27 m Long In-vacuum Undulator

Among third-generation light sources, SPring-8 is distinguished by the presence of four long straight sections allowing the achievement of super brilliant synchrotron radiation. During summer shutdown of 2000, a lattice of the storage ring was modified to create magnet free 30 m straight sections [1]. At the same time, the first long insertion device was installed at the X-ray beamline BL19LXU. The first device is an in-vacuum undulator with a 32 mm magnetic period similar to the SPring-8 standard type in-vacuum undulator. Main parameters of the undulator are detailed in Table 1. The net length of the undulator magnet is 25 m and all magnet blocks are arranged continuously. This is one of the advantages of in-vacuum devices. In the construction of long insertion devices, the magnets of the out of vacuum insertion device are separated by flanges at the vacuum chamber connection points as shown in Fig. 1 (b). On the other hand, for in-vacuum devices, the vacuum chambers are connected externally using bellows, therefore, there is no gap between magnet arrays (Fig. 1 (a)). As a result, all radiations emanating from each magnet array are superposed in phase; therefore, no complicated phase matching techniques are necessary.

The 27 m undulator consists of 5 segments (Fig. 2), each possessing a similar mechanical structure to a 4.5 m long in-vacuum undulator, which has been successfully operated for years at SPring-8 [2]. Each segment has an individual undulator gap driving system, controlled simultaneously by one signal since magnet arrays are mechanically connected between segments. The segment is also an unit to carry out magnetic field measurements [3] and transportation. The five segments were transported independently to the storage ring, then assembled together inside the ring tunnel. Figure 3 is a photograph of the installed undulator in the SPring-8 storage ring.

Table 1. Parameters of the 27 m long in-vacuum X-ray undulator for BL19LXU

Type	Pure permanent magnet (halbach)
Periodic length	32 mm
Number of periods	780
Gap range	12 ~ 50 mm
Maximum K	1.76 at 12 mm gap
E_{1st}	7.4 ~ 18 keV

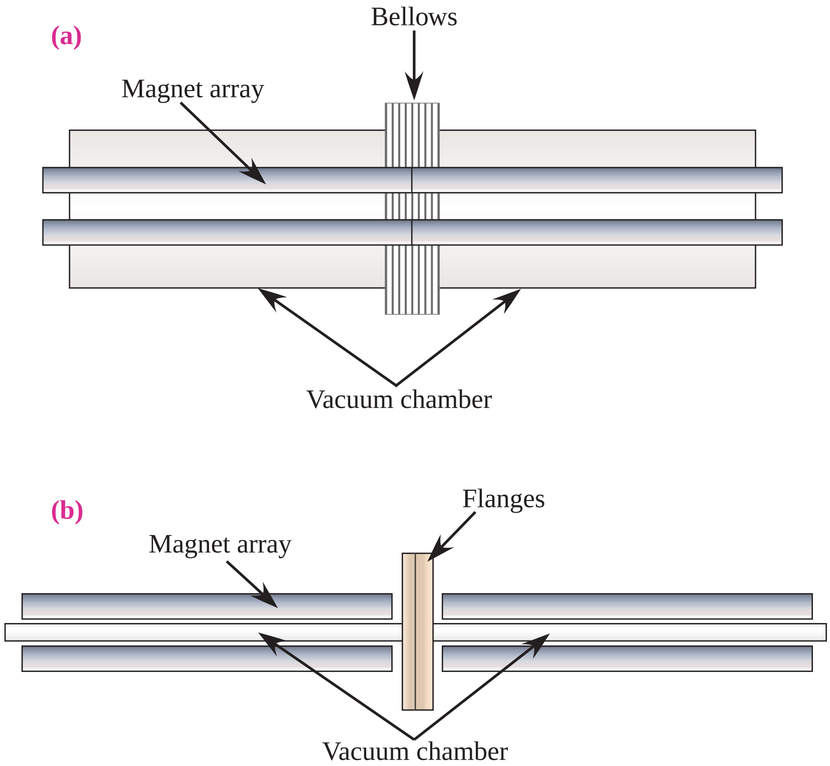

*Fig. 1. Schematics of the magnet array connections utilized for the long undulator construction, **(a)** in-vacuum device, **(b)** out of vacuum device.*

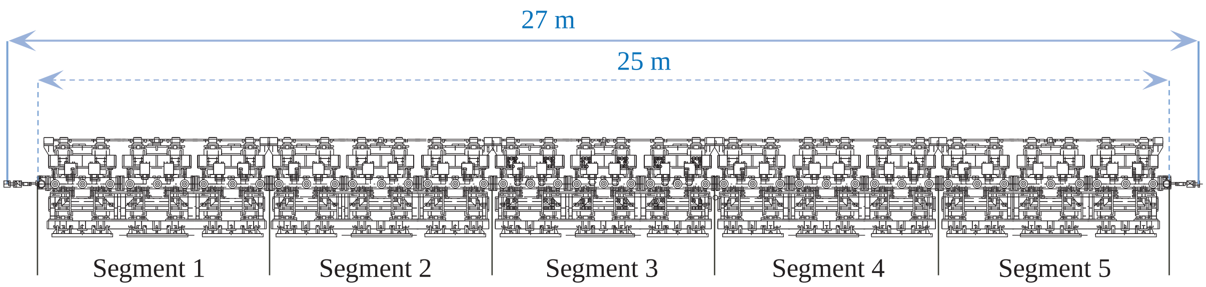

Fig. 2. Schematic of the 27 m undulator consisting of 5 segments.

