ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPGW048

DESIGN STUDY OF AN ELECTRON STORAGE RING FOR THE FUTURE PLAN OF HIROSHIMA SYNCHROTRON RADIATION CENTER

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Abstract

We present the latest result from the design study for the future plan of Hiroshima synchrotron radiation center (HSRC). The design goal is the energy of around 500 MeV, the circumference shorter than 50 m and the emittance smaller than 10 nm with straight sections for undulators more than 4. We have selected the lattice structure similar to ASTRID 2 compact light source in Aarhus University, Denmark.

INTRODUCTION

The HSRC in Hiroshima University was established in 1996 to promote advanced materials science using synchrotron radiation as well as to develop human resources. HSRC has a compact racetrack-type light source nicknamed 'HiSOR' [1]. The energy is 700 MeV. It has 2.7T normal conducting bending magnets which provide synchrotron radiation covering from VUV to X-rays. It has two straight sections for undulators to provide higher brightness VUV. With these unique features, the ring has been operated stably for more than 20 years. However, in these years, there are increasing demands for higher brightness synchrotron light. Since HiSOR has a large emittance of 400 nm and only two undulators, some upgrade plans have been considered. Initially, an accelerator based on MAX III storage ring at Lund University, Sweden was planned [2]. Next, torus knot type synchrotron radiation ring that the beam orbit closes after multiple turns around the ring was designed [3]. Recently, considering the current situation surrounding the facility, we start designing a new lattice structure referring to a compact and low emittance light source, ASTRID2 [4-5]. It is based on rather standard lattice and hardware design, and it seems to be suitable for a small facility in a university.

The accelerator is designed to have an emittance of smaller than 10 nm, a circumference of less than 50 m to be accommodated in the site, an energy of 500 MeV, and with three long and short straight sections for insertion devices and others. In this report, we present latest results from a lattice design, such as a structure of the storage ring, betatron functions, the tune survey results and Touschek lifetime and intrabeam scattering effect calculated by SAD code [6], as well as the spectra of synchrotron radiation calculated by SPECTRA [7].

LAYOUT OF STORAGE RING AND LATTICE PARAMETERS

Figure 1 shows the layout of the storage ring. The storage ring has a hexagonal shape with long and short straight sections. Circumference of this ring is 49.5 m and natural emittance is 9.4 nm in assumed operation condition. Long straight sections are 5 m to be capable of installing two undulators in tandem for advanced light source technologies [8]. Short straight sections are 2.2 m for installation of injection system, RF cavity and in-vacuum undulators. The main parameters of storage ring are shown in Table 1.

The betatron functions and a dispersion function for one third of the storage ring are shown in the Figure 2. The dispersion of straight sections is zero. The unit cells consist of two dipoles with defocusing combined function, four quadrupoles and three sextupoles.

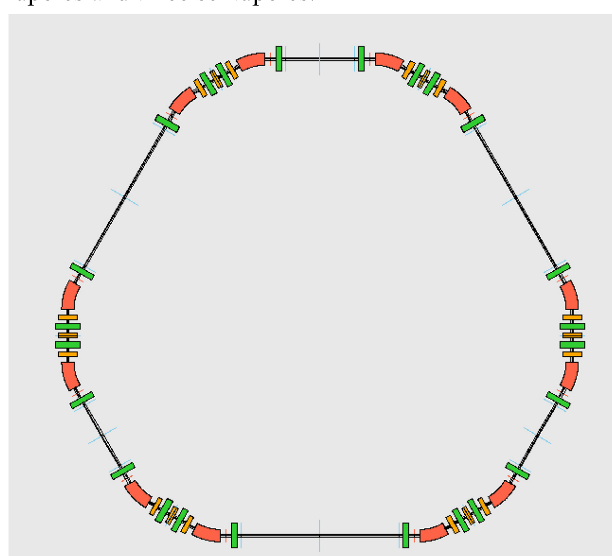

Figure 1: Schematic layout of HiSOR-II storage ring.

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Table 1: Parameters of Storage Ring

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

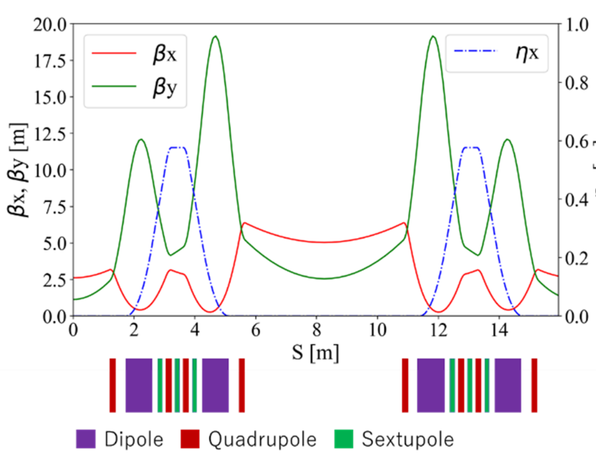

Figure 2: Betatron functions and dispersion function for one third of HiSOR-II storage ring.

