INSERTION DEVICES FOR SPring-8 UPGRADE PROJECT

T. Tanaka†, R. Kinjo, T. Hasegawa, RIKEN SPring-8 Center, Japan
T. Bizen, T. Seike, A. Kagamihata, H. Kishimoto, H. Ohashi, JASRI, Japan
S. Yamamoto, KEK PF, Japan

Abstract

In the upcoming major upgrade project of SPring-8 (SPring-8-II) planned in the early 2020's, the electron energy will be reduced from 8 GeV to 6 GeV and the straight sections will be shortened in order to accommodate more magnets, for the purpose of reducing the emittance down to around 140 pm.rad. The insertion devices (IDs) currently installed in SPring-8 are not compatible with the above upgrade plan, and thus most of them should be replaced with new ones optimized in the new storage ring, or at least be shortened to fit into the new straight sections. We report the status of R&Ds toward realization of IDs for SPring-8-II, such as reforming the fundamental structure of IDs to reduce the total cost and manufacturing lead time, refurbishment of existing IDs for shorter lengths and exploration of new light source concepts.

INTORDUCTION

After the successful operation of X-ray FEL facility SACLA, SPring-8 has now turned to upgrading the storage ring to facilitate applications using highly-coherent and high-energy photons. In this "SPring-8-II" project [1], the natural emittance will be reduced down to around 140 pm.rad, by exploiting a new lattice structure and reducing the electron energy from 8 GeV to 6 GeV. Because the specifications of existing insertion devices (IDs) are not necessarily compatible with the upgrade plan explained above, they need to be replaced with new ones or at least refurbished.

In this report, an overview of IDs for SPring-8-II is presented, together with the current status of relevant R&D.

BOUNDARY CONDITIONS OF IDS

First, we describe the boundary conditions of IDs to be installed in SPring-8-II. To be specific, we need to take care of two conditions to consider the design of IDs: length of the device and minimum magnet gap.

Length of Straight Section

In order to accommodate a large number of magnets (dipole, quadrupole and sextupole) to realize the 5-bend achromat lattice [1], we need to shorten the straight section for installation of IDs. To be specific, the regular straight section of the SPring-8-II storage ring is roughly 4.2 m long (flange to flange), which is 1.5 m shorter than the current value of 5.7 m. Taking into account the extra space for installation of auxiliary components of in-vacuum undulators (IVUs), such as RF transition tapers to smoothly connect the both ends of magnets and vacuum duct, the magnet length of IDs has been determined to be 3.6 m, which is 0.9 m shorter than the current value of 4.5 m.

ID Minimum Gap

Because of the shorter magnet length and smaller β_y, the minimum gap of IDs will be reduced. According to the experience of the beam life time degradation measured as a function of the aperture of the scraper in SPring-8, the minimum gap of SPring-8-II is estimated to be 5 mm, which is 3 mm narrower than the current value of 8 mm.

RECYCLING EXISTING IVUS

Currently, SPring-8 accommodates roughly 30 IVUs, and most of them have the period length of 32 mm and total magnet length of 4.5 m, which are optimized for the existing storage ring. In order to recycle these IVUs, we need to refurbish them so as to fit the boundary conditions in the new ring, especially in terms of (1) the shorter straight sections, and (2) the spectral shift due to the electron energy reduction.

As for the 1st issue, which is more critical than the 2nd, an efficient procedure to rearrange the mechanical components of existing IVUs to fit into the new straight section is under discussion. To be specific, the 3-unit structure of the current design will be reformed to the 2-unit structure, as illustrated in Fig. 1.

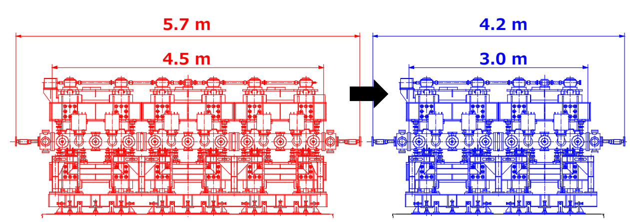

Figure 1: Restructuring the existing IVUs.

As for the 2nd issue, the undulator period should be shorter, meaning that the magnetic arrays are hopefully to be replaced with new ones. Because the optimum period depends on respective beamlines, several options are considered, with the typical values to be around 20 mm.

†ztanaka@spring8.or.jp

ISBN 978-3-95450-147-2

STRUCTURAL REFORM OF IVUS

Although more than 10 existing IVUs will be recycled as explained above, it seems impractical to refurbish all IVUs within the tight schedule for upgrading the storage ring. It is thus necessary to build new devices in advance and replace a number of existing ones with them, which can increase the total cost of the upgrade project. In order to suppress the manufacturing cost of new IVUs, several R&Ds are in progress.

