A LATTICE FOR THE FUTURE PROJECT OF THE VUV AND SOFT X-RAY HIGH BRILLIANCE LIGHT SOURCE (VSX)

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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 first phase ring of the VSX has an energy of 1 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 lattice is that it can reach a diffraction limit (1 nm•rad for the photon energy of 100 eV) and provide the VUV and Soft X-Ray light with a maximum brilliance of above 10^{20} [photons/sec/ mm^2/ $mrad^2$/0.1 % b.w.] using a long undulator placed in 30 m long straight section. An overview of the design is presented in this paper.

1 INTRODUCTION

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

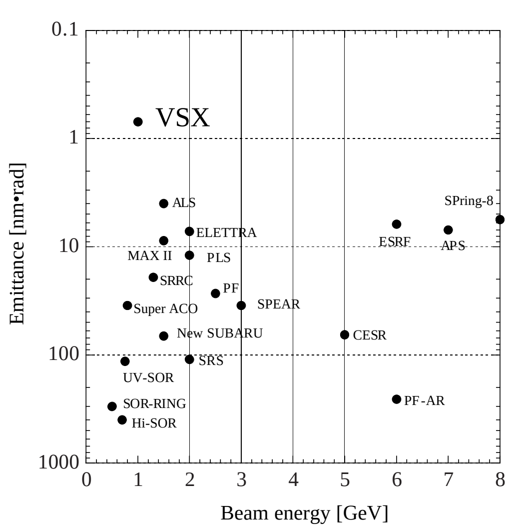

Figure 1: The emittance of synchrotron radiation light sources.

The VSX ring is able to reach the diffraction limited emittance given by $\varepsilon \sim \lambda/4\pi$ (λ being the wavelength of the emitted photon). For the typical photon energy of 100 eV (λ = 12 nm), the diffraction limited emittance is about 1 nm•rad. The present design value of the emittance is 0.715 nm•rad, which is extremely small compared with the existing synchrotron radiation light sources around the world (see Fig. 1).

The VSX has two 30 m long straight sections for insertion devices . A long undulator (27 m long) will be placed in one of them, which is capable of providing high brilliant light, and the brilliance may surpass 10^{20} [photons/sec/mm^2/$mrad^2$/0.1 % b.w.] (see Fig. 2).

The fundamental parameters of the VSX ring is listed in Table 1. In the following sections, the lattice configuration and the dynamic aperture are reported.

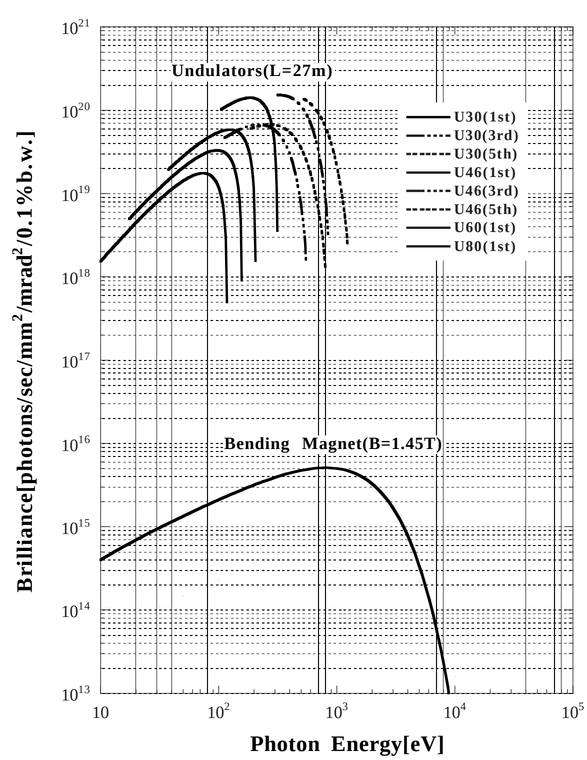

Figure 2: The brilliance of VSX Energy = 1.0 GeV, Current = 200 mA, Emittance = 1.52 nm•rad and Coupling = 10% are assumed. The emittance growth due to intrabeam scattering is taken into account.

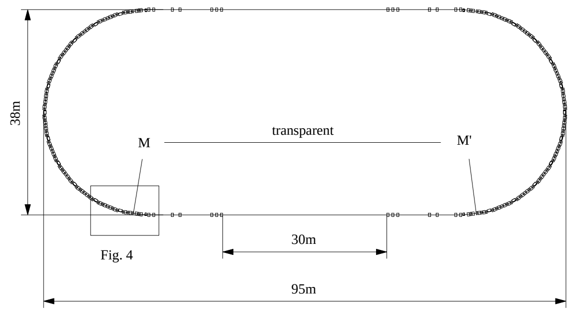

Figure 3: The VSX layout.

