A Future Project of VUV and Soft X-ray High-Brilliant Light Source in Japan

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I. Overview

A third-generation VUV and soft X-ray ring with a low emittance of several nm·rad is being designed at the Institute for Solid State Physics (ISSP) of the University of Tokyo, in close collaboration with the Photon Factory of KEK. The proposal to construct the light source facility is now in preparation for submission to the government; this project is one of the whole future plans of ISSP that will move to a new site called Kashiwa Campus. The accelerator scheme consists of a linac, booster synchrotron and storage ring. The storage ring has an energy of 2 GeV, a circumference of about 374 m, an emittance of less than 5 nm·rad, four 14 m long straight sections and twelve 7 m semi-long straight sections. Each of 14 m long straight sections is aimed to install a longer undulator, or a few kinds of undulators which may produce synchrotron light with different polarities and/or wavelengths.

II. Facility

Figure 1 shows a layout of the facility buildings: Light Source Building, High-voltage Power Station, Utility Center, Power Supply Station, Assembly Hall and Office Building. The large building at the center of the figure is the Light Source building that houses the injectors (Linac and Synchrotron), Storage Ring, Control Room, Experimental Hall and so on. Storage Ring is at ground level, while Synchrotron and Linac are underground and Control Room is on a second floor. The Experimental Hall is surrounded by a large hall called Hall for Special Experiments, Experimental Preparation Rooms and Users Offices.

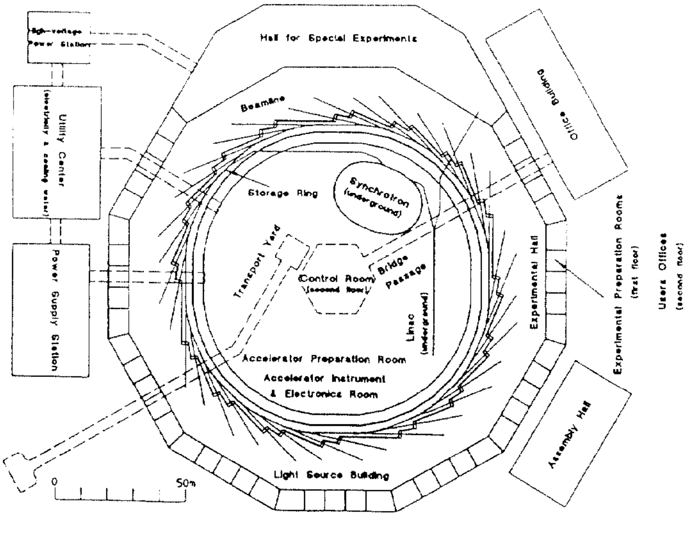

Fig. 1 Layout of the facility

III. Storage Ring & Injectors

The 2 GeV Storage Ring has a lattice type of DBA and four superperiods with sixteen cells. The betatron and dispersion functions in a superperiod are shown in Fig. 2. The principal parameters of Storage Ring are listed in Tables I. The chromaticity will be corrected by six families of sextupole: two of them are put in dispersion sections (four chromatic sextupoles in a cell), and two in dispersionless semi-long straight sections, the remaining two in long straight sections (four harmonic sextupoles in a straight section). Figures 3 and 4 show horizontal and vertical dynamic apertures versus momentum deviation in a case without magnet errors. The simulation including the errors is now in progress. Figures 5 and 6 show horizontal and vertical tune shifts dependent on the amplitude of betatron motion. The momentum-dependent tune is also shown in Fig. 7; a wide momentum aperture is required to obtain a long Touschek lifetime.

Table I. Principal parameters of Storage Ring

Energy E [GeV]	2.0
Lattice type	DBA
Superperiod N_S	4
Circumference C [m]	374.14
7-m straight section	12
14-m straight section	4
Natural emittance ε_{x0} [nm·rad]	4.878
Energy spread σ_E/E	6.66×10^{-4}
Momentum compaction α	7.13×10^{-4}
Horizontal tune ν_x	18.41
Vertical tune ν_y	9.80
Horizontal natural chromaticity ξ_x	-49.98
Vertical natural chromaticity ξ_y	-17.75
Horizontal damping time τ_x [msec]	23.26
Vertical damping time τ_y [msec]	23.35
Longitudinal damping time τ_E [msec]	11.69
Revolution frequency $f_{r\ ev}$[MHz]	0.80128
RF voltage V_{RF} [MV]	1.4
RF frequency f_{RF} [MHz]	500.0
Harmonic number h	624
Synchrotron tune ν_s	0.007
Bunch length σ_z [mm]	4.0
RF-bucket height ($\Delta E/E$)	0.028

