THE LATTICE OF THE 1.0 GeV VSX STORAGE RING

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Abstract

The University of Tokyo has been promoting a future project to construct a third-generation VUV and Soft X-ray light source (VSX). The VSX ring has an energy of 1.0 GeV, an emittance of about 0.7 nm•rad, a circumference of about 230 m and two 30 m long straight sections for insertion devices. The most significant characteristic of the VSX ring is that its emittance is below a diffraction limit for the photon energy of 100 eV. It can provide the VUV and Soft X-ray light with a maximum brilliance above 10^{20} [photons/sec/mm^2/mrad^2/0.1% b.w.] using a long undulator installed in 30 m long straight section.

1 INTRODUCTION

The University of Tokyo aims at constructing a third-generation VUV and Soft X-ray light source (VSX) in the new Kashiwa Campus. In general, a "third-generation" light source is characterized by a low emittance and a long straight section for insertion devices.

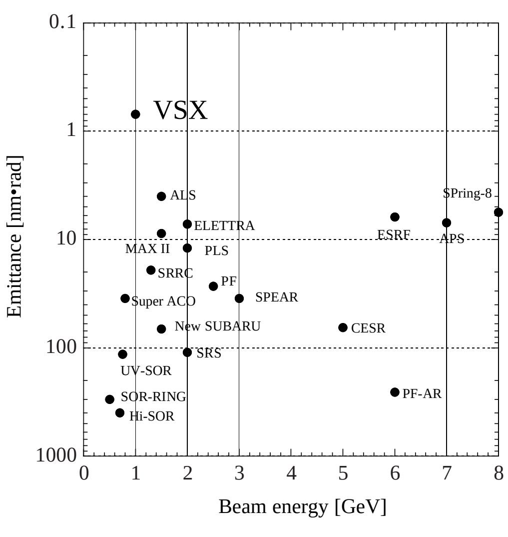

Figure 1: The emittance versus the beam energy for the typical synchrotron light sources in the world.

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The beam emittance of the VSX ring is able to reach the diffraction limit, ε ~ λ/4where λ is the wavelength of the emitted photon. For the typical photon energy of 100 eV (λ ~ 12nm), the diffraction limit is about 1 nm•rad. The minimum value of the beam emittance is 0.73 nm•rad, which is extremely small compared with the existing synchrotron light sources around the world (see Fig. 1). For a maximum current of 200 mA, the emittance becomes slightly larger than 1 nm•rad due to the intra-beam scattering.

The VSX ring has two 30 m long straight sections for insertion devices. The 27 m long undulator will be installed in one of them, which is capable of providing a unprecedentedly brilliant synchrotron light in the VUV region.

In the following sections, the lattice configuration, the linear optics, the chromaticity correction and the dynamic aperture are reported.

2 LATTICE

The storage ring has a shape of racetrack with a circumference of 230.2 m (see Fig. 2). It is composed of 22 *Normal Cell*s, four *Matching Section*s including four *Half Cell*s and two 30 m long straight sections. The *Half Cell* is slightly different from a half of *Normal Cell.*

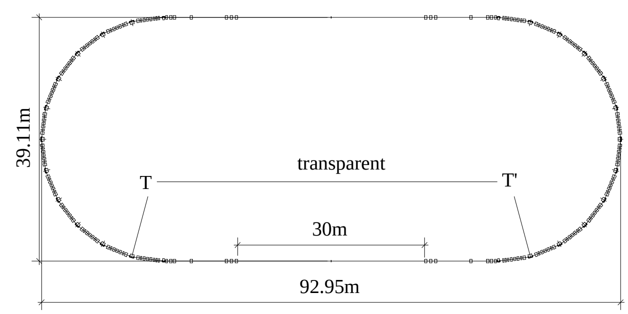


Figure 2: The VSX ring layout

2.1 Normal Cell

The lattice configuration of the *Normal Cell* is of Theoretical Minimum Emittance type [1], which has an emittance smaller than the DBA type by a factor of three. The theoretical minimum emittance is given by,

$$\varepsilon_{x0}^{\min} = \frac{1}{12\sqrt{15}J_x} C_q \gamma^2 \left(\frac{2\pi}{N}\right)^3, \qquad (1)$$

where $C_q = (55/32\sqrt{3})(\hbar/mc)$, J_x is the damping partition number and N is the number of bending magnets. As J_x is almost equal to 1 for the bending magnets of the separated function type, the theoretical minimum emittance is 0.56 nm•rad for N=24.

To realize this emittance in the VSX ring, the horizontal betatron function β_x and dispersion function η_x

should be 0.075 m and 0.0063 m at the center of a bending magnet. Thus a very small beam size less than 10 μm is attained at the magnet center, so that a high brilliant light can be supplied to bending beamlines.

