employed Dr. Amit Kumar, Dr. Xueyao Hou, and Dr. Lu Yao as young postdoc researchers. They all got Ph.D. in physics in September 2022. Dr. Kumar's thesis was temperature-dependent high-resolution angle-resolved photoemission (ARPES) study of the electron-phonon interaction in the topological surface state of Bi_2Te_3. He has joined BL-1 and Laser ARPES group. Dr. Hou's thesis was the experimental and theoretical study of the Cr_2O_3 and graphene interface, and she has joined BL-14 group. Dr. Lu's thesis was R&D of pulsed multipolar magnets for injection, and he has joined accelerator physics group.

The number of accepted proposals in FY2022 was 111, including 28 overseas proposals. The number of oversea proposals increased compared with that in FY2021 (17 proposals). However, due to the COVID-19 pandemic, some collaborators still could not come to run experiments. The HiSOR staff performed five substitute experiments for our international collaborators.

We published 41 peer-reviewed papers in 2022. Among them, 27 papers (78% of the peer-reviewed papers) were published under international collaborations. The number of the top 10% most cited papers was amount to 11% for the 2016–2021 period, indicating the quality of our publications.

The 27th Hiroshima International Symposium on Synchrotron Radiation (69 participants, including 16 overseas participants) was held on-site, combined with online sessions, on Mar. 9–10, 2023. We have also co-hosted the 11th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources, which was held in Hiroshima city on Oct. 6-10, 2022.

We have accepted 471 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 2022 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.

August 2023

Kenya Shimada

Director of the Hiroshima Synchrotron Radiation Center,

Hiroshima University

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Current Status of HiSOR

Status of the HiSOR storage ring

1. Introduction

The HiSOR is a synchrotron radiation (SR) source of Hiroshima Synchrotron Radiation Center, 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 rather large compared with other operational synchrotron light sources. It has two straight sections, where two insertion devices, a linear undulator and an APPLE-II undulator, are operational. The most outstanding advantage of the facility lies in good combination with state-of-the-art beamlines (BL's) for high-resolution photoelectron spectroscopy in the photon energy ranges between VUV and soft X-ray. Moreover, the high field bending magnets produce synchrotron radiation in wide spectral range including tender X-rays, which can be powerful probes in various research fields. 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)
Quasi-Periodic 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)

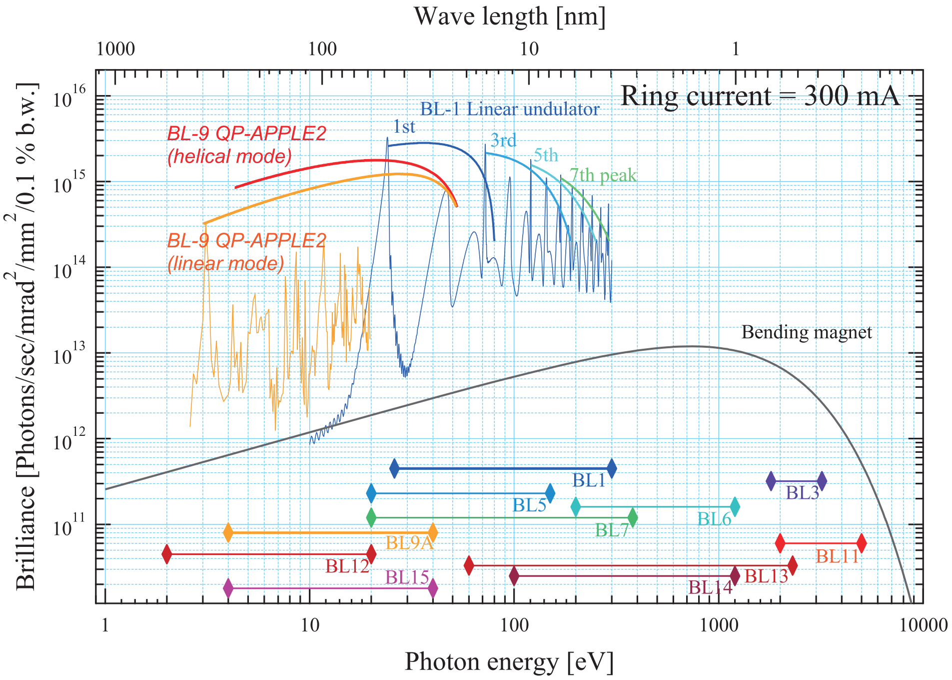

Figure 1: Photon energy spectra of the SR from HiSOR.

