HiSOR

ACTIVITY REPORT

2018

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 policies of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). A compact 700MeV electron-storage ring, called HiSOR (this center is often referred as HiSOR), produces synchrotron radiation in the range of ultraviolet and soft x-ray. The mission of the center is to promote advanced research in the field of condensed matter physics including interdisciplinary fields using synchrotron radiation, as well as to develop human resources making the most of the international research environment established in the national university. In FY2010, the center was authorized as a “Joint Usage / Research Center” by the MEXT for six years, and the authorization was extended until FY2021, in 2016.

In FY2018, the real number of HiSOR users amounted to 228 (Hiroshima University: 84, domestic institutes: 80, foreign institutes: 64). We have accepted 127 proposals including 36 proposals from outside Japan. Detailed scientific results are reported in this volume.

It is our great pleasure to note that Dr. Koji Miyamoto, an assistant professor of HiSOR, has received a commendation by the Minister of Education, Culture, Sport, Science and Technology for his outstanding achievements in spin-resolved photoemission studies of topological surface states. Furthermore, Dr. Shunya Matsuba, an assistant professor of HiSOR, has received a Young Scientist Award of the Physical Society of Japan for his work on the generation of vector beam with tandem helical undulators, which has been done in collaboration with the Institute of Molecular Science and Nagoya University.

From Oct. 4 to Oct. 6, 2018, we hosted the International Workshop on Trends in Advanced Spectroscopy in Materials Science (TASPEC) in the campus of Hiroshima University. The scope covered a broad range of experimental and theoretical hot topics of gas-phase molecules, liquids, solids and their surfaces/interfaces studied by various spectroscopic methods such as photoelectron spectroscopy, x-ray absorption spectroscopy, operand and/or *in situ* microscopy, and time-resolving techniques. The program consistsed of 20 invited talks, 14 contributed talks, and 45 posters. 110 participants from 11 countries attended the workshop and actively discussed the latest scientific results.

During FY2018, two distinguished visiting professors stayed at HiSOR. Prof. Junfeng He from the University of Science and Technology of China stayed one month to promote high-resolution angle-resolved photoemission study of correlated materials. Prof. Nikolai Sokolov from the Ioffe Physical-Technical Institute, Russian Academy of Sciences stayed three months to develop a soft x-ray reflection spectrometer on the beamline BL-14, and to run soft x-ray MCD studies on functional thin films grown in his laboratory.

In closing, I would like to thank all the staff members for their great efforts to operate HiSOR, and to maintain and advance experimental stations. I also want to thank our students and collaborators for their excellent scientific achievements, making full use of our facilities. Finally, I deeply appreciate the continued supports by Hiroshima University and the MEXT.

July 2019

Kenya Shimada

Kenya Shimada
Director of Hiroshima Synchrotron Radiation Center

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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 its natural emittance of 400π nmrad is rather large compared with those of the other medium to large storage rings. 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. The principal parameters of HiSOR are shown in Table 1.

HiSOR has two 180-deg. Normal-conducting bending magnets which generate a strong magnetic field of 2.7 T. This storage ring is equipped with two insertion devices, a linear undulator and a quasi-periodic APPLE-II undulator which replaced to the previous helical undulator in summer 2012. Major parameters of these undulators are listed in Table 2. The photon energy spectra of the SR from HiSOR are shown in Figure .

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 life time	~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)