One of the most important R&Ds is to reform the structure of IVUs for a more efficient and cost-effective design based on a force-cancellation system, which significantly reduces the attractive forces on the magnet arrays and thus enables a much simpler mechanical structure [3].

Cancellation of Magnetic Forces

Among many possible solutions to cancel the attractive force exponentially changing as the magnet gap, a magnetic method based on repulsive magnets is under development, which is schematically illustrated in Fig. 2.

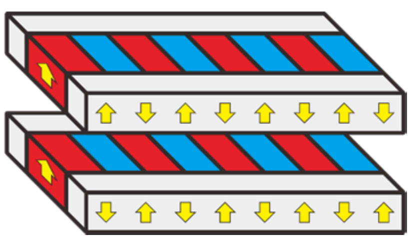

Figure 2: Force cancellation with monolithic repulsive magnets placed aside of the main magnets.

The side magnets, which are monolithic but periodically magnetized with the multipole magnetizing method [2], generate repulsive forces to cancel the attractive forces generated by the main undulator magnets. The monolithic structure of repulsive magnets, in contrast to the main magnets composed of a large number of blocks, makes it possible to significantly reduce the manufacturing cost and simplify the mechanical structure of magnet keepers.

Lightweight and Compact Frame

The mechanical frame to support and control the magnetic arrays can be much more lightweight and compact (Fig .3), by means of the above force-cancellation system.

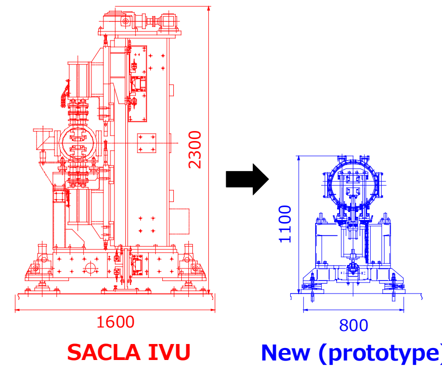

Figure 3: Left: Cross-sectional view of the SACLA IVU. Right: Prototype of the lightweight and compact frame.

LIGHT SOURCES BASED ON NEW CONCEPTS

In addition to the recycled and new IVUs explained so far, a number of light sources or undulators are to be used in SPring-8-II, which are based on new concepts as explained in the followings.

Helical-8 Undulator

The helical-8 undulator proposed in [4] can be operated in two different modes, and works both as the helical and figure-8 undulators, in order to allow for any polarization states with much less heat load than APPLE-type devices. This is quite important for soft x-ray beamlines in a high-energy facility like SPring-8.

An example of the magnetic field distributions actually measured for the prototype magnetic arrays are shown in Fig. 4 (a) and (b), in the helical and figure-8 undulator modes, respectively, with (c) and (d) showing the computed electron orbit projected on the transverse plane.

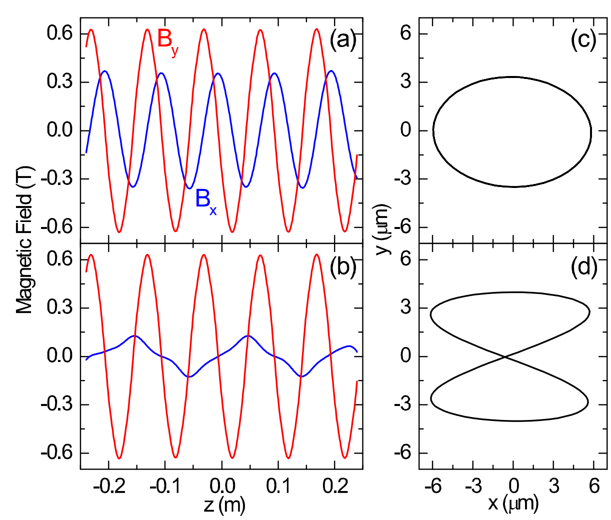

Figure 4: Measured magnetic field distributions (a,b) and computed electron trajectory (c,d) of the helical-8 undulator prototype.

Phase-Combined Undulator

The phase-combined undulator proposed in [5] offers another solution to cancel the attractive force of undulator magnetic arrays. Although the achievable field amplitude is about 30% lower than the repulsive-magnet method, the whole structure can be much simpler. This is beneficial especially for long-period undulators, whose specification on the field strength is not necessarily a critical issue.