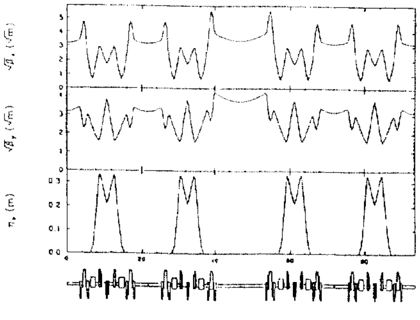

Fig. 2 Optics of a superperiod

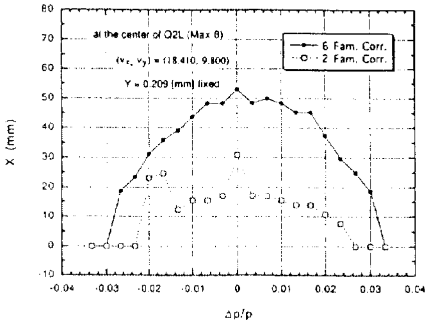

Fig. 3 Horizontal dynamic aperture versus momentum deviation

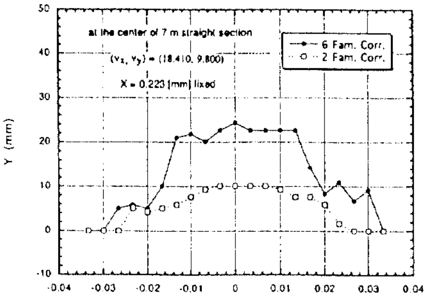

Fig. 4 Vertical dynamic aperture versus momentum deviation

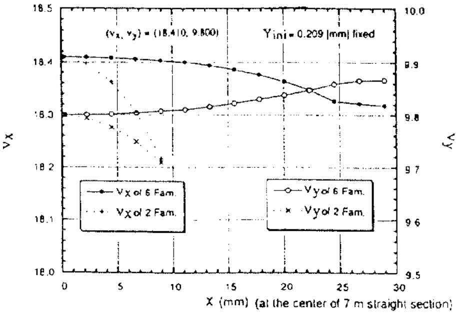

Fig. 5 Horizontal amplitude-dependent tune shift

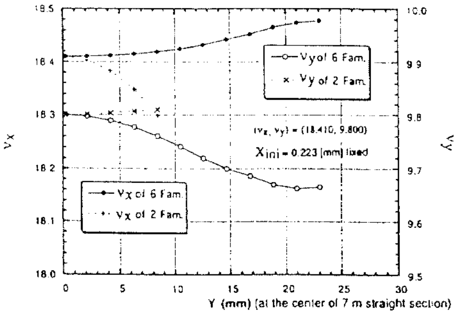

Fig. 6 Vertical amplitude-dependent tune shift

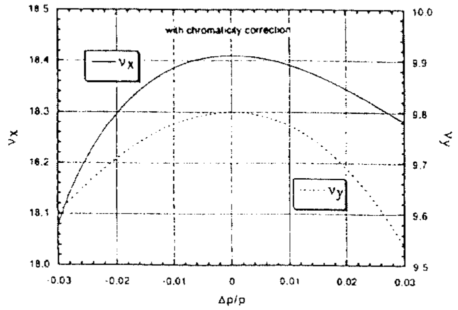

Fig. 7 Momentum-dependent tune

Gas-scattering and Touschek effects are sever factors of determining the beam lifetime for a third-generation synchrotron light source. The lifetime due to gas-scattering is shown in Fig. 8. Vacuum pressure indicated in the figure is the CO-equivalent gas pressure. The minimum gap of vacuum chamber is designed to be 16 mm at insertion devices. The pressure less than 1 nTorr is intended to attain for Storage Ring. The Touschek lifetime is shown in Fig. 9 as a function of RF voltage. The design value of RF voltage is about 1.4 MV. However, this value can be easily obtained by three RF-cavities being intended to install in Storage Ring.