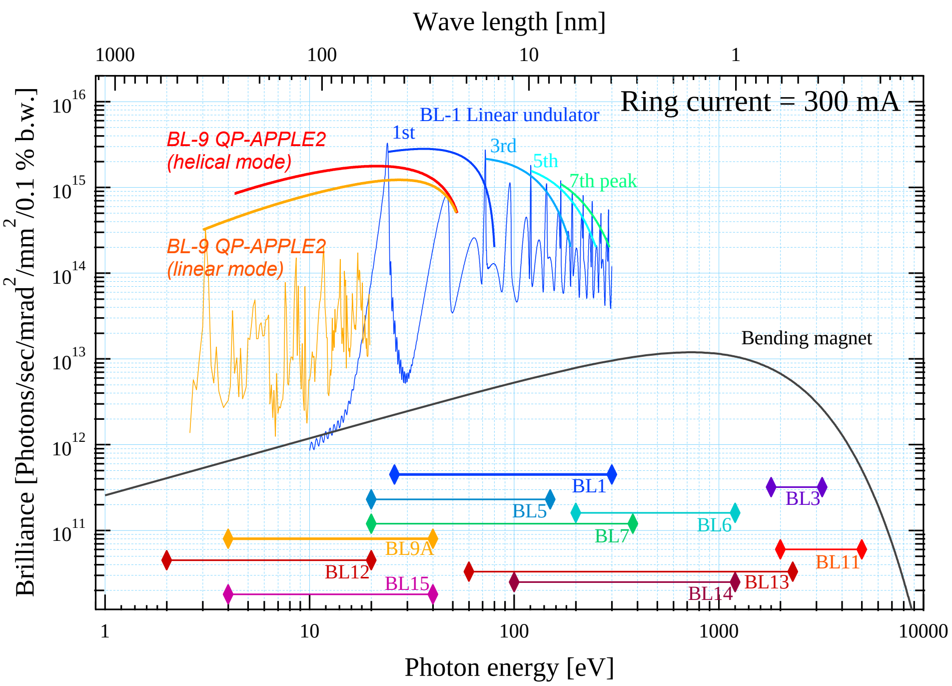

Figure 1: Photon energy spectra of the SR from HiSOR.

2. Operation status in FY 2018

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. Machine is operated for machine conditionings and studies on Monday.

Figure 3 shows monthly operation time of HiSOR storage ring in FY 2018. HiSOR has a long term shutdown period for maintenance works in every summer. The total user time of FY2018 achieved 1580 hours.

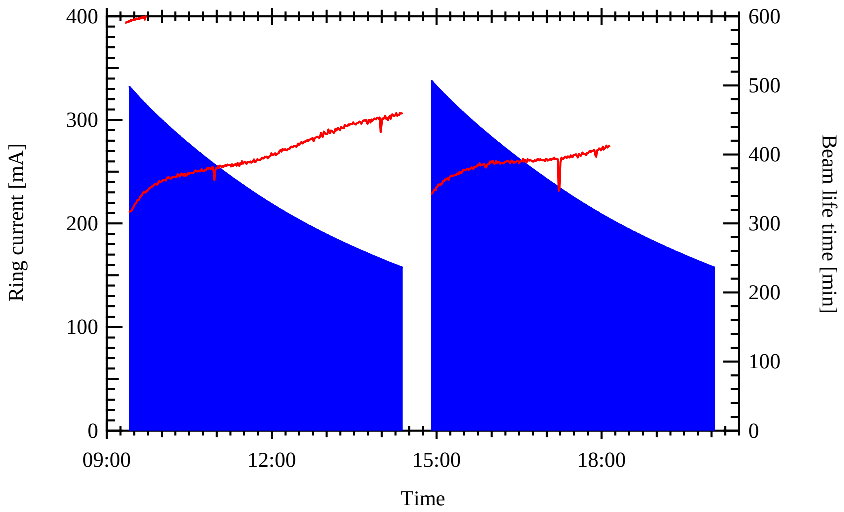

Figure 2: Typical daily operation status.

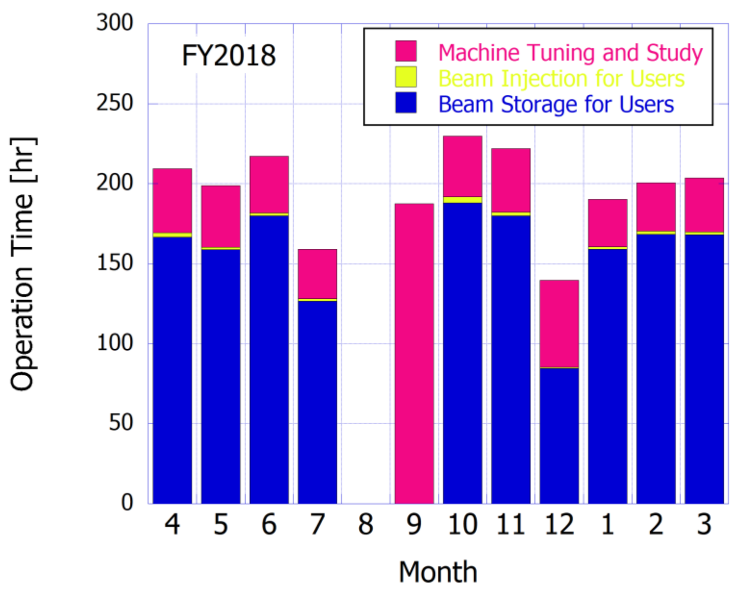

Figure 3: Monthly operation time in FY 2018.

