NEW DESIGN AND DEVELOPMENTS OF THE VSX LIGHT SOURCE

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Abstract

The VSX light source is a Japanese third-generation VUV and soft X-ray synchrotron light source promoted by the University of Tokyo. We recently modified the 1.0-GeV ring design after discussing with the user community. In the new design, 1.6 GeV low emittance operation as well as 1.0 GeV ultra-low emittance operation is realized only by lengthening all the bending magnets of the storage ring by 33 %. Two 2-m short straight sections with low betatron functions are added to install two mini-pole undulators. One of two 29-m long straight sections is designed to have a "saw-tooth" shape which makes possble simultaneous use of three 5-m undulators installed there. The other long straight section is used for a 27m long undulator. Prototypes for the magnet and vacuum systems have been constructed and will be tested soon. Test models of some other accelerator components and subsystems are under development.

1 INTRODUCTION

The VSX light source [1] is a third-generation VUV and soft X-ray synchrotron light source and its highly brilliant light will be used for nationwide user groups. The proposed VSX site is in a new campus at Kashiwa (Kashiwa Campus), to which two institutes including ISSP have already moved and a newly-established graduate school and several existing facilities will move in near future.

Since the 2-GeV ring plan[1] was not authorized due to financial difficulties in spite of extensive efforts for many years, a 1.0-GeV diffraction-limited ring[2] with a racetrack shape was proposed in autumn 1997. The user community accepted the proposal and then demanded that the light source should cover higher photon energy and have more insertion-device beamlines which can be simultaneously used. After intensive discussions with the user community, the ring was slightly modified in 1999 to be capable of operating at 1.0 GeV to 1.6 GeV and installing five more independent undulator beamlines.

In this paper, the new design of the VSX light source is described and its recent R&D's are briefly reported. These R&D's are based on the budget which has been provided for preparatory work of the project by the government since 1997.

2 DESIGN AND PERFORMANCE

Figure 1 shows a layout of the VSX light source facility, which includes a storage ring, an injector linac and a transfer line. The storage ring is composed of four arc sections (20 normal cells), two 29-m long straight sections, two 2-m short straight sections and eight matching sections. The lattice configuration of the normal cells is a type of "theoretical minimum emittance", which can attain a smaller emittance by a factor of three than

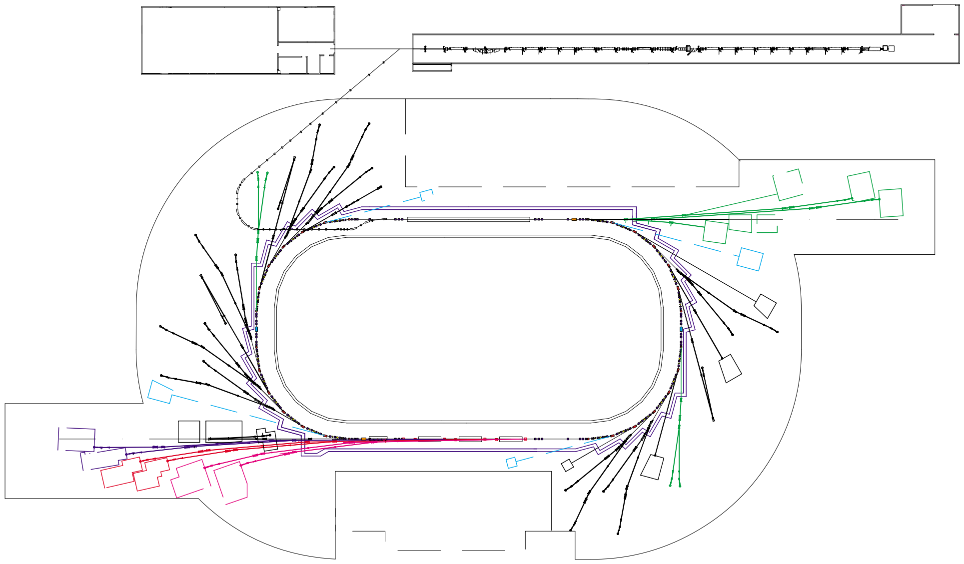

Figure 1: Layout of the VSX light source facility.