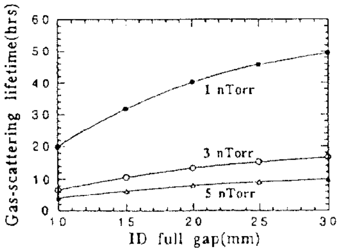

Fig. 8 Gas-scattering lifetime versus the chamber gap of insertion device

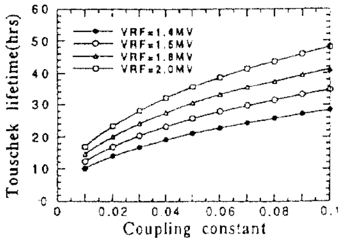

Fig. 9 Touschek lifetime versus the coupling constant of emittance

The present ring design does not need C-type quadrupole or sextupole, so that all ring magnets would be robust for deformation caused by magnetic field or thermal load. Almost all vacuum ducts of the ring will be made of aluminum alloy, except for flanges, bellows and vacuum ducts for undulators, which will be made of stainless steel. A challenging point of the vacuum design is that no in-situ baking of vacuum ducts will be made, though they are baked out before their installation in the ring. Cross-sectional views of the vacuum ducts for bending and quadrupole magnets and for undulators are shown in Figs. 10, 11 and 12, respectively.

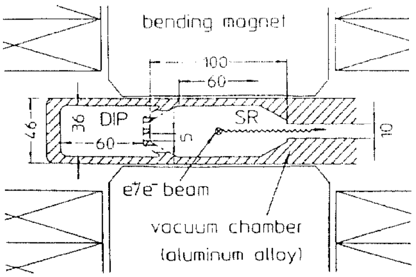

Fig. 10 Vacuum duct for bending magnet

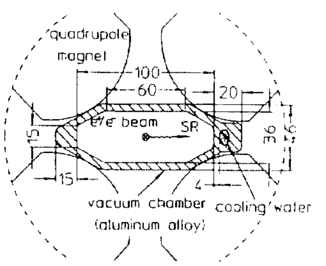

Fig. 11 Vacuum duct for quadrupole magnet

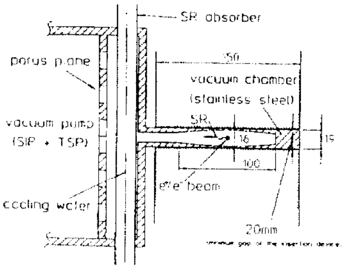

Fig. 12 Vacuum duct for insertion device

For the control system, its conceptual design has not yet been fixed. Whatever it is, the core of control system will consist of several UNIX workstations. And VME or VXI will be adopted as a standard of the computer interface to accelerator components. For the undulator design, the parameter survey for planer and circular undulators is being made. The brilliances of synchrotron light to be obtained by some typical undulators are shown in Fig. 13. Also shown in the figure is the brilliance of synchrotron light coming from a bending magnet. A second- or third-order harmonics will be used for higher energy photon experiments, though they are not shown in the figure.

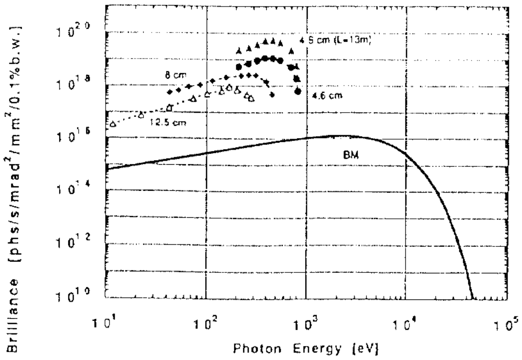

Fig. 13 Brilliance of synchrotron radiation
I = 400 mA, 10 % emittance coupling
λ_u = 4.6 cm, 8 cm, 12.5 cm for 5 m undulator
λ_u = 4.6 cm for 13 m undulator

For Synchrotron, the lattice design has not yet been fixed. The extraction energy of the synchrotron is, however, decided to be 2 GeV in order to meet the full-energy injection to the ring. The tentative parameters of Synchrotron are listed in Table II.

Table II. Principal Parameters of the Booster Synchrotron

Maximum Energy	E_{max} [GeV]	2.0
Circumference	C [m]	95.93
Horizontal tune	ν_x	4.78
Vertical tune	ν_y	4.72
Momentum compaction	α	0.059
Natural emittance	ε_{x0} [nm·rad]	261
Energy spread	σ_ε/E	6.9×10^{-4}
Horizontal natural chromaticity	ξ_x	-6.68
Vertical natural chromaticity	ξ_y	-6.07
Horizontal damping time	τ_x [msec]	5.49
Vertical damping time	τ_y [msec]	5.42
Longitudinal damping time	τ_ε [msec]	2.77
RF voltage	V_{RF} [MV]	0.8
RF frequency	f_{RF} [MHz]	500.0
Harmonic number	h	160
Synchrotron tune	ν_s	0.024
Bunch length	σ_z [mm]	26
RF-bucket height	($\Delta E/E$)	0.004

The parameters dependent on the beam energy are at 2 GeV.

