Status of the VSX Project
A VUV and Soft X-ray High Brilliance Synchrotron Radiation Source

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Abstract

The VSX project aims at constructing a VUV and soft X-ray high-brilliance synchrotron radiation source in a new campus of the University of Tokyo (Kashiwa Campus). The VSX light source is being designed intensively at the Institute for Solid State Physics (ISSP). The 2 GeV storage ring has a low emittance optics (ε_{x0} ~ 5 nm·rad) with wide dynamic apertures and 16 straight sections mainly used by insertion devices, which can produce VUV to soft X-ray radiation with a maximum brilliance of about 10^{20} photons/(sec·mm^2·mrad^2·0.1%b.w.). The linac and booster synchrotron meet the full energy injection of both positron and electron beams to the storage ring. The R&D's on the damped RF cavity and the single-pass monitor are progressing well. Prototypes of bending, quadrupole and sextupole magnets are now being manufactured and tested.

1 Introduction

The VSX light source [1] is a third-generation VUV and soft X-ray synchrotron radiation source and its highly brilliant radiation will be used for nationwide user groups of solid state physics, surface science, atomic and molecular science, chemistry, life science, micromachining and so on. The proposed VSX site is in a new campus of the university called Kashiwa Campus, to which several existing facilities of the university including ISSP will move in near future. The VSX light source will be constructed and managed by a newly organized body directly belonging to the university, the Center of High-Brilliance Light Source, which is supposed to join with a few other facilities for accelerator-related science into the Center of Accelerator Science after the construction of the light source. The conceptual design report for the VSX accelerators was already published in May 1996. Further study on the accelerator design is going on. In 1997, the government decided to give a budget for preparatory work for the VSX project. Based on this budget, a new R&D on storage ring magnets have been started in addition to those on the RF cavity and the single-pass monitor. This paper reports on the present status of the project.

2 Accelerator

Figure 1 shows a layout of the VSX accelerators with the experimental hall in the light source building. The accelerator complex consists of a linac, booster synchrotron and storage ring. The linac and synchrotron lie under the ground, while the storage ring is on the ground.

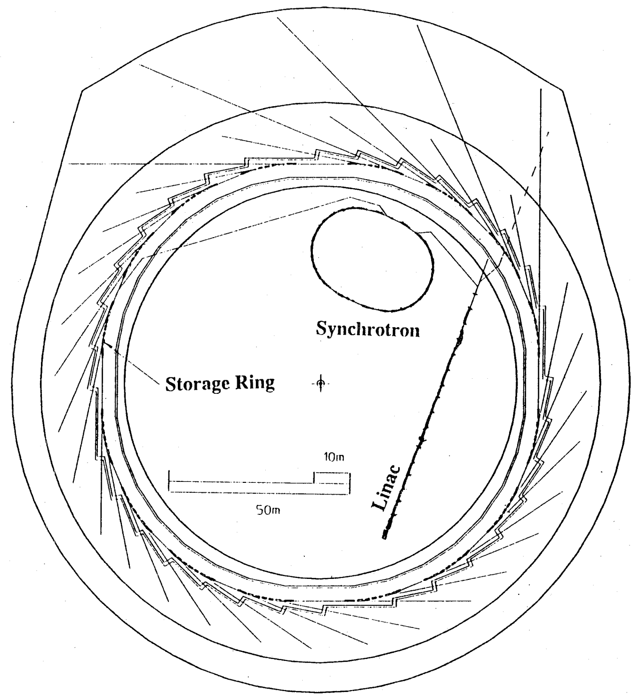

Fig. 1 Layout of the VSX accelerators.

2.1 Storage Ring

The 2 GeV storage ring has a lattice type of DBA with 16 cells and 4 superperiods. The fundamental parameters of the storage ring are summarized in Table 1. In the latest design [2], we obtained wide horizontal and vertical dynamic apertures for an emittance of 5.1 nm·rad by optimizing the harmonic sextupoles. The horizontal and vertical dynamic apertures are ~$150\sigma_x$ and ~$120\sigma_y$ (σ_x, σ_y: horizontal and vertical beam sizes) for zero momentum deviation, and ~$100\sigma_x$ and ~$90\sigma_y$ even when realistic field and alignment errors of magnets are taken into consideration.