2. Operation status in FY2022

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 around 9:00 and 14:30. The beam injection is normally completed within 30 minutes. 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 FY2022. 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. Fortunately, in FY2022, there was no cancellation of the machine time due to COVID-19 pandemic nor serious machine troubles. The total user time in FY2022 achieved 1628 hours.

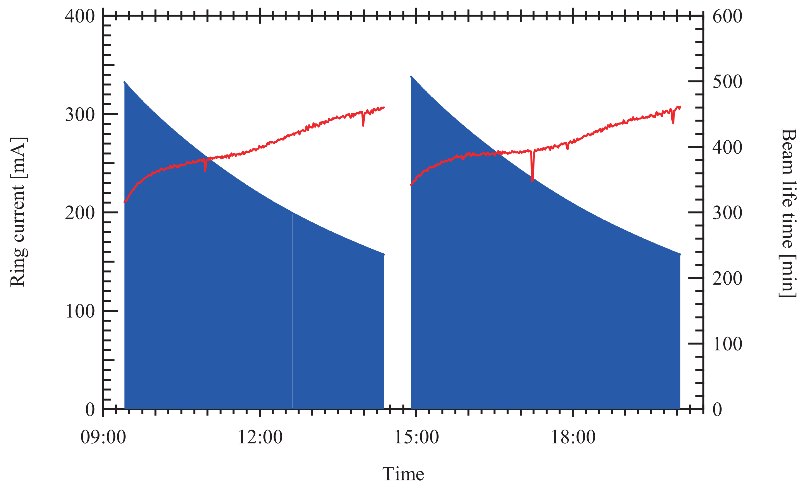

Figure 2: Typical daily operation status.

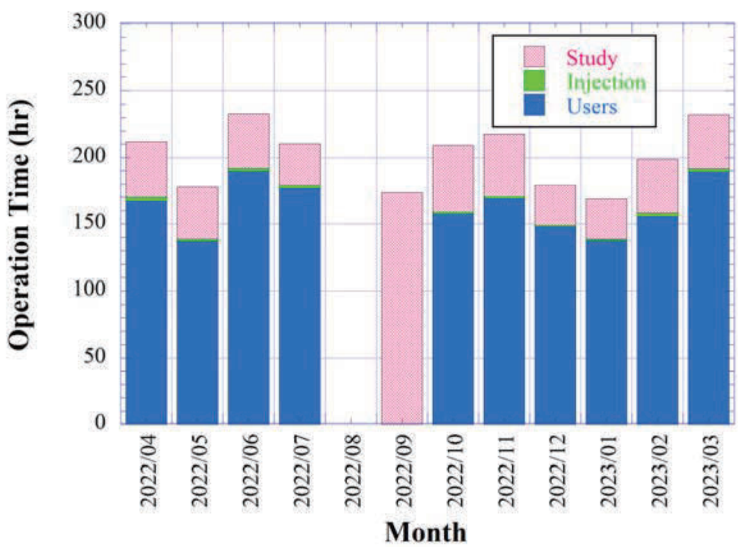

Figure 3: Monthly operation time in FY 2022.

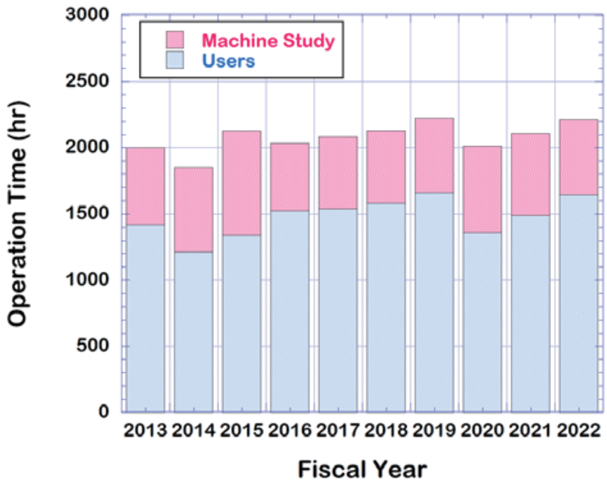

Figure 4: Operation time in FY 2013-2022.