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).

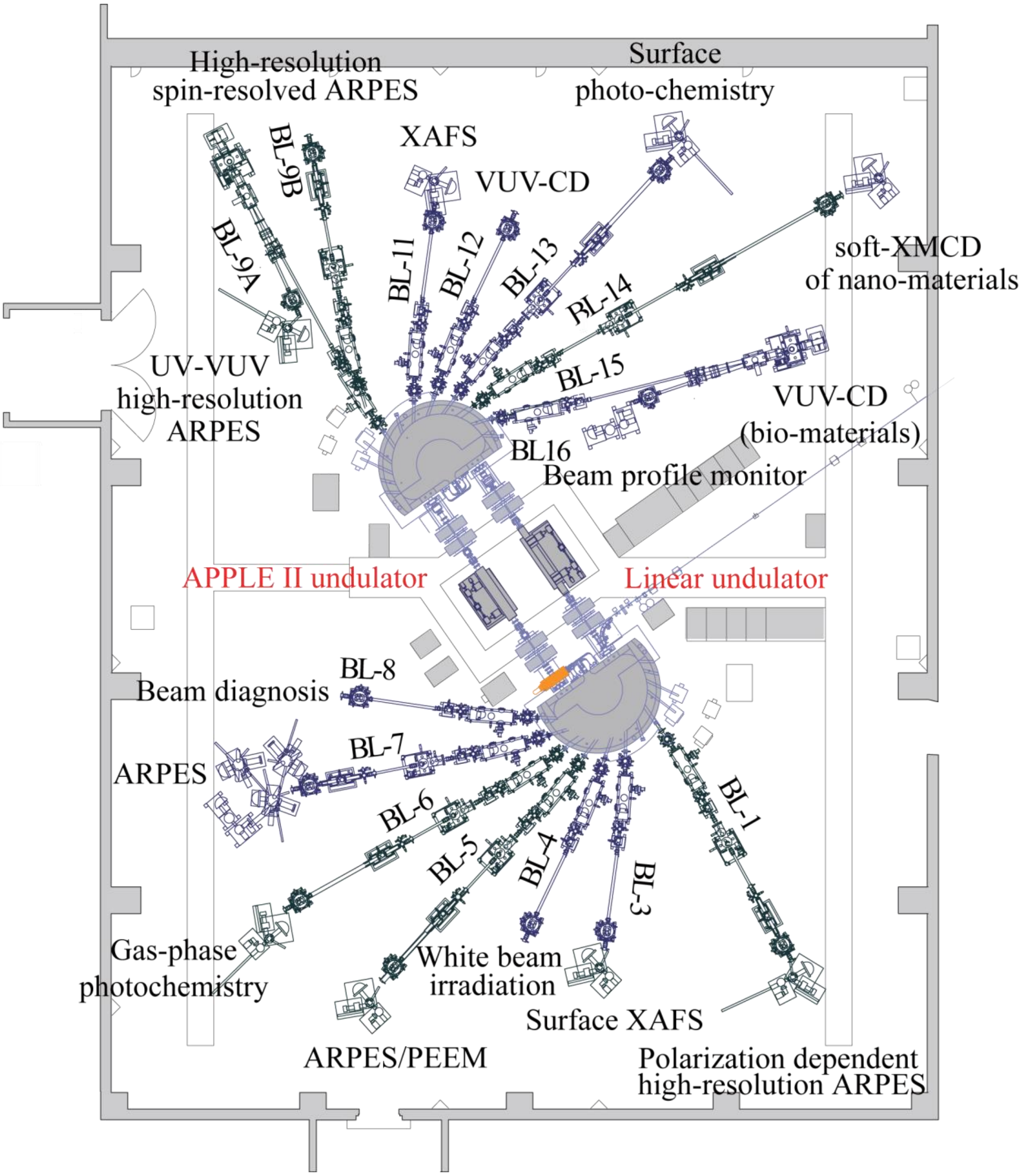

Fig. 1: Schematic view of the experimental hall.

