J. Synchrotron Rad. (1998). **5**, 339–341

Design of a synchrotron radiation source at Tohoku University

Masahiro Katoh,[a]* Shigeru Sato,[b] Shoji Suzuki,[b] Masumi Sugawara[b] and Makoto Watanabe[b]

[a]*KEK-PF, Tsukuba, Japan, and* [b]*Tohoku University, Sendai, Japan. E-mail: katohm@mail.kek.jp*

(*Received 4 August 1997; accepted 2 October 1997*)

The construction of a third-generation light source has been proposed at Tohoku University. The emittance is 7.3 nm rad at the nominal beam energy, 1.5 GeV. The circumference is 194 m. The ring consists of 12 double-bend achromatic cells. Ten of 12 dispersion-free long straight sections are 5 m long and will be used for insertion devices and some accelerator components. The remaining two are each 15 m long and reserved for advanced devices, such as a very long undulator or a free-electron laser. A stretcher–booster ring, which is now under commission, will be used as an injector. In total, about 50 beamlines can be constructed and ten of them will be those of insertion devices. The present status of the project is 'waiting for approval'.

Keywords: light sources; storage rings; free-electron lasers.

1. Overview of the facility

The construction of a synchrotron radiation facility was proposed at Tohoku University in Sendai, Japan (Sato *et al.*, 1996), to meet strong demands for high-brilliance synchrotron radiation in the VUV and soft X-ray region.

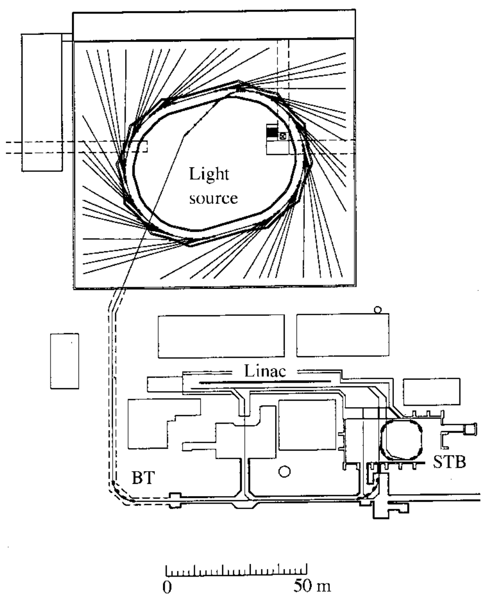

Figure 1
Plan view of the synchrotron radiation facility. The 300 MeV linac, 1.2 GeV stretcher–booster ring (STB), injection beam-transport line (BT) and light source are shown.

Table 1
Parameters of the linac.

Beam energy	150–300 MeV
Repetition rate	300 Hz
Pulse length	2 ms

Table 2
Parameters of the STB (booster mode).

Circumference	49.8 m
Lattice	DBA × 4 cells
Beam energy	300 MeV–1.2 GeV
Emittance	170 nm rad at 1.2 GeV
Repetition rate	1.0 Hz

The facility will be constructed at the site of the Laboratory of Nuclear Science of the University. A plan view is shown in Fig. 1. The accelerator complex consists of a 300 MeV linac, a 300 MeV–1.2 GeV stretcher–booster ring (STB) and a 1.2–1.8 GeV storage ring: the light source. The linac is in operation and the STB is now under commission (Oyamada *et al.*, 1995). Although the main function of the STB is to convert the bunched beam from the linac to a quasi-continuous beam for nuclear science, it also has the capability of providing a bunched beam of 1.2 GeV for the proposed light source.

The storage ring was designed to be a high-brilliance VUV–SX light source. The emittance is 7 nm rad at the nominal beam energy, 1.5 GeV. The beam energy will be ramped from 1.2 GeV to the operation energy after injection. To meet the demands for harder X-rays, a maximum energy of 1.8 GeV can be achieved. The ring has ten straight sections for insertion devices, including superconducting wigglers. Two of them are 15 m long and reserved for developments of advanced light sources, such as a free-electron laser (FEL) or a very long undulator.

The light source has a racetrack-like shape and a circumference of 194 m. Because space at the site is very limited, special consideration is given to the layout of the storage ring, as shown in Fig. 1, to keep as much space for synchrotron radiation beamlines as possible. About 50 synchrotron radiation beamlines can be constructed in the experimental hall.

2. Injector and beam-transport line

The 300 MeV linac has been used for nuclear science research for about 30 years and also for studies on coherent IR radiation by utilizing the very-short-bunched beam (Nakazato *et al.*, 1989). The parameters of the linac are given in Table 1.