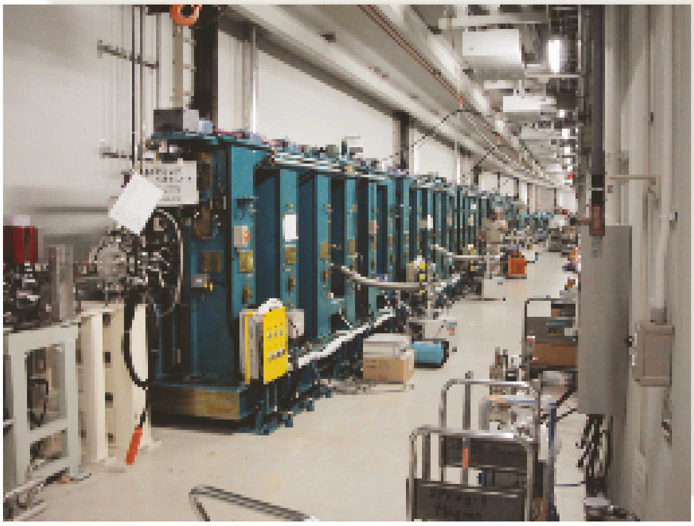

Fig. 3.   27 m in-vacuum undulator installed in the SPring-8 storage ring.

The beamline was commissioned in October 2000, and the first undulator radiation was observed on October 25th (Fig. 4). The brilliance of the 27 m undulator was increased approximately 4~5 times from that of 4.5 m undulators. The measured spectrum at 12 mm undulator gap utilizing a front-end (FE) slit aperture of 0.2 mm $\times$ 0.2 mm [4] demonstrated that 50% of the calculated flux was obtained under these conditions (Fig. 5). The undulator radiation Bose degeneracy surpasses one during high peak current operation mode of the ring. Experiments using high photon flux and spatial coherency of the undulator radiation will dominate the use of the beamline.

The success of the 27 m undulator will be the basis of the upcoming self-amplified spontaneous emission (SASE) based FEL project, which requires the precise control of the electron beam inside the undulator. For example due to its long length, we have observed the effect of a weak uniform field of 0.1 G, such as the earth field, on the undulator spectrum. Together with the techniques of the field alignment and construction, the experience in using the 27 m in-vacuum undulator forms the next step in pursuit of innovative light sources.

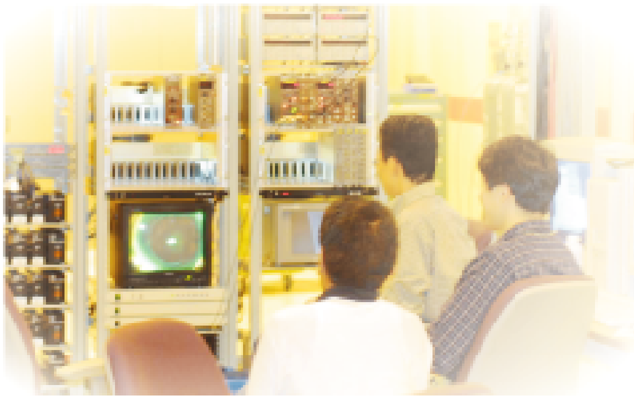

Fig. 4.   First observation of the undulator radiation at BL19LXU.

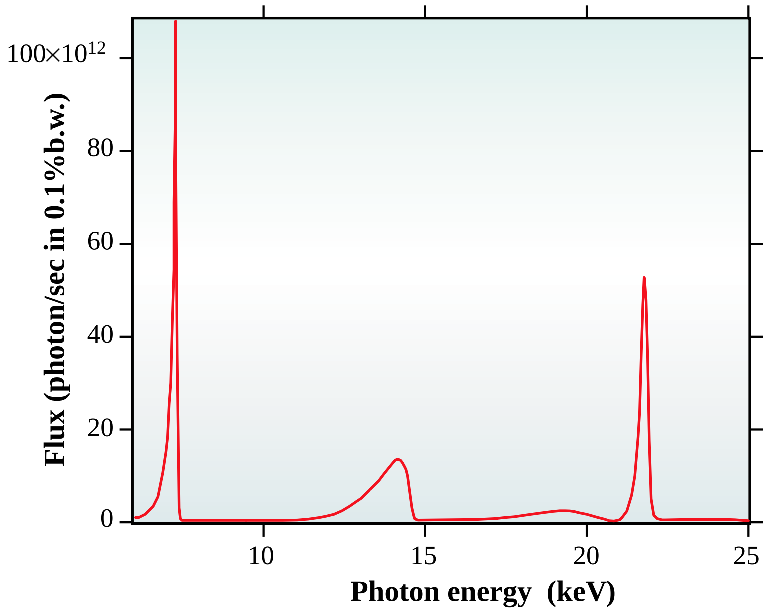

Fig. 5. Undulator spectrum measured at 12 mm gap with a 0.2 mm × 0.2 mm FE slit.

References

[1] N. Kumagai, SPring-8 Information, No.1, **6** (2001) 5.

[2] H. Kitamura, J. Synchrotron Rad. **7** (2000) 121.

[3] T. Tanaka *et al.*, SRI2000, to be published in Nucl. Instrum. Meth.

[4] T. Ishikawa *et al.*, to be published in J. Jpn. Soc. for Synchrotron Rad. Res.

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