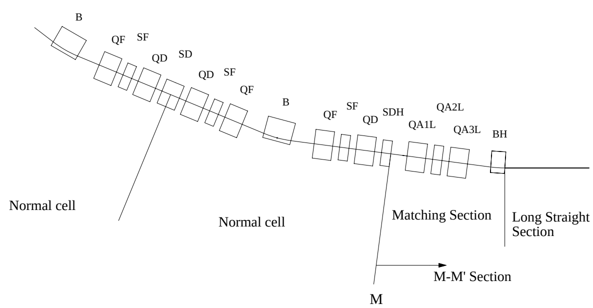

Figure 4: *Normal* cell and *Matching Section*.

2 LATTICE

The storage ring has a shape of racetrack with a circumference of 233.2 m (see Fig. 3). It is composed of 22 *Normal* cells, four *Matching Section*s and two long straight sections (see Fig. 4).

The *M-M' Section* (see Fig. 4) is composed of a long straight section and two *Matching Section*s which are placed both ends of the long straight section. The long straight section is dispersion free with the quadrupole magnets {Q1AL, Q2AL, Q3AL: 3 families}. In order to make *M-M' Section* "transparent" for non-linear elements, the horizontal and vertical phase advances are set to 4π and 2π using the quadrupole magnets {QB1L ~ QB7L: 7 families} in the long straight section. Therefore, the optics looks as if it is 22-fold symmetric.

The lattice configuration of the *Normal* cell is of Theoretical Minimum Emittance type [1] which has an emittance smaller than the DBA type by 1/3. 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 $C_q = \left(55/32\sqrt{3}\right)\left(h/2\pi mc\right)$, J_x is the damping partition number and N is the number of bending magnets. As J_x is almost 1 for the bending magnets of separated function type, the theoretical minimum emittance is 0.56 nm•rad for N = 24.

Table 1: Fundamental parameters of the VSX.

Energy	E [GeV]	1.0
Lattice type		Theoretical Minimum Emittance
Superperiod	Ns	~22
Circumference	C [m]	233.2
Long straight section		30 m x 2
Natural emittance	ε_{x0} [nm•rad]	0.715
Energy spread	σ_E /E	5.67×10^{-4}
Momentum compaction	α	3.11×10^{-4}
Horizontal tune	ν_x	19.21
Vertical tune	ν_y	8.15
Horizontal natural chromaticity	ξ_x	-37.4
Vertical natural chromaticity	ξ_y	-41.3
Horizontal damping time	τ_x [msec]	40.1
Vertical damping time	τ_y [msec]	40.3
Longitudinal damping time	τ_z [msec]	20.2
Revolution frequency	f_{rev}[MHz]	1.286
RF voltage	V_{RF} [MV]	0.4
RF frequency	f_{RF} [MHz]	500.1
Synchrotron tune	ν_s	0.0028
Bunch length	σ_z [mm]	2.38
RF-bucket height	$(\Delta E/E)_{RF}$	0.043

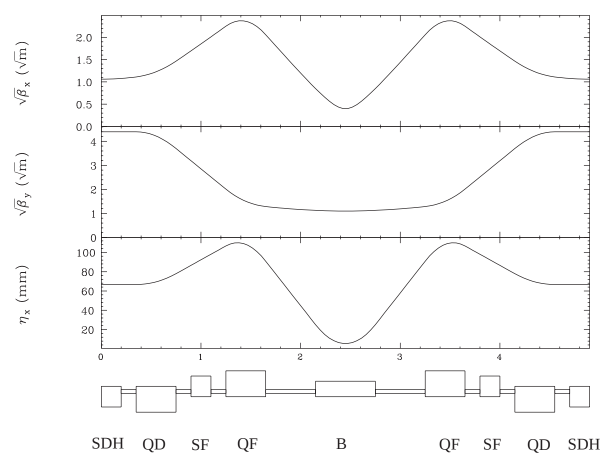

Figure 5: The optics of the *Normal* cell.

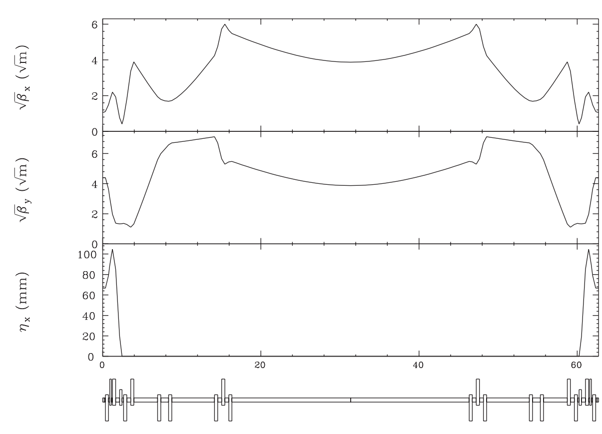

Figure 6: The optics of the *M-M' Section*.

To realize this emittance, the horizontal betatron function β_x and dispersion function η_x must be 0.075 m and 0.0063 m at the center of the bending magnet. This small beam size is able to provide bending beamlines with high brilliant light. The bending magnet (B) is 0.6 m long and the quadrupole is 0.4m long. The Normal Cell is 4.9 m long for the present design.