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[1] ISSP moved to Kashiwa in 2000 March.

a DBA type. There are two operation modes prepared for synchrotron radiation experiments: ultra-low emittance mode (ULEM) and low emittance mode (LEM). The natural emittance in ULEM is extremely small in comparison with the existing synchrotron light sources around the world and both horizontal and vertical emittances can reach the diffraction limit for the photon energy below about 130 eV, though the emittance may exceed 1 nm•rad due to the intra-beam scattering for a maximum stored current of 200 mA. In LEM, the beam energy can be accelerated up to 1.6 GeV, and thus the ring can provide photons of higher energy than the 1.0-GeV ring design[2]. This energy up is attained by lengthening the bending magnet from 60 cm to 80 cm, without any design change of the quadrupole and sextupole magnets. The fundamental parameters of the storage ring are listed in Table 1. The details of the new ring optics will be described elsewhere[3].

Table 1: Fundamental parameters of the storage ring

	ULEM	LEM
Energy E [GeV]	1.0	1.6
Circumference C [m]	249.38	
Natural emittance ε_{x0}[nm•rad]	0.75	5.65
Coupling constant κ[%]	10	1
Natural energy spread σ_E/E	$4.91\text{x}10^{-4}$	$7.85\text{x}10^{-4}$
Momentum compaction α	$5.69\text{x}10^{-4}$	$11.0\text{x}10^{-4}$
Tune ν_x, ν_y	19.40, 8.71	14.26, 12.19
Natural chromaticity ξ_x, ξ_y	-37.1, -39.5	-39.5, -21.7
Bending magnet field B[T]	1.092	1.747
Critical Photon energy ε_c[keV]	0.73	2.97
Radiation loss[keV/turn]	28.9	189.7
Damping time[ms] τ_x, τ_z	57.2, 28.8	14.0, 7.0
Revolution frequency f_0[MHz]	1.202	
RF voltage V_{RF} [MV]	0.7	1.4
RF frequency f_{RF} [MHz]	500.1	
Harmonic number h	416	
Synchrotron tune ν_s	0.0051	0.0079
Natural bunch length σ_z [mm]	2.16	4.30
RF-bucket height $(\Delta E/E)_{RF}$	0.0420	0.0312

Nine insertion devices will be installed in the VSX ring in total. The brilliances of typical insertion devices are shown in Fig. 2. A 27-m long undulator installed in a 29-m long straight section can provide an unprecedented photon beam with a brilliance of 10^{19} - 10^{20} photons/s/mm^2/mrad^2/0.1%b.w. in the VUV and soft X-ray region, which is suitable for ultra-high resolution experiments and high coherence experiments. As shown in Fig. 3, the 27-m undulator light itself has an extremely narrow spectral line with a resolving power of 250 - 350 (e.g. the minimum linewidth of 0.3 eV for the photon energy of 100eV), and thus it can be used for ultra-high flux experiments without any monochromator. Three 5-m undulators will be installed in the other 29-m long straight section called "saw-tooth" section which is slightly undulated by seven additional dipole magnets in order to extract three undulator photon beams seperately. Two 1-m undulators are installed in the 2-m short straight sections (newly added to the ring design) with low betatron functions. They are in-vacuum minipole types with a period of 20 - 30 mm and a minimum gap of 5 mm and can generate the first harmonic up to about 1 keV and the higher harmonics up to several keV. The saw-tooth section and the two short straight sections increase the number of independent undulator beamlines by five. A 4-m undulator, a 1-m multipole wiggler (MPW) and a 6-Tesla superconducting wiggler (SCW) will be installed in the matching straight sections located between the arc and long-straight sections.