2.2 Matching Section

A *T-T' Section* (see Fig.2 and 3) is composed of a long straight section and two *Matching Section*s. The *Half Cell*, the section between SD and BH, reduces the η_x of *Normal Cell*s to be zero. For the *T-T' Section* to be "transparent" for the non-linear effects and behave as a *Normal Cell*, the phase advances should be,

$$\Delta\phi_x = 2\pi m + \phi_{x\ \mathrm{Normal\ Cell}}, \quad (2)$$

$$\Delta\phi_y = 2\pi n + \phi_{y\ \mathrm{Normal\ Cell}}. \quad (3)$$

For the VSX ring, m=1 and n=2 are chosen. Then the optics looks as if it were perfectly 24-fold symmetric for on-momentum particles.

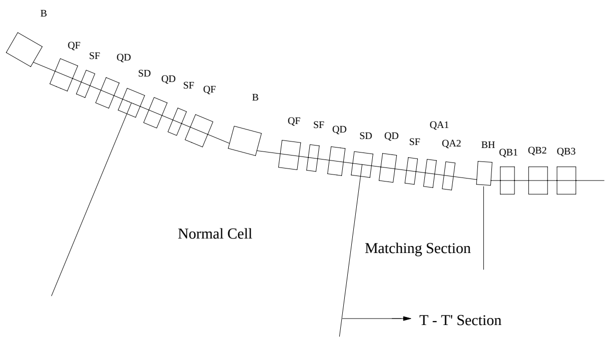


Figure 3: The *Matching Section* layout

3 OPERATION MODE

Since the Touschek effect is severe for *Low Emittance Mode* (LEM), a moderate operation of *High Emittance Mode* (HEM) is prepared for easy commissioning and stable operation.

3.1 Low Emittance Mode

The emittance of *Low Emittance Mode* is 0.73 nm•rad. The fundamental parameters of this mode are listed in Table 1. The Touschek lifetime is 5 hours due to the small beam size, while the Coulomb lifetime is about 10 hours at 10^{-10} Torr.

Table 1: Fundamental parameters of the VSX ring (*Low Emittance Mode*)

Energy		E [GeV]	1.0
Lattice Type			Theoretical Minimum Emittance
Superperiod		Ns	~24
Circumference		C [m]	230.2
Long Straight Section			30 m x 2
Natural Emittance		ε_{x0} [nm•rad]	0.732
Energy Spread		σ_E /E	$5.67\mathrm{x}10^{-4}$
Momentum Compaction Factor		α	$4.49\mathrm{x}10^{-4}$
Tune	Horizontal	ν_x	17.4
	Vertical	ν_y	7.71
Natural Chromaticity	Horizontal	ξ_x	-38.7
	Vertical	ξ_y	-39.3
Damping Time	Horizontal	τ_x [msec]	39.6
	Vertical	τ_y [msec]	39.8
	Longitudinal	τ_z [msec]	19.9
Revolution Frequency		f_{rev}[MHz]	1.302
RF Voltage		V_{RF} [MV]	0.5
RF Frequency		f_{RF} [MHz]	500.1
Synchrotron Tune		ν_s	0.0037
Bunch Length		σ_z [mm]	2.52
RF-bucket Height		$(\Delta E/E)_{RF}$	0.040

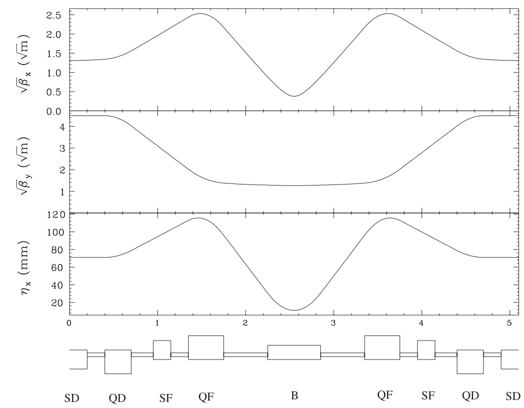


Figure 4: The optics of the *Normal Cell* (LEM)

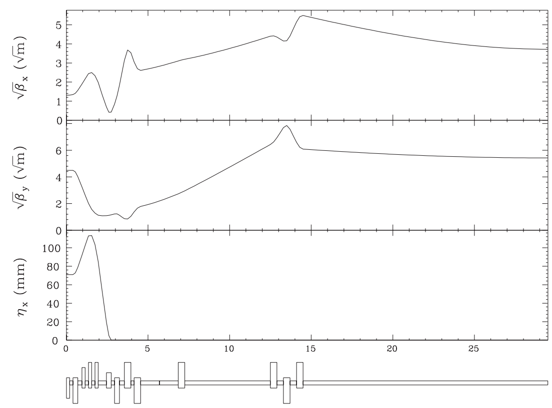


Figure 5: The optics of the *Matching Section* (LEM)

The optics of the *Normal Cell* and the *Matching Section* are shown in Fig. 4 and 5. The parameters of magnets are listed in Table 2.

The chromaticity is corrected by only 2 families of sextupoles (SF, SD) in the *Normal Cell*s, but the so-called harmonic sextupole is not used. The horizontal and vertical dynamic apertures after chromaticity correction are shown in Fig. 8.