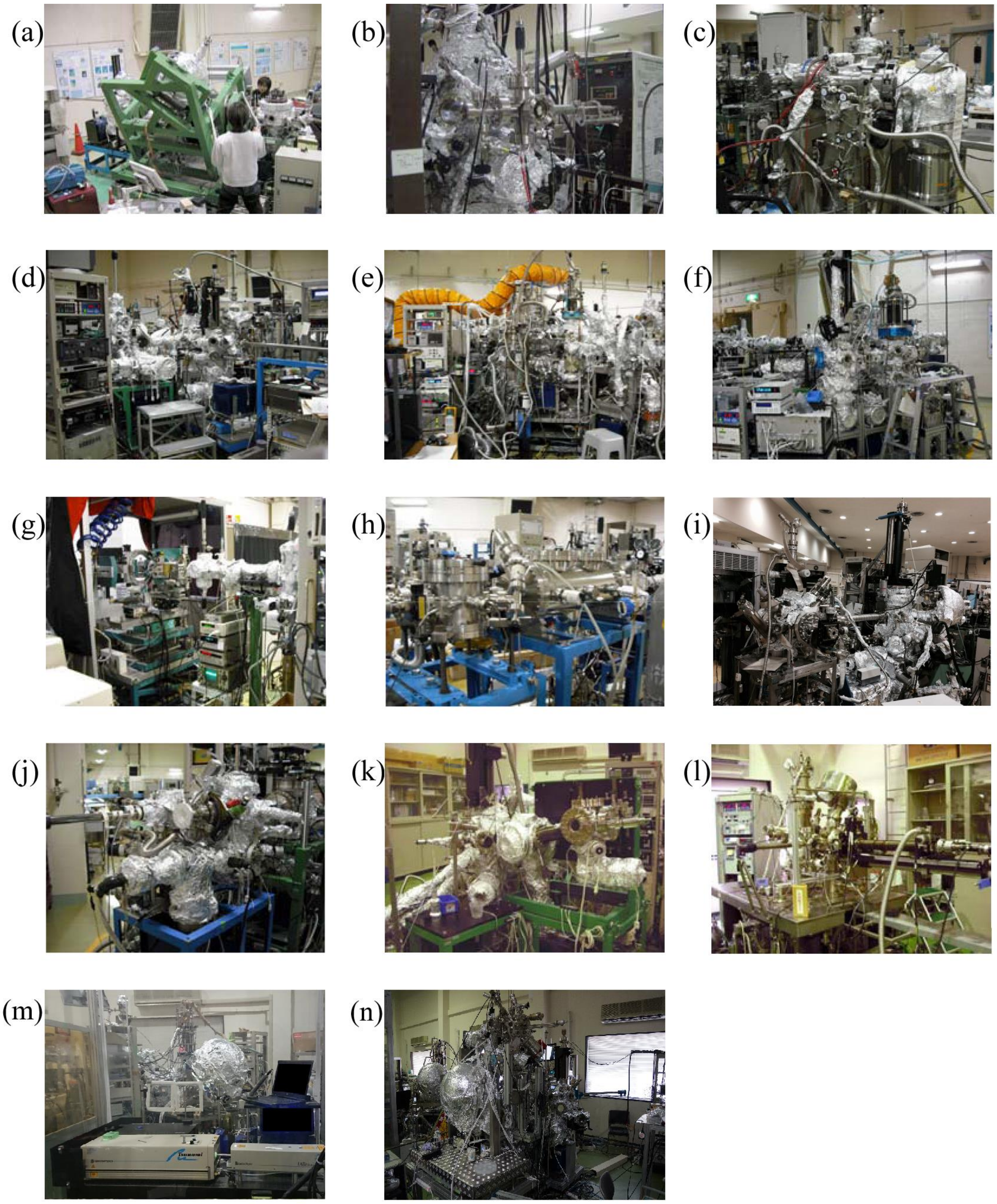

Fig. 2: Experimental stations on the beamline and offline: (a) BL-1, (b) BL-3, (c) BL-6, (d) BL-7, (e) BL-9A, (f) BL-9B, (g) BL-11, (h) BL-12, (i) BL-13, (j) BL-14, (k) RIPES (offline), (l) LT-STM (offline), (m) Laser ARPES (offline), (n) Laser spin-ARPES (offline).