A stretcher–booster ring is now under commission (Oyamada *et al.*, 1995). The circumference is about 50 m. The lattice consists of four double-bend achromatic cells. The ring has three operating modes: pulse-stretcher mode, booster mode and storage mode. In the pulse-stretcher mode, a 300 MeV bunched beam from the linac is converted to a quasi-continuous beam by slow extraction for nuclear research. The storage mode is for internal target experiments. In the booster mode, the injected beam is accelerated to 1.2 GeV and is ejected to the beam-transport line to the light source with a repetition rate of 1 Hz. The main parameters of the STB are given in Table 2.

A rather long beam-transport (BT) line will be constructed between the STB and the light source, as shown in Fig. 1. About half of it will be constructed in an existing tunnel previously used for a TOF experiment. While the linac, the STB and the major part of the BT line are underground, the light source is located at ground level. The BT line ascends to ground level in the light-source building. The beam is injected into the storage ring horizontally from the inside.

3. Storage ring

The storage ring was designed (Katoh *et al.*, 1996) (i) under space limitation, (ii) to realise a beam energy higher than 1.5 GeV, (iii) with an emittance less than 10 nm rad, (iv) with straight sections for as many insertion devices as possible, and (v) to keep open possibilities for developments of advanced light sources, such as an FEL or a long undulator. Comparing various kinds of lattice structures, a double-bend achromatic (DBA) cell was selected for normal cell structure.

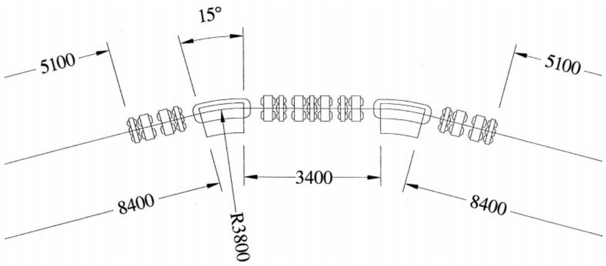

Figure 2
Magnetic lattice of a normal cell. Two bending magnets, eight quadrupole magnets and seven sextupole magnets are shown. Dimensions are given in meters.

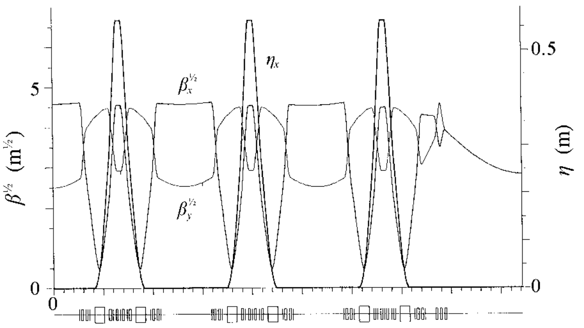

Figure 3
Optical functions of the storage ring. One quadrant is shown (12 DBA cells, two 15 m-long straight sections, low-emittance optics). The emittance is 7 nm rad.

Table 3
Parameters of the light source.

	Minimum ε	Detuned
Circumference	194.2 m	
Lattice	DBA × 12	
Straight sections	5 m × 10, 15 m × 2	
Beam energy	1.2–1.8 GeV	
Emittance	7.3 nm rad at 1.5 GeV	13.5 nm rad at 1.5 GeV
Betatron tunes	(12.20, 3.15)	(11.20, 3.15)
Natural chromaticity	(−46.2, −14.3)	(−21.4, −13.4)
Momentum compaction	0.0014	
Momentum spread	6.60×10^{-4}	
Harmonic number	324	
RF frequency	500 MHz	
RF voltage	1 MV	
Synchrotron tune	0.0069	
Natural bunch length	0.41 cm	

The ring consists of 12 DBA cells. The magnetic lattice of a cell is shown in Fig. 2. To keep as much space as possible for the straight sections, the magnets are arranged compactly. All the straight sections are dispersion-free. Their lengths are 5 m, except for two whose lengths are 15 m. As a result, the ring is shaped like a racetrack of circumference 194 m.

An emittance as small as 7 nm rad can be achieved with this lattice. The beam optics are shown in Fig. 3. The major beam parameters are presented in Table 3. In addition to these low-emittance optics, detuned optics with a larger emittance of 13 nm rad were designed. These optics have a larger dynamic aperture and are adequate for commissioning. The beam lifetime is limited by the Touschek effect. To keep the lifetime longer than 12 h, momentum acceptance should be larger than 2%. This requires a 1 MV RF voltage and some sophisticated sextupole correction scheme.

