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VUV·SX High-Brilliance Light Source

VSX Accelerator Group (presented by Yukihide KAMIYA)

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I. Introduction

A third-generation VUV and soft X-ray ring (VSX ring in short) 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 for constructing the light source facility (VSX Light Source) is now in preparation for submission to the government. This project was previously considered as one of the whole future plans of ISSP that will move to a new site called Kashiwa Campus. However, it is now proposed that the light source facility should be constructed by a newly organized body, the Center of Accelerator Science, which directly belongs to the university: the new center is expected to be established soon, probably within a year (see Fig. 1). Following a recommendation on synchrotron radiation science made last June by the Accelerator Science Subcommittee of the Minister of Education and Science, the establishment of the new center is aimed to obtain full support for the construction of the VSX Light Source from all through the university and to make up its own firm base of the necessary manpower and budget for the facility construction, the administration and so forth. The center is also aimed to concentrate the university's efforts of other accelerator related sciences; synchrotron radiation science of X-ray region, a cyclotron facility for nuclear study and a facility for utilizing various low-energy ion beams.

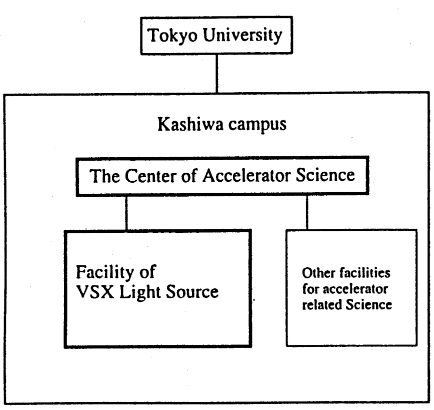

Fig. 1 New organization

The SR (Synchrotron Radiation) Users Group of Tokyo University organized a few years before has set a working group in order to discuss the scientific opportunities provided by the extremely high-brilliant VSX Light Source, and to explore potential users and then get new proposals from these users as well as from the already active X-ray users. In addition, a new nationwide users group (VSX Users Group), in which several hundred people are expected to participate, will be established this September. The users group will discuss how to use VSX Light Source and what to study there, and also take part in the construction of the facility, specifically the construction of the beamlines and their operation; it is otherwise impossible for the in-house staff to construct and operate about thirty beamlines available at the facility. After the construction completed, this users group becomes a central body of the user community of VSX Light Source. Furthermore, an official committee, the Advisory Committee of VSX Project, has been established at ISSP (see Fig. 2): the committee is a decision-making body of the project, and it coordinates two Users Groups and gives advice and recommendation to the construction groups. It will be a steering committee of the facility in future. Three working groups, accelerator, beamline and research groups, which are presently the driving forces of the project, is being reorganized as three construction groups under the Advisory Committee. Meanwhile, the Positron Users Group with active researchers of Tokyo University, who have expressed much interest in utilizing slow positron beam produced by the facility, is being involved in the project.

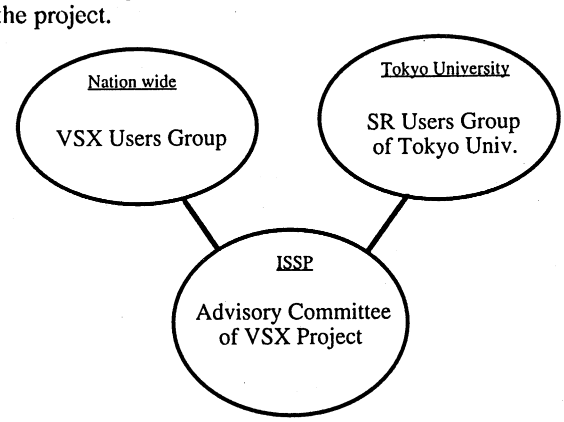

Fig. 1 Users groups and the committee of the project

The accelerator scheme of the VSX project consists of a linac, booster synchrotron and storage ring. The storage ring has an energy of 2 GeV, a circumference of about 388 m, an emittance of less than 5 nm·rad, four 12.5 m long straight sections and twelve 7 m semi-long straight sections. Each of 12.5 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. The conceptual design report of the VSX accelerators is now in preparation.

II. Facility

Figure 3 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 (first floor) and Users Offices (second floor). A general construction company and a large construction design company have been already involved in the design work of the facility buildings and their utilities. The basic design of buildings will be completed early next year.