The storage ring has four 14.3 m long straight sections and twelve 7 m semi-long straight sections. The 7 m semi-long straight sections are used for 10 insertion devices, injection magnets and RF cavities. Each of 14.3 m long straight sections is aimed to install a long undulator with a length of about 12 m, or a few kinds of undulators which may produce synchrotron light with different polarities and/or wavelengths. Figure 2 shows the spectral brilliances of 12 m undulators with typical magnetic periods and the bending magnet. The maximum brilliance of the

VSX light source can exceed 10^{20} photons/(sec·mm^2·mrad^2 ·0.1%b.w). The photon energy is available up to a few keV by use of the higher harmonics. Multipole wigglers are also installed for generating hard X-rays above 10 keV.

Table 1: Fundamental parameters of the storage ring

Energy	E [GeV]	2.0
Lattice type		DBA
Superperiod	N_s	4
Circumference	C [m]	388.45
Semi-long straight section		7.0m x 12
Long straight section		14.3m x 4
Natural emittance	ε_{x0}[nm•rad]	5.10
Energy spread	σ_E/E	6.66×10^{-4}
Momentum compaction	α	6.87×10^{-4}
Horizontal tune	ν_x	18.84
Vertical tune	ν_y	9.55
Horizontal natural chromaticity	ξ_x	-47.78
Vertical natural chromaticity	ξ_y	-18.45
Horizontal damping time	τ_x [msec]	24.17
Vertical damping time	τ_y [msec]	24.25
Longitudinal damping time	τ_z [msec]	12.14
Revolution frequency	f_{rev}[MHz]	0.771759
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]	4.04
RF-bucket height	$(\Delta E/E)_{RF}$	0.028

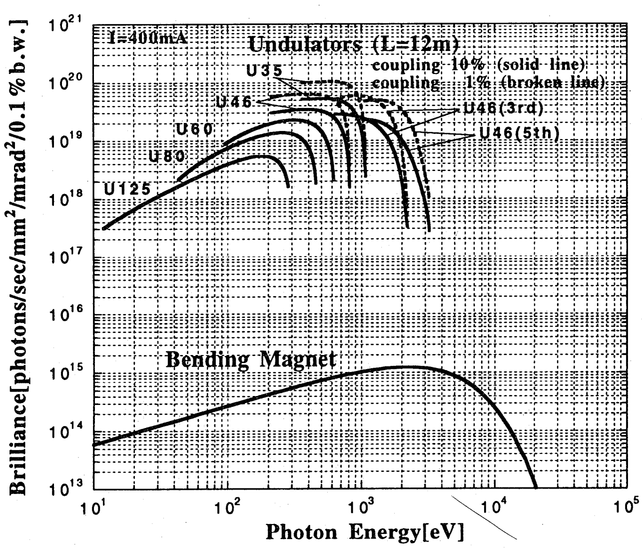

Fig. 2 Brilliances of 12 m undulators with typical periods and the bending magnet.

2.2 Linac and Synchrotron

The linac can generate and accelerate a positron beam as well as an electron beam with a maximum repetition rate of 50 Hz. The linac parameters are shown in Table 2. This linac has five beam modes; the pulse length and peak current of the linac beam depend on these beam modes. In four beam modes, the linac feeds the electron or positron beam to the synchrotron. The short and semi-long beam modes correspond to single-bunch and multi-bunch operations of the storage ring, respectively. Two SLED cavities are adopted for the positron beam to obtain the beam energy more than 250 MeV and the momentum spread less than 0.25 % (with an Energy Compression System on) for a linac length of about 70 m. In the long electron beam mode, the high-power electron beam is provided for a slow-positron production target in the slow-positron experiment facility. The linac can be dedicated to slow-positron experiments when the storage ring is in a storage mode.