3 CHROMATICITY CORRECTION AND DYNAMIC APERTURE

The horizontal chromaticity is -37.4 and the vertical one is -41.3. The chromaticity arising from the *M-M' Section*s are -8.8 (horizontal) and -6.1 (vertical), which is not corrected locally, because the *M-M' Section* dose not have sextupole magnets.

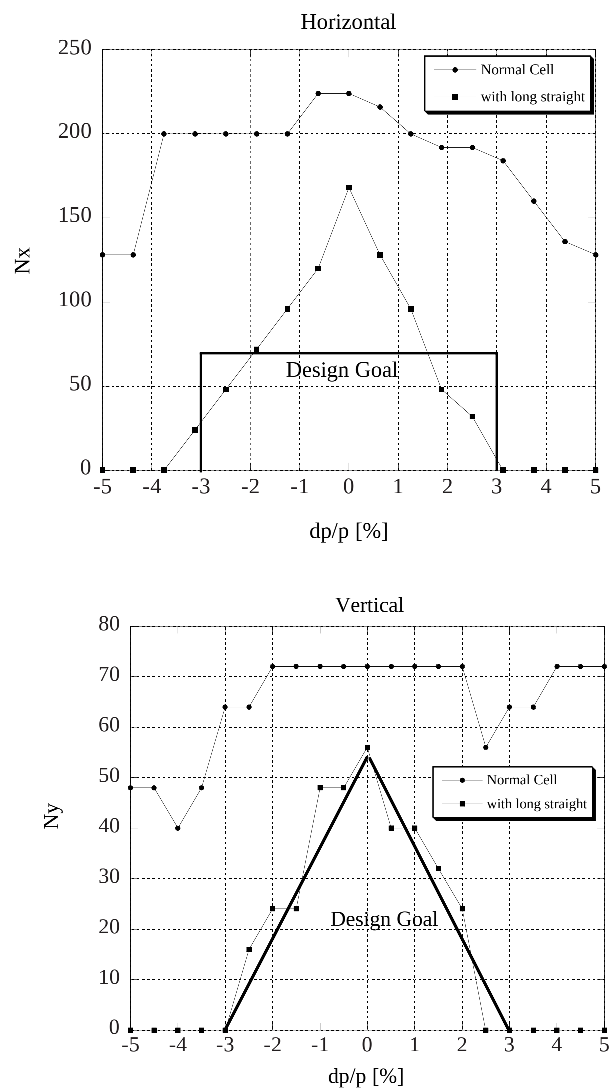

Figure 7: The horizontal and vertical dynamic aperture normalized by $\sqrt{\beta \varepsilon_{x0}}$. "Normal Cell" represents 22-fold symmetric lattice and "with long straight" represents the lattice of the VSX ring.

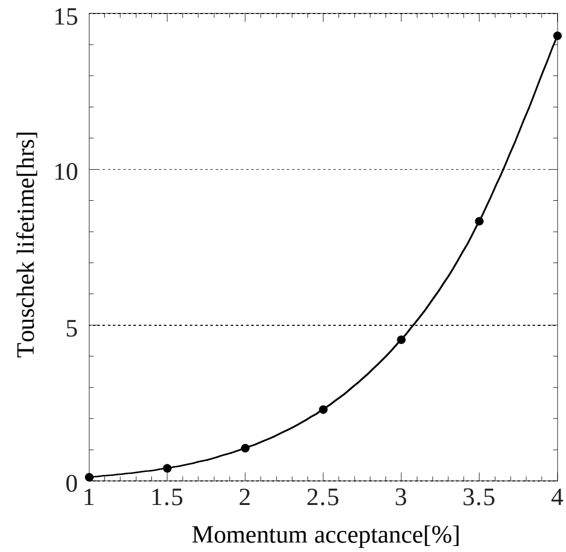

Figure 8: The momentum acceptance vs. Touschek lifetime. Energy = 1.0 GeV, Beam Current = 200 mA, RF bucket height = 4% and Coupling 10% are assumed.

The total chromaticity is corrected by 2 families of sextupoles (SF, SD in Fig. 5) in 22 *Normal* cells. The strength of these sextupoles are 686 [T/m^2] (SF) and -555 [T/m^2] (SD).

Figure 7 shows the horizontal and vertical dynamic apertures after the chromaticity correction. There is a very large momentum acceptance for the 22-fold symmetric lattice, while the momentum acceptance becomes smaller for the lattice of the VSX ring. The reason is the existence of a locally large chromaticity in the *M-M' Sections*. This large chromaticity destroy the "transparent" condition in the *M-M' Sections* for the off-momentum particles.

The design goal of the Touschek lifetime is about 5 hours, for which Nx ~ 70 at dp/p of ±3% is required (see Fig. 8). The Touschek lifetime due to the dynamic aperture is obtained, so far, only around 1 hour.

New lattice configurations are now under study, taking account of the following;

1) the reduction of the chromaticity arising from the *M-M' Section*,
2) the local correction of the chromaticity with the finite dispersion function in the long straight section.

It is expected that they have large momentum acceptance.

REFERENCES

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