Fast Helicity Switching by Spectrum Splitting

As proposed in [6], this scheme will enable much faster polarization switching than that based on the conventional kicker magnets. As illustrated in Fig. 5, the phase shift inserted between undulator segments controls the spectral profile; in the top configuration, the spectrum of RCP (right-handed circular polarization) component is split at the fundamental photon energy, while that of the LCP (left-handed circular polarization) component is not, and vice versa in the bottom configuration. After passing through the monochromator, only the LCP/RCP light survives. Because the trajectory error induced by the phase shit is expected to be much smaller than the kicker magnets and can be easily corrected, the expected switching speed can be much higher.

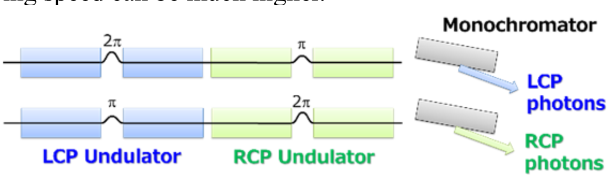

Figure 5: Fast helicity switching by spectrum splitting.

ID SPECIFICATIONS AND EXPECTED PERFORMANCES IN SPRING-8-II

Table 1 summarizes the specifications of IDs to be installed in SPring-8-II, and Fig. 6 shows the expected light source performances available with these IDs, computed using the code *SPECTRA* [7]. Performances currently available in existing beamlines in SPring-8 (BL09XU for hard x rays and BL27SU for soft x rays) are also plotted for reference.

Table 1: Summary of IDs to be installed in SPring-8-II. Note: (1) in mm, (2) for helical mode operation.

Type	Abbrev.	(1) Period	Max. K_y	Max. K_x
In-vacuum	IVU*	20.4/22 25/28	1.95/2.23 2.76/3.29	
In-vacuum EPU	-	22	1.12	0.92
In-vacuum Figure-8	-	24	2.33	1.58
Twin EPU	T-EPU*	64/84/ 100	4.45/6.86 8.82	3.20/5.44 7.40
Figure-8	F8U*	64	5.32	3.34
Helical-8	EPU*	96/124/ 132/160	(2)4.20/5.74 6.19/8.17	(2)3.88/5.86 6.32/7.98

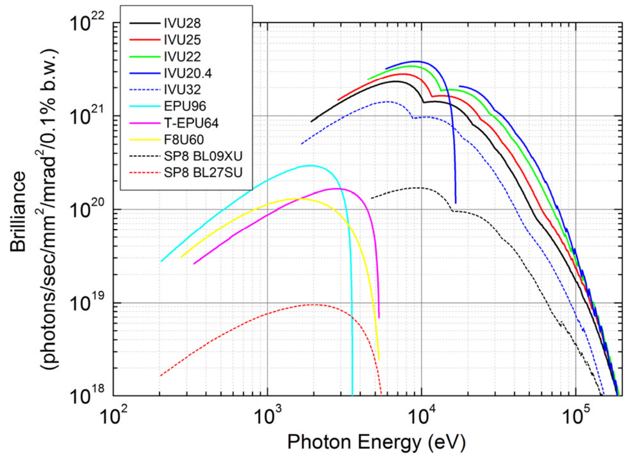

Figure 6: Light source performances expected in SPring-8-II, in comparison with the existing beamlines in SPring-8 (BL09XU and BL27SU).

The number indicated after the device type denotes the period length in mm. For example, IVU22 means the in-vacuum undulator with the period length of 22 mm. Also note that the electron beam parameters assumed in the computations are those reported in [1], which are subject to change, and so are the expected performances.

REFERENCES

[1] SPring-8-II Conceptual Design Report (2014), available from http://rsc.riken.jp/pdf/SPring-8-II.pdf

[2] S. Yamamoto, *J. Phys. Conf. Ser.,* 425 (2013) 032014

[3] R. Kinjo, T. Bizen and T. Tanaka, Synchrotron Radiation News 15, 45 (2015)

[4] T. Tanaka and H. Kitamura, *Nucl. Instrum. Meth.* **A659**, 537 (2011)

[5] R. Kinjo and T. Tanaka, *Phys. Rev*. ST-AB 17, 060702 (2014)

[6] R. Kinjo and T. Tanaka, J. Synchrotron Rad. 23, (2016) in press, doi: 10.1107/S1600577516004604

[7] T. Tanaka and H. Kitamura, *J. Synchrotron Rad*. **8**, 1221 (2001)

ISBN 978-3-95450-147-2