The booster synchrotron accelerates the electron or positron beam from the linac up to 2 GeV for the full-energy injection to the storage ring. The lattice is a FODO type with a betatron phase advance per cell of 95 degrees and two dispersionless straight sections for an RF cavity and an injection/extraction system. The fundamental parameters are listed in Table 3. By use of this synchrotron, the design beam current of the storage ring, 400 mA for the multi-bunch operation and 10 mA for the single-bunch operation, can be stored within a few minutes for the electron beam and within thirty minutes for the positron beam.

Table 2: Fundamental parameters of the linac

Total length[m]	68.23				
Repetition rate[Hz]	50 (max.)				
Beam mode	electron			positron	
	short	semi-long	long	short	semi-long
Energy[MeV]	310	300	230	250	250
Pulse duration	1 ns	0.3 μs	4 μs	1 ns	15-30 ns
Peak current[A]	200	50	300	10	6
Energy spread[%]	±0.25	±0.25	–	±0.25	±0.25

Table 3: Fundamental parameters of the synchrotron

Injection energy	E_{ini} [GeV]	0.25 - 0.30
Maximum energy	E_{max} [GeV]	2.0
Circumference	C [m]	97.11
Maximum repetition rate	f_{rep}[Hz]	4
Natural emittance (2 GeV)	ε_{x0}[nm•rad]	304
Energy spread (2 GeV)	σ_E/E	7.59×10^{-4}
Momentum compaction	α	0.058
Horizontal tune	ν_x	5.17
Vertical tune	ν_y	4.79
Revolution frequency	f_{rev}[MHz]	3.087
Harmonic number	h	162
Synchrotron tune	ν_s	0.024
Bunch length	σ_z[mm]	26
RF-bucket height	$(\Delta E/E)_{RF}$	0.004

3 R & D

3.1 Damped RF Cavity

We have developed a single-cell 500 MHz cavity with a simple damped-structure. The cavity has a beam duct with a comparatively large diameter on each side and a part of the beam duct is made of an SiC microwave absorber. The higher-order modes (HOMs) are guided out of the cavity to the beam ducts and dissipated by the SiC part. It was already confirmed in the low-power test of two cold-model cavities that Q-values of the HOMs are strongly damped by the SiC absorber [3]. Furthermore a high-power model of the cavity was manufactured, and after the high-power conditioning for 60 hours input power of 150 kW was attained without any severe problems. It means that the cavity can store RF power five times as high as the required one [4].

In the summer of 1996, two damped RF cavities were installed at the Photon Factory (PF) storage ring in place of two old cavities(Fig. 3). The new cavities were successfully operated for the scheduled two-month user run in the autumn of 1996. During this operation, any dangerous coupled-bunch instabilities were not observed. In addition, the maximum stored current of 773 mA, a new record higher by ~200 mA than the last one, was achieved [5].

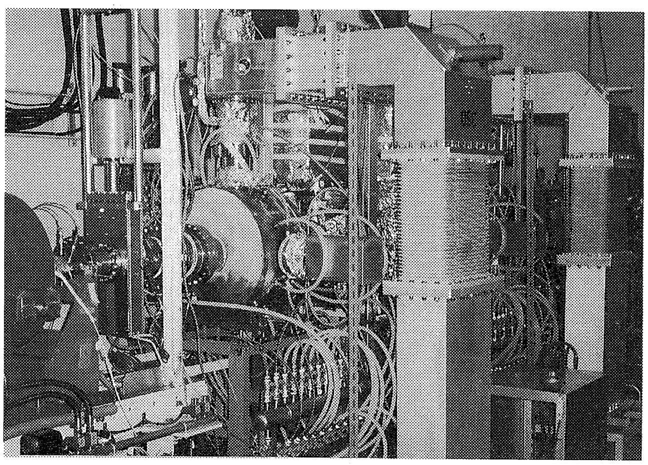

Fig. 3 Damped RF cavities installed at the PF ring.