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 pulse magnet system is one of most serious because its key device, the thyratron, has already been discontinued. We have started preparing for the total replacement of the system which utilizes semiconductor devices.

The undulators in HiSOR has been controlled via the accelerator control system. To meet the demand from the users who wanted to control the pole gaps from the beamline control systems, the undulator control system was modified to accept the control request from the beamlines. In parallel, a totally new control system has been developed and is being prepared for commissioning, which will enable the users to control the pole gap with a sufficient speed for cooperation with the monochromator.

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 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		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).

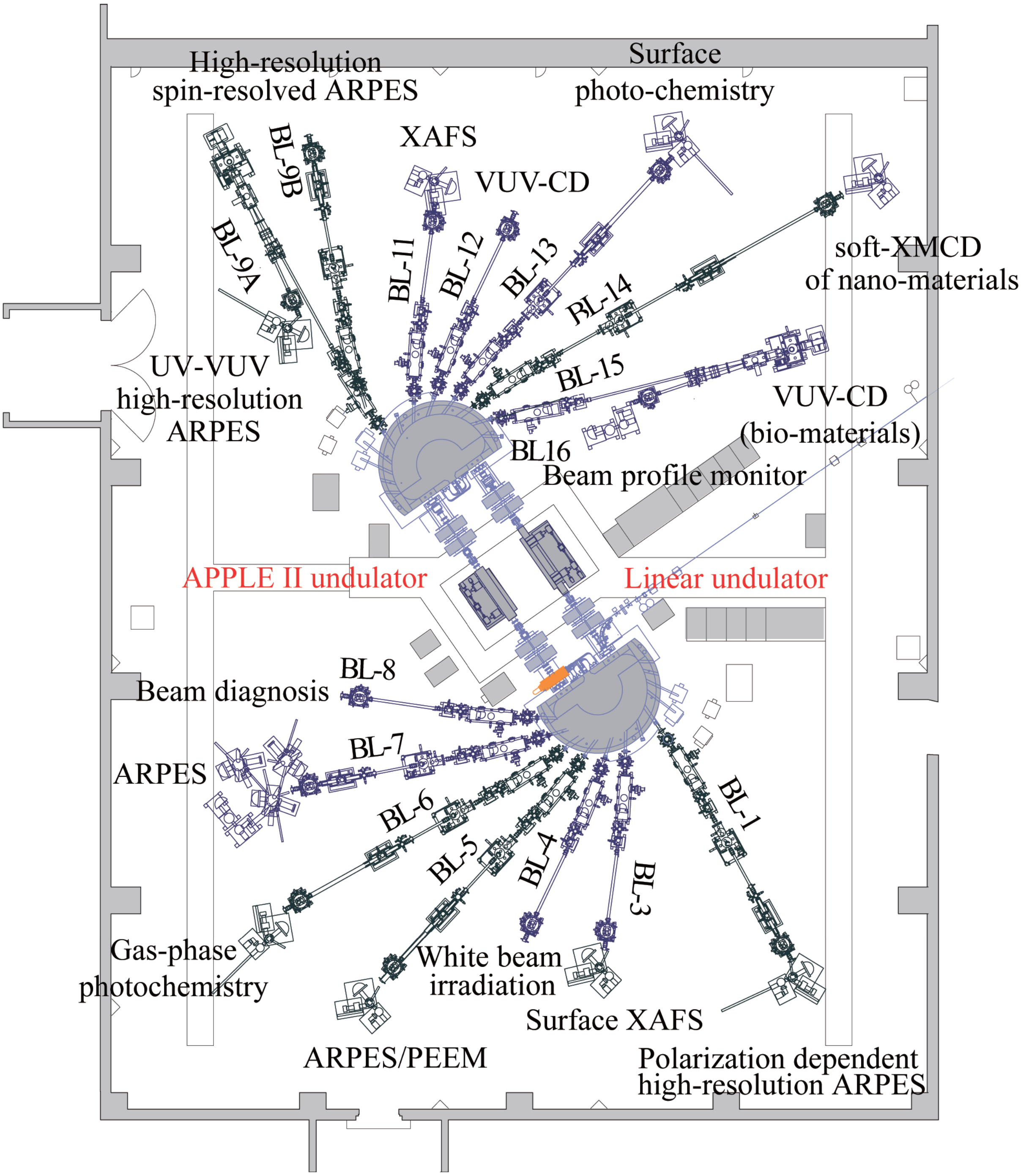

Fig. 1: Schematic view of the experimental hall.