3.2 High Emittance Mode

The emittance of *High Emittance Mode* is 2.6 nm•rad. The fundamental parameters of this mode are listed in Table 3. Touschek lifetime becomes over 10 hours.

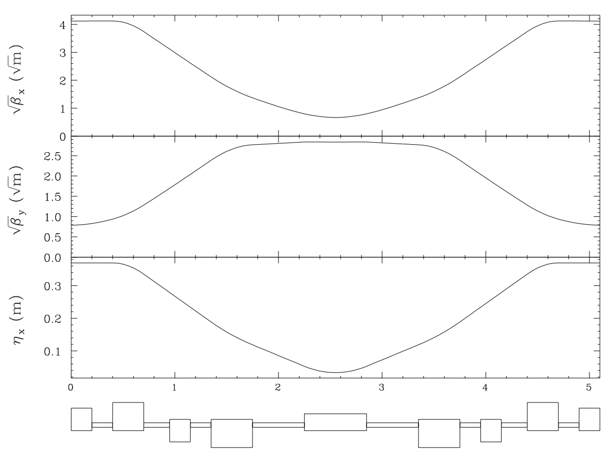
The optics of the *Normal Cell* and the *Matching Section* are shown in Fig. 6 and 7. The horizontal and vertical dynamic apertures after chromaticity correction are shown in Fig. 8.

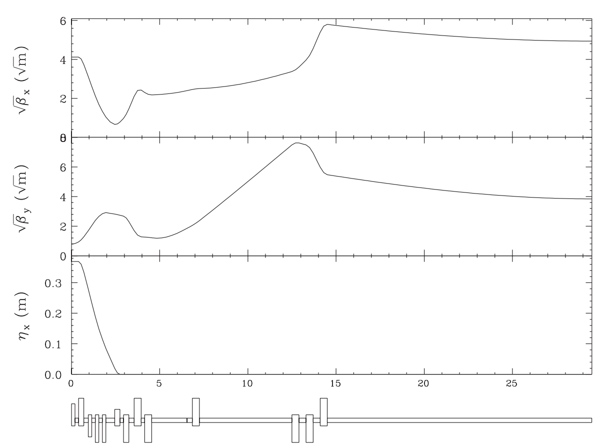
Table 2: Parameters of Magnets

		LEM	HEM
B	[T]	1.450 [T]	1.450 [T]
QF	B' l/B ρ [1/m]	1.664	-0.622
QD	B' l/B ρ [1/m]	-0.715	0.630
SF	(B'' l/B ρ) [1/m^2]	33.168	-7.590
SD	(B'' l/B ρ) [1/m^2]	-26.747	4.015

Table 3: Parameters for *High Emittance Mode*

Natural Emittance	ε_{x0} [nm•rad]	2.64
Momentum Compaction Factor	α	1.02×10^{-3}
Natural Chromaticity Horizontal	ξ_x	-34.6
Vertical	ξ_y	-18.7
RF Voltage	V_{RF} [MV]	0.7
Bunch Length	σ_z [mm]	3.20
RF-bucket Height	$(\Delta E/E)_{RF}$	0.032





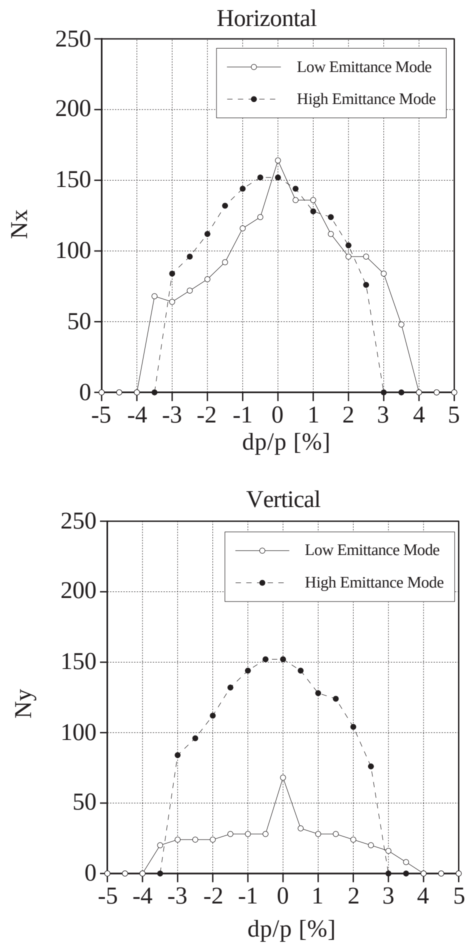


Figure 6: The optics of the *Normal Cell* (HEM)

Figure 7: The optics of the *Matching Section* (HEM)

Figure 8: The horizontal and vertical dynamic apertures normalized by $\sqrt{\beta \varepsilon_{x0}}$.

4 REFERENCES

[1] Y. Kamiya and M. Kihara, "On the design guideline for the low emittance synchrotron radiation source", KEK 83-16.