12th Int. Particle Acc. Conf. IPAC2021, Campinas, SP, Brazil JACoW Publishing
ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB122

PRESENT STATUS OF HiSOR

M. Katoh[1†], M. Shimada[2], H. Miyauchi[2], K. Goto, HSRC, Higashi-hiroshima, Japan
[1]also at UVSOR, Okazaki, Japan
[2]also at KEK, Tsukuba, Japan

Abstract

HiSOR is a compact synchrotron light source of 700 MeV. The circumference is 22 m. The ring has two straight section for undulators, which provide high brilliance VUV radiation. The two 180 bending magnets have 2.7 T field strength, which provide broadband radiation in VUV and soft X-ray range. The injector is a 150 MeV microtron. The beam injection is made twice a day with 5 hour interval. HiSOR has been operated stably for about 25 years. The accelerator complex is getting aged. The large emittance of 400nm-rad makes it difficult to compete with new high brilliance light sources of new generations. The compactness of the storage ring makes it difficult to introduce new technologies. We have started seeking possible upgrades, including construction of a completely new facility.

OVERVIEW

The HiSOR is a synchrotron light source of Hiroshima Synchrotron Radiation Center (HSRC), Hiroshima University, established in 1996. It is a compact racetrack-type storage ring of 700 MeV electron energy and of 21.95 m circumference [1]. Its natural emittance is 400 nm-rad, which is rather large among the second and third generation synchrotron light source. The ring has two straight sections which are available for installing insertion devices. Its injector is a microtron of 150 MeV. The beam injection is made at 150 MeV, and then the energy is ramped up to 700 MeV. The stored beam current just after the ramping is about 300 mA. The major parameters of HiSOR are summarized in Table 1.

Table 1: Major Parameters of HiSOR

Parameters	Values
Circumference	21.95 m
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
Betatron tune (ν_x, ν_y)	(1.72, 1.84)
RF frequency	191.2 MHz
Harmonic number	14
RF voltage	200 kV
Stored current (nominal)	300 mA
Natural emittance	400 nm-rad
Beam lifetime	~10 hours@200mA

† mkatoh@hiroshima-u.ac.jp

HiSOR has two 180-degree normal-conducting bending magnets (Figure 1 and Figure 2) which generate a strong magnetic field of 2.7 T. The return yokes of the magnets act as radiation shield walls. The synchrotron light is extracted through holes in the yokes. Thanks to the strong field of the bending magnets, HiSOR is capable of producing tender X-rays. HiSOR is equipped with two insertion devices, a linear undulator and a quasi-periodic APPLE-II undulator, which are capable of producing vacuum ultraviolet and soft X-ray radiation of high brightness. Major parameters of these undulators are listed in Table 2. The photon energy spectra of the SR from HiSOR are shown in Figure 3.

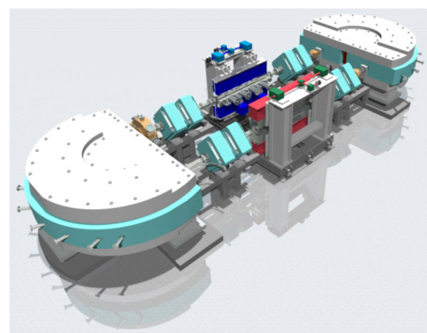

Figure 1: HiSOR electron storage ring.

Figure 2: Recent view of HiSOR and beam-lines.

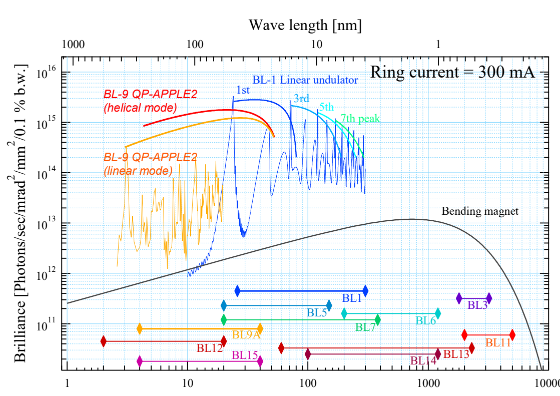

Figure 3: Photon energy spectra of HiSOR.