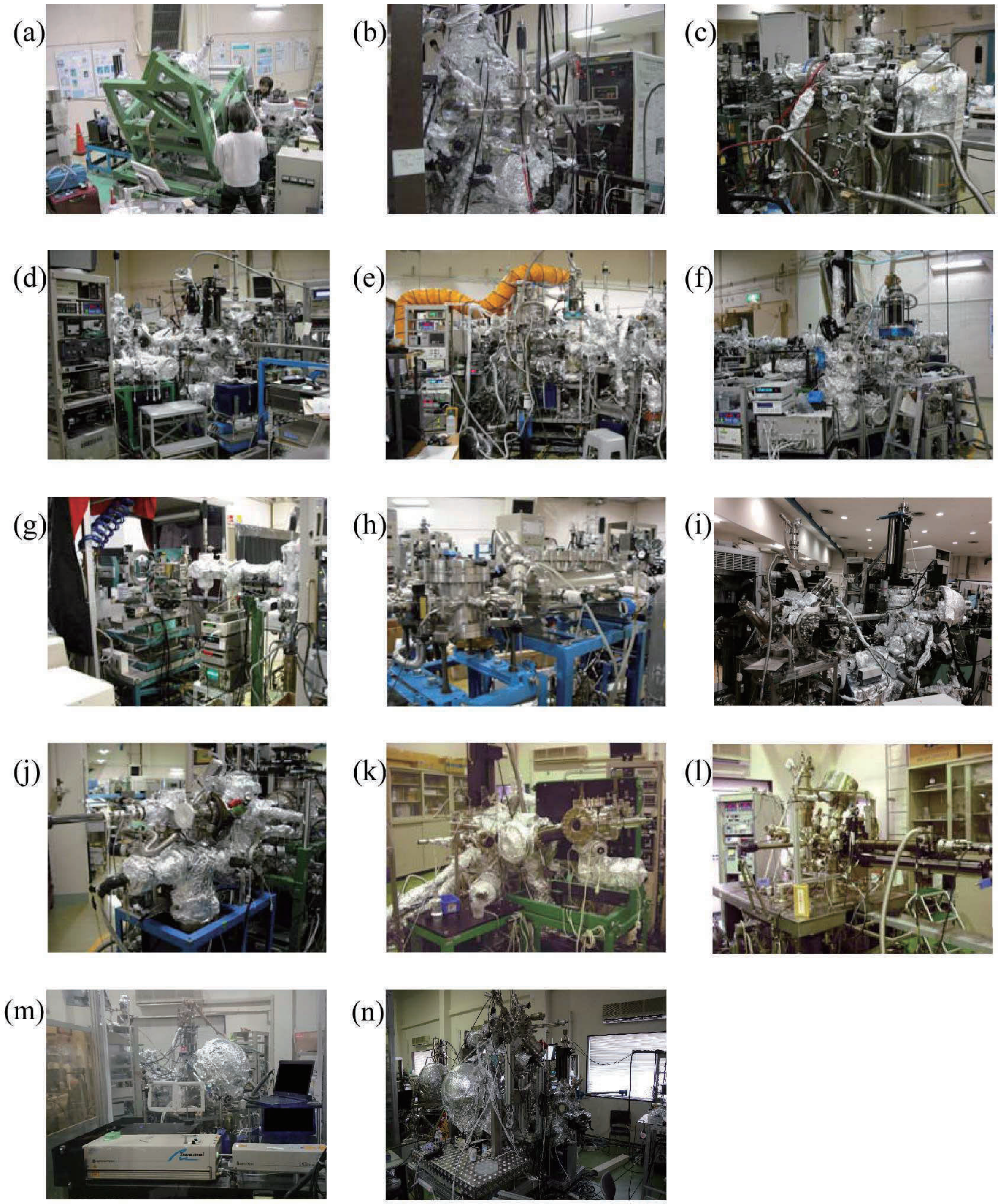

Fig. 2: Experimental stations on the beamline and offline: (a) BL-1, (b) BL-3, (c) BL-6, (d) BL-7, (e) BL-9A, (f) BL-9B, (g) BL-11, (h) BL-12, (i) BL-13, (j) BL-14, (k) RIPES (offline), (l) LT-STM (offline), (m) Laser ARPES (offline), (n) Laser spin-ARPES (offline).