Table III. Principal Parameters of the Linac

Electron gun	200 kV x 10A
Klystron	80 MW x 3
Number of SLED cavity	2
SLED output power	400 MW
Accelerator guide	3 m x 9, 2 m x 1
Total length	about 50 m
Maximum repetition rate	25 Hz
Normalized emittance (electron)	100 π mm·mrad
Normalized emittance (positron)	3000 π mm·mrad

The designed linac is less than 50 m long, but it can provide 300 MeV positron beam together with electron beam. This design has become only possible by adopting the SLED scheme for RF generation and also by incorporating recent results of R&D for high-gradient linacs, which are aimed at materializing linear colliders. The design parameters of the linac are listed in Table III. To realize the positron beam, a target of positron generation is put in the middle of the linac. A short pulse of 1 nsec makes possible a single-bunch operation of the ring. On the other hand, when the ring requires a positron beam longer than 1 nsec, the linac is able to deliver a semi-long pulse of a few tens nsec. For electron beam, the linac can provide 800 MeV short pulse (1 nsec) and about 250 MeV long pulse (2 μsec). In addition, this design of linac makes possible an option, the production of slow positrons with a pulse length of 2 μsec. The target for slow positron production will be located at the end of linac. When the ring is in a storage mode, the linac can provide slow positrons for material science experiments. Various beam modes of the linac are listed in Table IV.

Table IV. Beam modes of the linac

Electron / Positron	Energy	Pulse width	Current
Electron (short pulse)	800 MeV	1 nsec	1 A
Electron (long pulse)	230 MeV	2 μsec	100 mA
Positron (short pulse)	300 MeV	1 nsec	30 mA

IV. R&D

BPM

We have developed a BPM system that uses PIN diodes for switching and attenuating RF-signals from pickup electrodes. This system has already been installed in SOR-RING, one of the oldest synchrotron light sources in the world. The relative accuracy of the system obtained with a real beam of SOR-RING is horizontally 0.3 μm and vertically 0.4 μm [1]. With the BPM system developed, a global orbit feedback has been applied to SOR-RING. For the horizontal feedback the orbit is corrected by exciting the steerings and by changing the RF frequency, while for the vertical feedback it is corrected only by exciting the steerings. Figures 14 and 15 show the horizontal and vertical C.O.D.'s with a global orbit feedback switched on; otherwise the orbit drifts on the order of 100 μm.

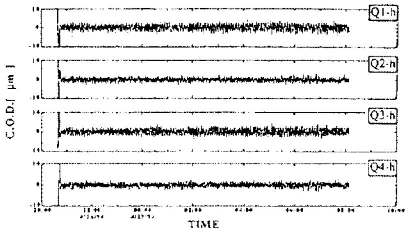

Fig. 14 Horizontal C.O.D. with a global feedback ON

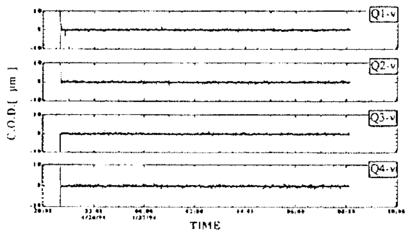

Fig. 15 Vertical C.O.D. with a global feedback ON

RF

The feature of the RF-cavity is that resistive material of SiC attached to both ends of the cavity is used for damping the HOM's (see Fig. 16). Two model cavities have already been made, and their low power test is near completion. The production process of SiC and the method of welding SiC to metal are being studied. And further a hot model cavity that can store the same amount of RF power as the designed value or more will be fabricated in this fiscal year (for more details see the reference [2]).

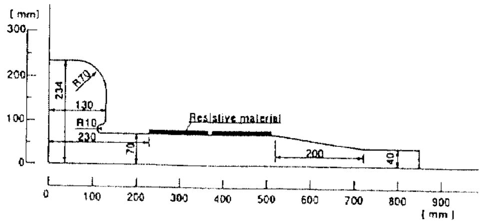

Fig. 16 Schematic of the RF-cavity
with HOM dampers made of SiC

V. References

[1] K. Shinoe et al., *Beam Position Monitoring System using PIN Diode Switches*, Proc. of 1993 PAC, pp. 2295-2297.

[2] T. Koseki et al. ; *An RF cavity with SiC Absorbers*, in these proceedings.