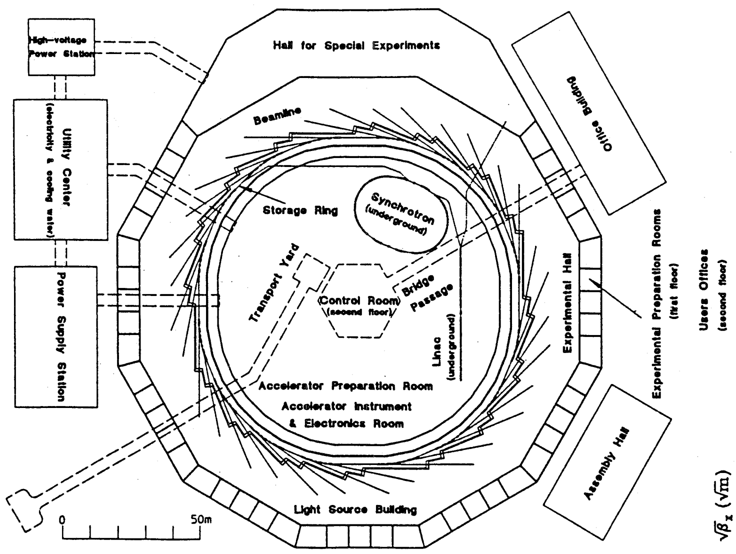

Fig. 3 Layout of the facility

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. 4. 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). Figure 5 shows a typical example of horizontal and vertical dynamic apertures versus momentum deviation in a case without magnet errors. A wide momentum aperture is required to obtain a long Touschek lifetime.

Gas-scattering and Touschek effects are sever factors of determining the beam lifetime for a third-generation synchrotron light source. The vacuum pressure less than 1 nTorr is a design goal to be attained at a maximum beam current of 400 mA and the design value of the minimum gap of vacuum chamber is 16 mm at insertion devices. Total RF voltage is about 1.4 MV in order to increase the Touschek lifetime. This value can be easily obtained by three RF-cavities to be installed in Storage Ring. The lifetimes due to gas-scattering and Touschek effects are shown in Figs. 8 and 9 of Ref. 1.

Table I. Principal parameters of Storage Ring

Energy E [GeV]	2.0
Lattice type	DBA
Superperiod N_s	4
Circumference C [m]	388.45
7-m straight section	12
12.5-m straight section	4
Natural emittance ε_{x0} [nm·rad]	4.78
Energy spread σ_ε/E	6.66×10^{-4}
Momentum compaction α	6.87×10^{-4}
Horizontal tune ν_x	18.29
Vertical tune ν_y	9.66
Horizontal natural chromaticity ξ_x	-48.27
Vertical natural chromaticity ξ_y	-29.64
Horizontal damping time τ_x [msec]	24.17
Vertical damping time τ_y [msec]	24.25
Longitudinal damping time τ_ε [msec]	12.14
Revolution frequency f_{rev}[MHz]	0.7718
RF voltage V_{RF} [MV]	1.4
RF frequency f_{RF} [MHz]	500.1
Harmonic number h	648
Synchrotron tune ν_s	0.007
Bunch length σ_z [mm]	4.0
RF-bucket height (ΔE/E)	0.028