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB122

Table 2: Major Parameters of Undulators

Parameters	Values
Linear undulator	
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
Quasi-Periodic APPLE-II	
Total length	1845 mm
Periodic length λu	78 mm
Periodic number	23
Pole gap	23-200 mm
Maximum magnetic field	0.86 T (horizontal)
	0.59 T (vertical)
	0.50 T (helical)
Magnetic material	Nd-Fe-B

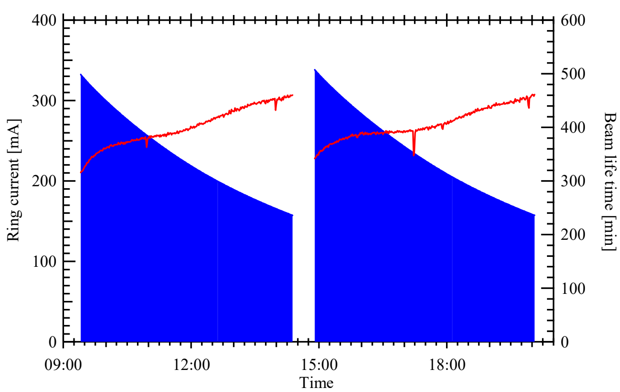

Figure 4: Typical operation pattern in a day.

The facility has 14 beamlines (BL's), which are not only for the users in Hiroshima University but also for public users including those from industries. Synchrotron light from two undulators is provided to the photo-electron spectroscopy beam-lines. The recent view of the experimental hall can be seen in Figure 2.

OPERATION STATUS

The ring is operated for users from Tuesday to Friday. Figure 4 shows an example of typical users operation in one day. Beam injection for HiSOR is executed twice a day, at around 9:00 and 14:30. It takes about 20 minutes for the beam injection and the energy ramping. HiSOR is operated for about 10 hours a day. It stops during night. On Monday, it is operated for machine conditionings and studies. It stops during weekends.

Figure 5 shows operation time of HiSOR in recent years. It is operated for about 1500 hours per year for users. However, in 2014 and 2015, we had some vacuum troubles in the storage ring. We had to reduce the operation time in these years. In 2020, due to the COVID-19 pandemic, we reduced the operation time. Also, the number of the users from outside of the university was significantly reduced.

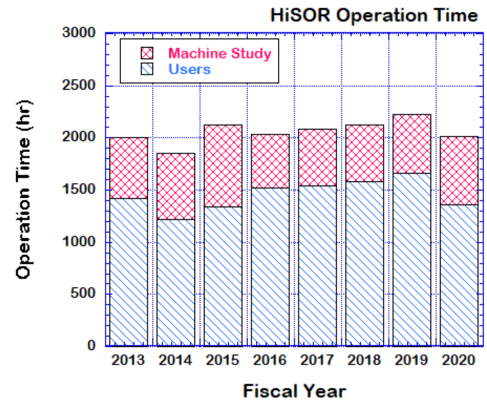

Figure 5: Operation status in recent years.

FUTURE PLAN

HiSOR has been operated for about 25 years. It has been providing VUV and soft X-ray radiation to nation-wide users and also to international users. HiSOR has a large emittance of 400 nm-rad and only two undulators. There are increasing demands for higher brightness synchrotron light. There is no more space for insertion device. The compactness of HiSOR makes it difficult to improve the performance by introducing new technologies, such as top-up injection. On the other hand, the accelerator complex is being aged.

So far, some upgrade plans have been considered. Initially, a new storage ring was planned based on the design of MAX III storage ring [2]. Next, a unique torus knot type storage ring, in which the beam orbit closes after multiple turns around the ring, was designed [3]. Then, a compact and low emittance storage ring is being considered [4], following the design of ASTRID2 [5], which is based on rather standard lattice and hardware design and seems to be suitable for a small facility in a university. The layout and the optical functions based on a tentative design are shown in Figure 6 and Figure 7. The target parameters of the design work are shown in Table 3.

We are continuing the effort of designing a new facility as taking into the account the situation surrounding the facility and the university. A more compact race-track-type ring is under consideration, following the design of NIJI-IV storage ring [6], which consists of two triple-bend cells and two long straight sections. One interesting possibility is installing superconducting bending magnets as the central magnets of the triple bend cells. If we use the superbends similar to those in Aichi SR [7], thanks to the high field up to 5 T, the synchrotron light spectrum is extended to the tender X-rays as the present HiSOR with the lower electron energy, 500 MeV. We are also investigating a possibility to inject the beam with a pulse multipole magnet [8], which makes the injection system simpler and more compact.