Tune Survey

For searching operation tune that is compatible with low emittance and large dynamic aperture, a tune survey is performed. The survey region is determined by referring to the ASTRID2 operation tune. The strength of sextupoles near long straight section and those near short straight sections are adjusted to give larger dynamic aperture while correcting linear chromaticity. As a result, the higher field of sextupoles near long straight sections seemed to be better.

Figure 3 shows tune survey results for emittance, horizontal aperture and vertical aperture. The dynamic aperture of the selected operation point is shown in Figure 4. The horizontal aperture is about 20 to -30 mm and vertical aperture is about 9 mm.

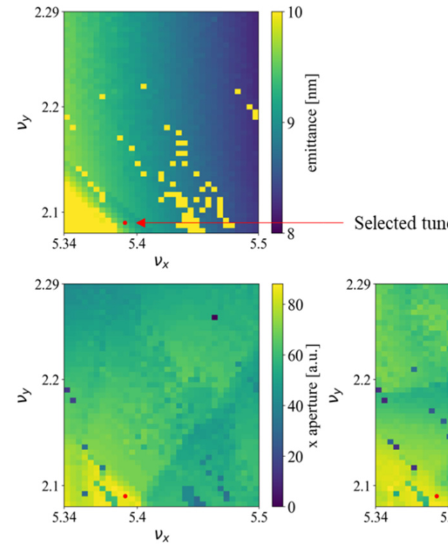

Figure 3: Results of tune survey for emittance (upper left), horizontal aperture (lower left) and vertical aperture (lower right).

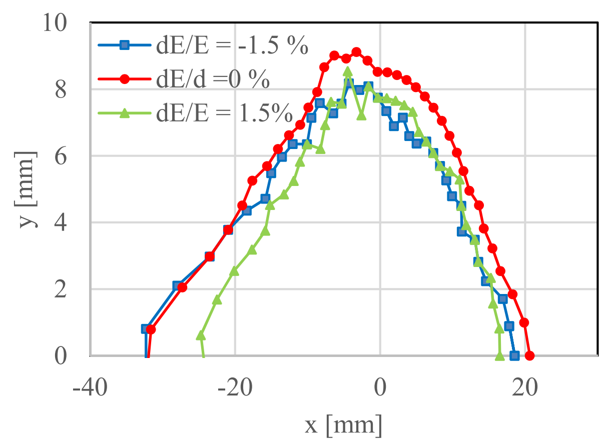

Figure 4: Dynamic aperture of the HiSOR-II storage ring.

Touschek Lifetime and Intrabeam Scattering

Touschek lifetime depends on the momentum acceptance. Momentum acceptances at longitudinal location S in the ring were obtained by particle tracking starts from S for the particles with the same positive and negative momentum offset. These momentum acceptances are maximum momentum offset of particles which survive after circulating enough turn [9].

In this estimation, the momentum acceptances of each center of lattice components were calculated and averaged considering the length of components. The averaged momentum acceptance of the ring is estimated as 2.8 %. The acceptance of 2.8 % indicates the touschek life time of 4.5 hours by SAD calculation.

Intrabeam scattering effect makes emittance 12 nm and bunch length 23. 0 mm for the XY coupling of 3%. The use of harmonic cavity to reduce the intrabeam scattering effects by making the bunch longer should be considered.