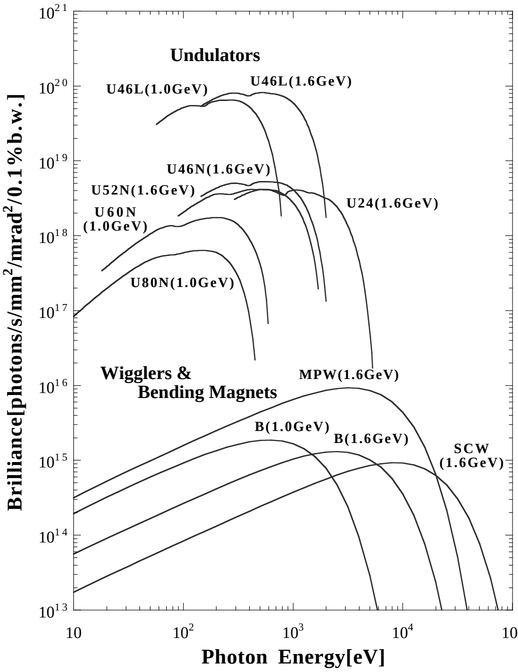

Figure 2: Brilliance of synchrotron light from insertion devices and bending magnets.

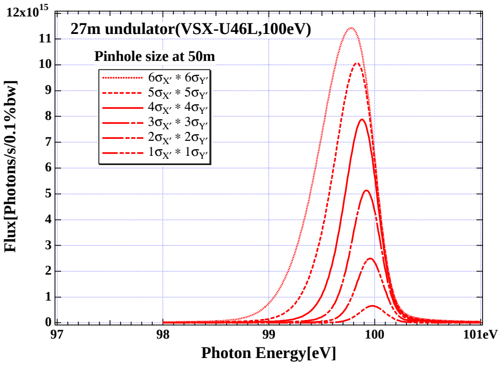

Figure 3: Flux spectra for the first harmonic of 100eV through pinholes at 50m from the 27m undulator. Pinhole sizes are shown in units of effective angular sizes of the photon beam.

The linac consists of an electron gun, a pre-buncher, a buncher and accelerating sections. A positron generation section and an ECS(Energy Compression System) section are also illustrated in Fig. 2, but they are future options. The accelerating tubes, each 3m long, are driven by 80MW klystrons and the SLED cavities for reducing the linac length. The fundamental parameters of the linac are shown in Table 2. There are three operation modes: short, semi-long and long pulse modes. The linac can provide a 1.0-GeV electron beam to the storage ring in the short and semi-long pulse modes. The short 1-ns pulses make possible single-bunch operation of the ring and the semi-long pulses are used in multi-bunch operation. In the long pulse mode, the linac can produce the high-power electron beam with a maximum energy of 500 MeV and a peak current of 300 mA. Electrons are converted to positrons at the end of linac and then a brilliant slow-positron beam is transferred to the slow-positron experimental hall. The linac can be dedicated to slow-positron experiments except for beam injection to the ring.

Table 2: Fundamental parameters of the linac

RF frequency[MHz]	2856		
Repetition rate[Hz]	50 (max.)		
Normalized emittance	50π mm• mrad		
Operation mode	short	semi-long	long
Pulse duration	1 ns	15 - 30 ns	0.5 - 2 μs
Energy	1 GeV	1 GeV	500 MeV
Peak current[mA]	400	400	300
Energy spread[%]	±0.25	±0.25	-

3 R&D STATUS

In 1999, prototypes of the bending magnet, the quadrupole magnet and the fast steering magnet were constructed and a prototype of the power supply for the quadrupole and sextupole magnets was also manufactured. Figure 4 shows the prototypes of the bending and quadrupole magnets. A vacuum chamber prototype made of an aluminium alloy was constructed in March 2000 (see Fig. 5). This is for the quadrupole and sextupole magnets just downstream of the bending magnet in the normal cell. A model bellow with an RF shield and a test ID chamber with copper coating were also fabricated for reducing structural and resistive-wall impedances. The performance test of these prototypes and test components are being prepared.