3.2 Single-Pass Monitor

Single-pass measurement of beam position is expected to play an important role in commissioning and tuning of the VSX accelerators. A program to develop a single-pass monitor system using a fast digitizing oscilloscope is under way at a 500 MeV electron storage ring, SOR-RING[6]. In this system, the four button signals of four beam position monitors (BPMs) are combined by the RF power combiners and then fed into a 4-channel digital oscilloscope (TDS684A by Tektronix). Each channel of the oscilloscope has a 8-bit digitizer with a maximum sampling rate of 5G samples/s and a maximum record length of 15000 points. The digitized data are sent to a workstation (HP715), and the beam position is calculated from the intensities of four button signals. The relative accuracy of less than 100 μm has been obtained in this system.

3.3 Magnet

The VSX storage ring contains 32 identical bending magnets with 1.3 m long, 144 quadrupole magnets with two different lengths, 0.4 m and 0.6 m, and 128 sextupole magnets with 0.15 m and 0.2 m. All these magnets are conventional, room temperature, DC magnets, and they are optimized for a nominal operating energy of 2.0 GeV, but capable of reaching a maximum energy of 2.5 GeV. The 2-dimensional field calculation of the magnets was made by the computer program LINDA, which allowed to determine a pole shape with shim profile.

Prototypes of all three magnets are currently fabricated and tested at Energy & Industrial Systems Center of Mitsubishi Electric Corporation. Figures 4 and 5 show the bending and the quadrupole magnet prototypes, respectively. The bending and quadrupole magnet prototypes will be delivered in September 1997 and their field measurement will be carried out this autumn. The construction of the sextupole magnet prototype is also in progress, and it will be completed by the end of December 1997.

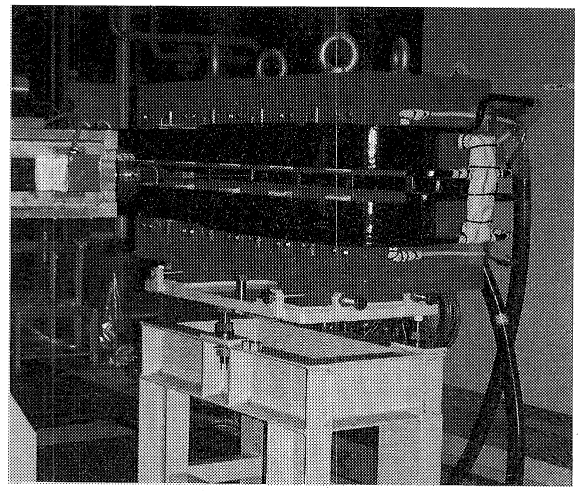

Fig. 4 Prototype of bending magnet under test.

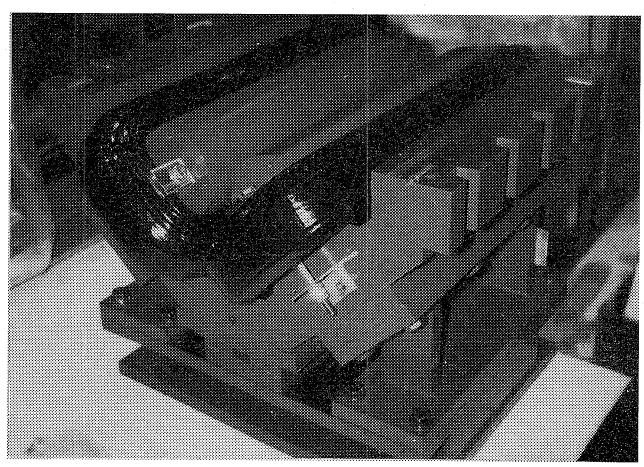

Fig. 5 Prototype of quadrupole magnet under construction.

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