Future Plan of HiSOR

Design Study of an Electron Storage Ring for the Future Plan of Hiroshima Synchrotron Radiation Center

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Keywords: Storage Ring, Lattice, Undulator, Brilliance.

We have designed a magnetic lattice of a storage ring for the future plan of Hiroshima synchrotron radiation center [1]. We selected a basic cell structure similar to that of ASTRID2 [2]. Circumference of this ring is 49.5 m and natural emittance is 9.4 nm. The ring has three long and three short straight sections as shown in FIGURE 1. The 5m long straight sections are capable of installing long or tandem undulators for advanced light source technologies [3]. The 2.2 m short straight sections are for installation of injection system, RF cavity and an in-vacuum undulator. The optical functions are shown in FIGURE 2 and the main parameters of storage ring are summarized in TABLE 1.

Figure 3 shows synchrotron radiation spectra calculated using a code SPECTRA [4] for a 4 m long APPLE-II type with periodic length of 60 mm and the maximum K value of 3.4 in the horizontal polarization condition and a 2 m long in-vacuum type with periodic length of 38 mm and K-value of 2.4-0.19. The brilliance of the new ring is typically larger by 1 or 2 orders of magnitude than the present HiSOR at the beam current of 300 mA, as shown in FIGURE 3.

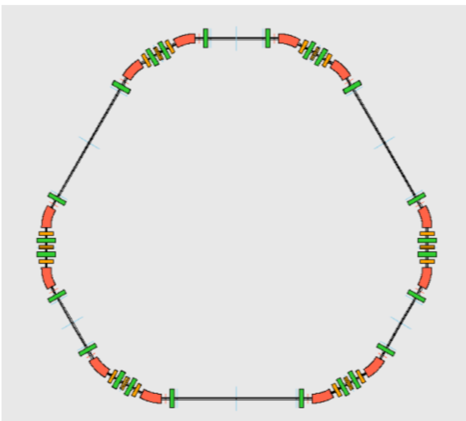

FIGURE 1. Schematic layout of HiSOR-II storage ring [1].

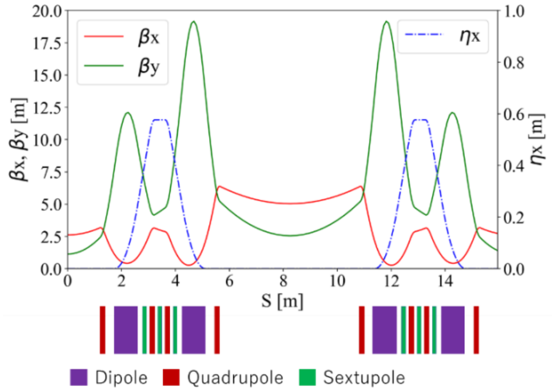

FIGURE 2: Betatron functions and dispersion function for one third of HiSOR-II storage ring [1].