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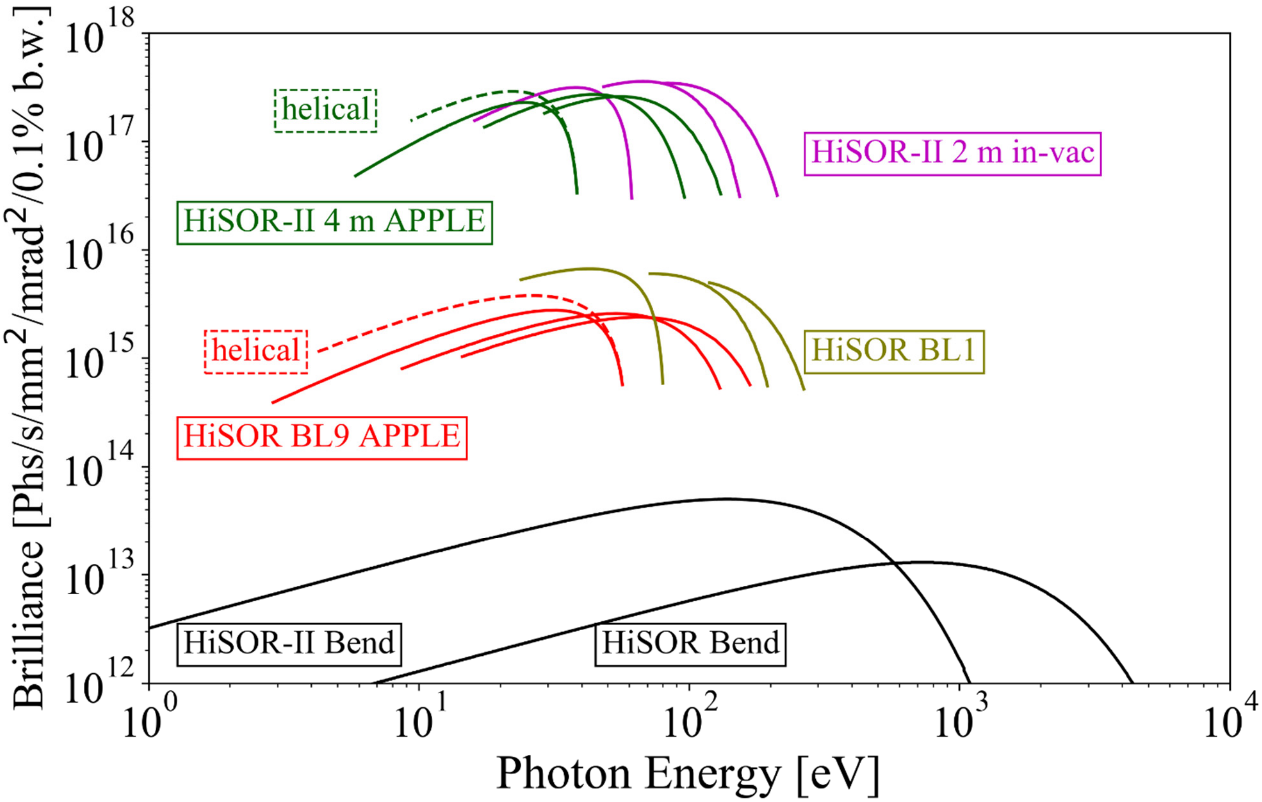

Figure 5: Comparison of brilliance of the synchrotron radiation from HiSOR and HiSOR-II.

INSERTION DEVICES AND SYNCROTRON RADIATION SPECTRUM

Figure 5 shows synchrotron radiation spectra calculated using a code SPECTRA [7]. In this calculation, stored current of storage ring is set to be 300 mA. Undulators in long straight sections are assumed as 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. Undulators in short straight sections are assumed as 2 m long in-vacuum type with periodic length of 38 mm and K-value of 2.4-0.19.

The comparison of brilliance between HiSOR (present storage ring) and HiSOR-II (future storage ring) are shown in the Fig. 5. Below photon energies of 100 eV, brilliances are increased by 1 or 2 orders of magnitudes.

CONCLUSION

We have designed a new storage ring for HSRC, Hiroshima University. The natural emittance and circumference of current design is less than 10 nm and 50 m, respectively. Moreover, brilliances of photons with energies around 10 eV exceed 10^{17} photons/mm^2/mrad^2/0.1%b.w.. These pa-rameters are adequate for HSRC future plan.

REFERENCES

[1] K. Yoshida, T. Takayama, and T. Hori, "Compact synchrotron light source of the HSRC", *J. Synch. Rad.* vol. 5, pp. 345-347, 1998.

[2] A. Miyamoto, K. Goto, S. Hanada, S. Sasaki, and H. Tsutsui, "HiSOR-II, Future Plan of Hiroshima Synchrotron Radiation Center", in *Proc. 1st Int. Particle Accelerator Conf. (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. 6th Int. Particle Accelerator Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 1560-1562. doi:10.18429/JACoW-IPAC2015-TUPWA060

[4] N. Hertel, S. P. Møller, and J. S. Nielsen, Preliminary Design Report for ASTRID2 http://www.isa.au.dk/facilities/astrid2/docs/ASTRID2-PreliminaryDesign-Report-August2009.pdf

[5] K. Kawase and S. Matsuba, "Upgrade Plan of Synchrotron Radiation Source at Hiroshima Synchrotron Center, Hiroshima University", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 2670-2671. doi:10.18429/JACoW-IPAC2017-WEPAB040

[6] Strategic Accelerator Design Home Page, http://acc-physics.kek.jp/SAD/index.html

[7] T. Tanaka and H. Kitamura, "SPECTRA: a synchrotron radiation calculation code", *J. Synch. Rad.*, vol. 8, pp. 1221-1228, 2001.

[8] S. Matsuba, K. Kawase, A. Miyamoto, S. Sasaki, M. Fujimoto, T. Konomi, N. Yamamoto, M. Hosaka, M. Katoh, "Generation of vector beam with tandem helical undulators", *Appl. Phys. Lett.*, vol. 113, p. 021106, 2018.

[9] A. Streun, "Momentum acceptance and Touschek lifetime" SLS Note 18/97.