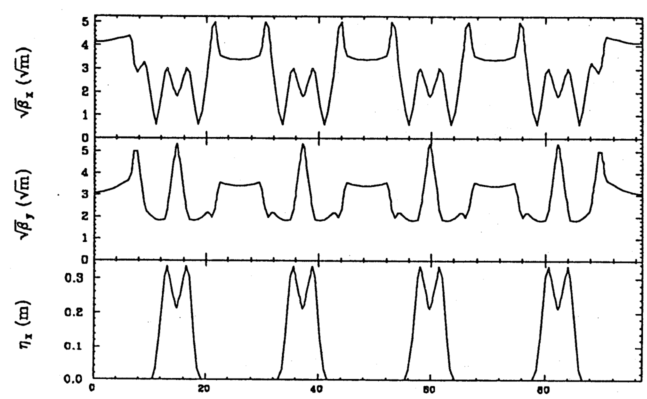

Fig. 4 Optics of a superperiod

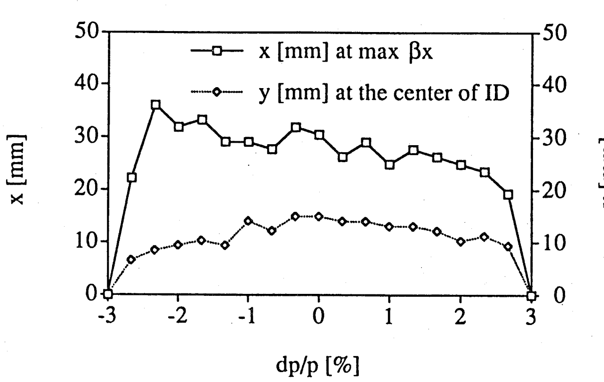

Fig. 5 Horizontal and vertical dynamic apertures versus momentum deviation

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 in-situ baking of vacuum ducts is not made, though they are baked out before installation in the ring (see Figs. 10, 11 and 12 of Ref. 1 for the cross-sectional views of the vacuum ducts for bending and quadrupole magnets and undulators). For the control system, its conceptual design has been almost fixed. The core of control system will consist of several UNIX workstations. FDDI is adopted for the main data highway and Ethernet for the branch lines. VME and VXI is a standard of the computer interface to accelerator components. For the undulator, the basic designs of typical undulators, both planer and circular undulators, have been finished. The brilliances of synchrotron light to be obtained by some typical undulators as well as bending magnets are shown in Fig. 13 of Ref. 1. A second- or third-order harmonics may be utilized for higher energy photon experiments.

For Synchrotron, the lattice design has been finished. The extraction energy of the synchrotron is 2 GeV in order to meet the full-energy injection to the ring. The injection energy is, however, variable around 300 MeV; it depends on electrons or positrons and on the pulse length of the Linac beam. The principal parameters of Synchrotron are listed in Table II.

Table II. Principal Parameters of the Booster Synchrotron

Injection Energy	E_{inj} [GeV]	0.3
Maximum Energy	E_{max} [GeV]	2.0
Repetition Rate	frep [Hz]	4.0
Circumference	C [m]	97.11
Horizontal tune	ν_x	5.17
Vertical tune	ν_y	4.79
Momentum compaction	α	0.058
Natural emittance	ε_{x0} [nm·rad]	262
Energy spread	σ_ε/E	7.0×10^{-4}
Horizontal natural chromaticity	ξ_x	-6.34
Vertical natural chromaticity	ξ_y	-6.38
Horizontal damping time	τ_x [msec]	5.48
Vertical damping time	τ_y [msec]	5.50
Longitudinal damping time	τ_ε [msec]	2.76
RF voltage	V_{RF} [MV]	0.8
RF frequency	f_{RF} [MHz]	500.1
Harmonic number	h	162
Synchrotron tune	ν_s	0.024
Bunch length	σ_z [mm]	26
RF-bucket height	(ΔE/E)	0.004

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

Linac is about 60 m long including an ECS system: 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. The design parameters of 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 multi-bunch mode of positron beam, the linac is able to deliver a semi-long positron 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.

Table III. Principal Parameters of the Linac

Electron gun	200 kV × 10A
Klystron	80 MW × 4
Number of SLED cavity	2
SLED output power	400 MW
Accelerator guide	3 m × 10, 2 m × 1
Total length	about 60 m
Maximum repetition rate	50 Hz
Normalized emittance (electron)	100 π mm·mrad
Normalized emittance (positron)	3000 π mm·mrad

R&D's of BPM and RF-cavity are now underway. 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. The relative accuracy of the system obtained so far with a real beam of SOR-RING is horizontally 0.3 μm rms and vertically 0.4 μm rms [2]. 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. The orbit drifts have been suppressed horizontally less than ten μm and vertically within a few μm; otherwise the orbit fluctuates around the order of 100 μm. The examples are shown in Figs. 14 and 15 of Ref. 1.

The R&D of RF-cavity is going well. 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. Two model cavities were made and their low power test was completed. The production process of SiC and the method of welding SiC to metal have been well studied. And further a hot model cavity that can store the same amount of RF power as the design value or more was fabricated last March. Presently about 100 kW RF power has been successfully stored in the cavity [3].

References

[1] Y. Kamiya et al., *A Future Project of VUV and Soft X-ray High-Brilliant Light Source in Japan,* Proc. of 1994 EPAC, pp. 639-641.

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

[3] T. Koseki et al. ; *High Power Test of a Damped Cavity for High-Brilliant Synchrotron Radiation Source,* in these proceedings.