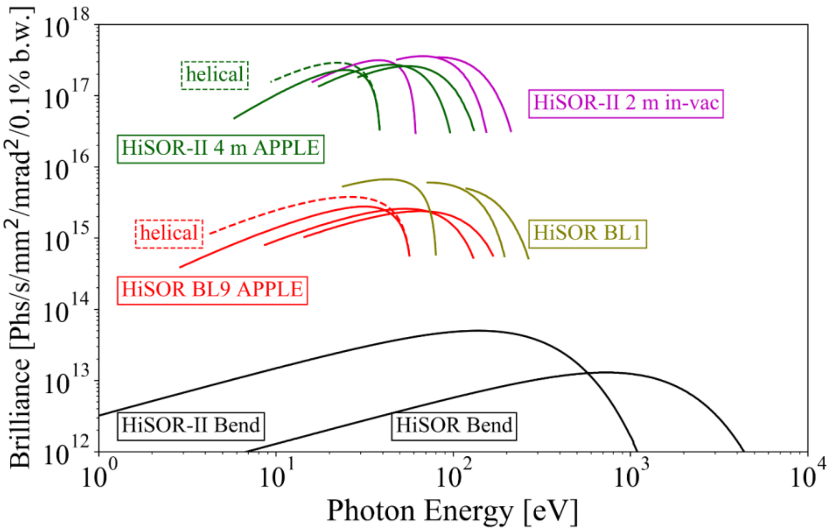

FIGURE 3: Comparison of brilliance of the synchrotron radiation from HiSOR and HiSOR-II.[1]

TABLE 1: Main Parameters.

Beam energy	500 MeV
Circumference	49.5 m
Magnetic field	1.027 T
Beam radius	1.623 m
Natural emittance	9.4 nm
Betatron tune	5.39, 2.09
Momentum compaction	0.01
RF frequency	102.96 MHz
Harmonic number	17
RF voltage	50 kV
Sored current	200 mA
Energy loss per turn	3.4 keV
Energy spread	0.00037
Bunch length	17.8 mm

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Research Activities

– Accelerator Studies –

Vector beam generation with tandem helical undulators in UVSOR

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Vector beams is a sort of structured light which have a donuts-shaped intensity with spatially dependent polarization that direction rotates around its beam axis [1,2]. Some examples of vector beams are shown in the Figure.1. Vector beams of radial polarization, shown in the left figure of Fig.1, can be focused beyond the diffraction limit and longitudinal electric fields appear when focused. Therefore, they have been investigated for many applications including imaging and optical communication, plasmon excitation and acceleration of electrons [2]. Vector beams has long been interest in laser community. Edge radiation and transition radiation are known as radial polarized beam in accelerator light source. Therefore, we propose a scheme to generate vector beams by synchrotron radiation [3]. The scheme is akin to cross undulator which produces circularly polarized light from tandem horizontally and vertically polarized undulators [4]. We expand to the scheme into two-dimensional superposition of second harmonics from two oppositely circular polarized undulators. Second harmonics of helical undulators is known as optical vortices which have a donut-shaped intensity, uniform circular polarization state with forming spiral phase front. It is well known that vector beams can be created by superposing two optical vortex beams. The example of experimental results are shown in the right figures of Fig.1. We present principle and experimental details of this scheme in this presentation.

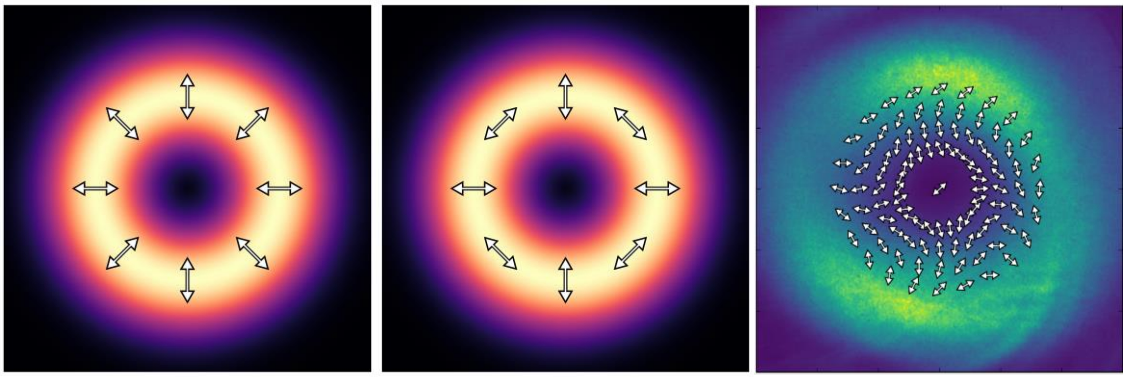

Fig. 1. A schematic illustration of vector beams (left and middle) and distributions of directions of polarization obtained by experiment (right). The arrows and back ground indicated polarization direction and intensity of each positions.

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