Development of a HOM coupler is going on to reduce impedances of HOM's hardly absorbed by the SiC duct of the damped RF cavity. Two cold models are successfully tested[4] and high-power models are under test. A fast orbit feedback system for beam stabilization is being developed in both hardware and software. A model feedback control system was already constructed[5] and a new COD correction method for uniting global and local feedbacks was studied[6]. For the linac, a model accelerating section with higher shunt impedance than the conventional SLAC-type structure was fabricated and its performance will be investigated in near future. Development of a system for compensating initial beam loading by amplitude control of klystron input is in progress to reduce serious beam loss in the long pulse mode[7]. The details of the R&D's until autumn 1999 were described in a separate paper [8].

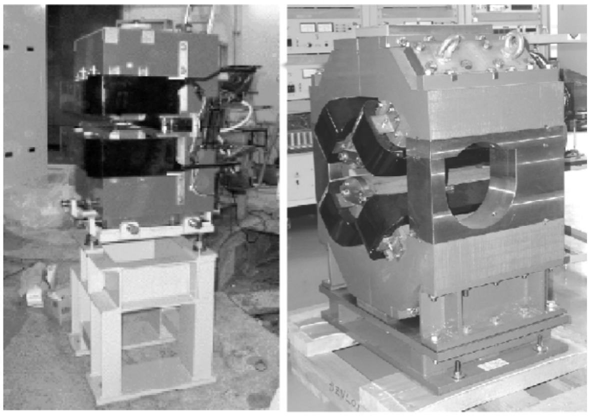

Figure 4: Photographs of magnet prototypes (left: bending magnet, right: quadrupole magnet).

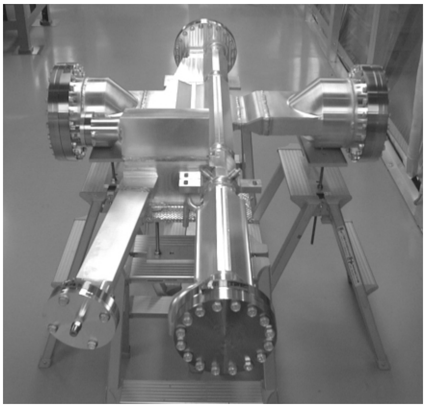

Figure 5: Prototype of vacuum chamber. The chamber has electron and photon beam ducts and two pumping ports extending to the outside of the quadrupole magnet.

REFERENCES

[1] Y. Kamiya, J. of Electron Spectrosc. Relat. Phenom. 92, 1998, p.301; N. Nakamura, Proc. of the 11th Symp. on Accel. Sci. and Tech., Harima, October 1997, p.510.
[2] H. Takaki et al., "The Lattice of the 1.0 GeV VSX Storage Ring", Proc. of the 1999 PAC, New York, 1999, p.2436.
[3] H. Takaki et al., to be submitted to SRI 2000, Berlin, August 2000.
[4] T. Koseki et al., "HOM Coupler for the Damped Cavity of High Brilliance SR Source", Proc. of the 6th EPAC, Stockholm, 1998, p.1776.
[5] M. Satoh et al., Proc. of the 12th Symp. on Accel. Sci. and Tech., Wako, October 1999, p.498.
[6] M. Satoh, N. Nakamura and Y. Kamiya, "Error Analysis of a New COD Correction Method uniting Global and Local Orbit Feedbacks", Proc. Of the 1999 PAC, New York, 1999, p.1174.
[7] M. Satoh et al., "Compensation of Initial Beam Loading for Electron Linacs", these proceedings.
[8] T. Koseki et al., Proc. of the 12th Symp. on Accel. Sci. and Tech., Wako, October 1999, p.373.