Two 500 MHz RF cavities will be installed at one of the short straight sections. At another, injection septum will be installed. The other eight short straight sections are reserved for insertion devices. Two long straight sections are reserved for future developments of advanced devices.

4. Beamlines

In total, about 50 beamlines can be constructed. The major axis of the storage ring is tilted with respect to the rectangular building, as shown in Fig. 1. By this arrangement, the lengths of all the beamlines can be longer than 30 m. Some of them can be 50 m long and are reserved for high-resolution experiments.

At each normal cell, a maximum of five beamlines can be constructed. One of them is that of the insertion device and the others are those of bending radiation. One of the bending lines is

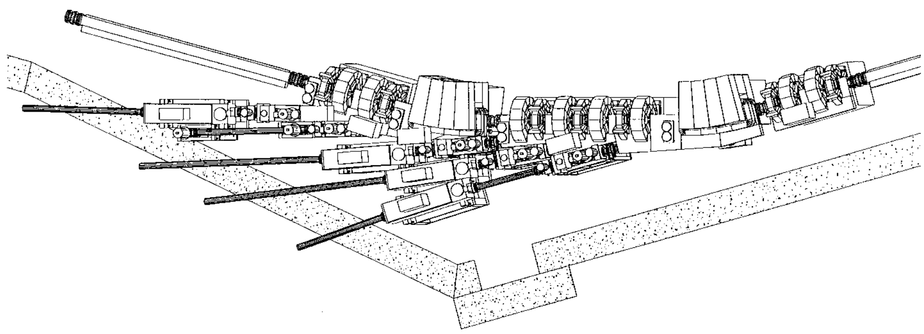

Figure 4
Conceptual design of the accelerator components and synchrotron radiation beamlines. One normal cell is shown.

reserved for a beam monitor. A conceptual design of the beamlines is shown in Fig. 4.

Various kinds of insertion devices are planned to be installed to cover the wide spectral range from the far-IR to X-rays. Some examples of the available photon flux are shown in Fig. 5.

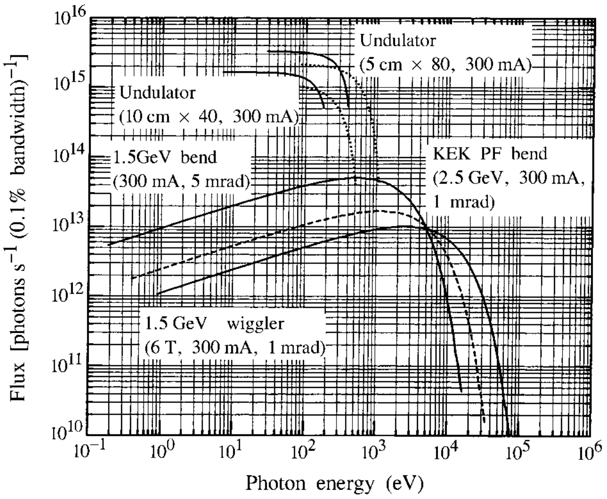

Figure 5
Typical photon flux from insertion devices and bending magnets.

67 experiments have been proposed (Sato *et al.*, 1996). Design studies of experimental stations are now in progress.

5. Conclusions

The construction of a high-brilliance VUV–SX light source was proposed at Tohoku University. A laboratory site is reserved for this project. There, an accelerator complex, which will be used as an injector, is under commission. Conceptual designs of the light source are almost completed. Studies of the details of the hardware designs of the accelerator and experimental stations are in progress. The present status of the project is ‘waiting for approval’.

References

Katoh, M., Sato, S., Suzuki, S. & Yamakawa, T. (1996). *Proc. Eur. Part. Accel. Conf.* **1**, 653–655.

Nakazato, T., Oyamada, M., Niimura, N., Urasawa, S., Konno, O., Kagaya, A., Kato, R., Kamiyama, T., Torizuka, Y., Nanba, T., Kondo, Y., Shibata, Y., Ishi, K., Ohsaka, T. & Ikezawa, M. (1989). *Phys. Rev. Lett.* **63**, 1245–1250.

Oyamada, M., Kasagi, J., Kanno, O., Kurihara, A., Mutoh, M., Nakazato, T., Nanao, M., Oonuma, T., Shibasaki, Y., Sugawara, M., Takahashi, S., Tamae, T., Urasawa, S., Yamakawa, T., Katoh, M., Momose, T. & Isoyama, G. (1995). *Proc. 10th Symp. Accel. Sci. Technol., Hitachinaka*, pp. 463–465.

Sato, S., Suzuki, S., Sugawara, M. & Watanabe, M. (1996). *Synchrotron Rad. Sci. Technol. Inf.* **6**(3), 34. (In Japanese.)