In parallel to the design studies, we have started R&D's on the accelerator components in collaboration with KEK.

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB122

An important direction of the hardware developments is reducing the construction cost. As its first step, we are now investigating recycling of the accelerator components.

Table 3: Target Parameters of New Ring

Parameters	Values
Electron Energy	500 MeV
Circumference	< 50 m
Number of Straight Sections	> 4
Injection Energy	500 MeV
Beam Current	300 mA (top-up)
Natural Emittance	~ 10 nm-rad

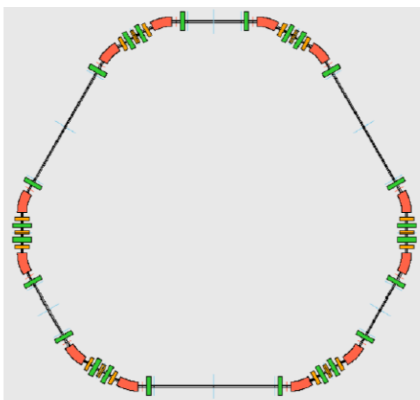

Figure 6: A design of new storage ring [4].

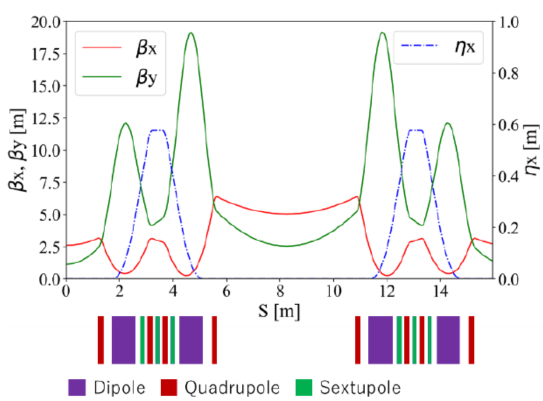

Figure 7: Optical functions of new ring [5].

CONCLUSION

A compact synchrotron light source, HiSOR, has been operated for about 25 years. It has been providing VUV and soft X-rays to users in various research fields, including industries. The accelerator complex is being aged. The demands for higher brightness are being increased. HiSOR is too compact to introduce new ideas or new technologies. We have to find an accelerator upgrade plan which can be realized with reasonable cost and the limited manpower.

REFERENCES

[1] K. Yoshida, T. Takayama, and T. Hori, “Compact synchrotron light source of the HSRC” *J. Synchrotron Rad.,* Vol. 5, p. 345, 1998. doi:10.1107/S0909049597014532

[2] A. Miyamoto, K. Goto, S. Sasaki, S. Hanada, and H. Tsutsui, “HiSOR-II, Future Plan of Hiroshima Synchrotron Radiation Center”, in *Proc. IPAC’10*, Kyoto, Japan, May 2010, paper WEPEA029, pp. 2546–2548.

[3] A. Miyamoto and S. Sasaki, “Design of Diffraction Limited Light Source Ring with Multi-bend Lattice on a Torus-knot”, in *Proc. IPAC’15*, Richmond, VA, USA, May 2015, paper TUPWA060, pp. 1560–1562. doi:10.18429/JACoW-IPAC2015-TUPWA060

[4] S. Matsuba *et al.*, “Design study of an electron storage ring for the future plan of Hiroshima Synchrotron Radiation Center”, *J. Phys.: Conf. Ser.,* Vol. 1350, p. 012015, 2019. doi:10.1088/1742-6596/1350/1/012015

[5] Niels Hertel, Søren Pape Møller, and Jørgen S. Nielsen, Preliminary Design Report for ASTRID2, 2009.

[6] M. Kawai *et al.*, “Present status of a 500 MeV compact electron storage ring for UV FEL experiments”, *Nucl. Instr. Meth.*, vol. 318, p. 135, 1992. doi:10.1016/0168-9002(92)91039-C

[7] M. Hosaka *et al.*, “Present Status of Accelerators in Aichi Synchrotron Radiation Center”, in *Proc. IPAC’17*, Copenhagen, Denmark, May 2017, paper WEPAB048, pp. 2691–2693. doi:10.18429/JACoW-IPAC2017-WEPAB048

[8] N. Yamamoto et al., “Beam injection with pulsed multipole magnet at UVSOR-III”, *Nucl. Instr. Meth.*, vol. 767, p. 26, 2014. doi:10.1016/j.nima.2014.07.059