A Lattice for the Future Project of VUV and Soft X-Ray High Brilliance Light Source

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Abstract

The lattice design for a future project of a third-generation VUV and soft X-ray at the University of Tokyo is presented.

1. Introduction

A third-generation VUV and soft X-ray ring with a low emittance of several nm·rad is being designed at the University of Tokyo, in close collaboration with the Photon Factory of KEK. The accelerator scheme[1] consists of a linac, booster synchrotron and storage ring. The linac generates an electron or a positron beam, either with an energy of 300 MeV. The booster synchrotron accelerates it up to 2 GeV. The storage ring has an energy of 2 GeV, a circumference of about 400 m, an emittance of less than 5 nm·rad, four 12.5-m long straight section and twelve 7-m semi-long straight sections.

We first present the lattice design of the storage ring, and next the chromaticity correction and dynamic aperture.

2. Lattice Design

Table 1 shows the fundamental parameters of the ring, which has a circumference of 388.45 m and an emittance of 4.87 nm·rad. The ring consists of 16 DBA cells. Each cell has two half straight sections for insertion devices at both ends. The number of the straight sections are 16. Four of them are 12.5 m long and twelve of them are 7 m long. The 12.5-m long straight sections are arranged with a four-fold symmetry. A cell with 7-m half semi-long straight sections at both ends is called *Normal Cell* and a cell with 12.5-m half long straight section at one end is called *Long Cell* (see Table 2). The lattice configuration of a Long Cell is the same as that of Normal Cell except for three quadrupole magnets (QL1, QL2, QL3), which is used for matching the betatron functions in the 12.5-m long straight section. Figure 1 shows the betatron and dispersion functions for an octant of the ring. We have used SAD[2] code for the lattice calculation.

Table 1: Fundamental parameters of the storage ring

Energy	E [GeV]	2.0
Lattice Type		DBA
Superperiod	Ns	4
Circumference	C [m]	388.45
Semi-Long Straight Section		7.0m x 12
Long Straight Section		12.5m x 4
Natural Emittance	ε_{x0} [nm·rad]	4.87
Energy Spread	σ_E/E	6.66 x 10^{-4}
Momentum Compaction	α	6.87 x 10^{-4}
Tune	ν_x	18.41
	ν_y	9.78
Natural Chromaticity	ξ_x	-46.73
	ξ_y	-30.0
Damping Time	τ_x [msec]	24.17
	τ_y [msec]	24.25
	τ_s [msec]	12.14
Revolution Frequency	f_{rev} [MHz]	0.771
RF Voltage	V_{rf} [MV]	1.4
RF Frequency	f_{rf} [MHz]	500.1
Harmonic Number	h	648
Synchrotron Tune	ν_s	0.0070
Bunch Length	σ_z [mm]	4.042
RF Bucket Height	$(dp/p)_{rf}$	0.0278

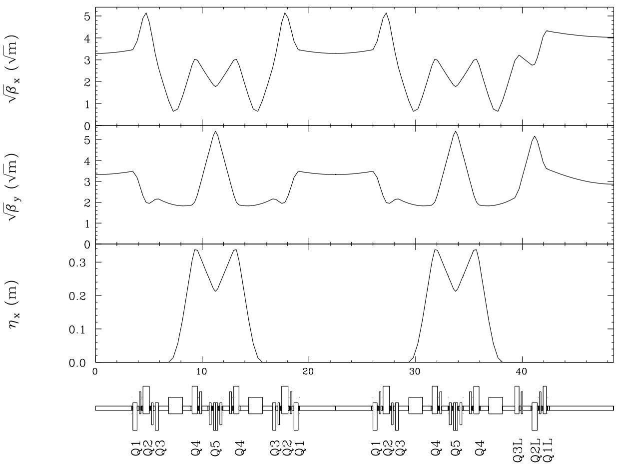

Fig 1: Optics for an octant of the ring

Table 2: The lattice of the Normal Cell and Long Cell.

*1 is the symmetric point of 7-m insertion section, *2 the mirror symmetric point of Normal Cell, *3 the symmetric point of 12.5-m insertion section. *4 the point where Long Cell is connected to the mirror symmetric point of Normal Cell.

Normal Cell		Long Cell	
Element	L [m]	Element	L [m]
*1	-	*3	-
	3.5		6.30
Q1	0.4	Q1L	0.3
	0.2		0.2
SF1	0.15	SF1L	0.15
	0.2		0.2
Q2	0.6	Q2L	0.5
	0.2		0.86
SD1	0.15	SD1L	0.15
	0.2		0.2
Q3	0.3	Q3L	0.4
	0.95		1.15
B	1.3	B	1.3
	0.9		0.9
Q4	0.5	Q4	0.5
	0.2		0.2
SF0	0.2	SF0	0.2
	0.7		0.7
SD0	0.2	SD0	0.2
	0.2		0.2
Q5 (half)	0.2	Q5 (half)	0.2
*2	-	*4	-

3. Chromaticity Correction and Dynamic Aperture

The horizontal chromaticity of the ring is -46.73 and the vertical one is -30.00. The chromaticities have been corrected by using chromatic sextupoles (SF0, SD0) located in the dispersive region of the cell (2 families correction). The strengths of these sextupoles are B´´ = 376 [T/m^2] for SF0 and B´´ = -268 [T/m^2] for SD0.

These sextupoles, however, introduce nonlinear effects which limit the dynamic aperture. In order to obtain a dynamic aperture as large as possible, the additional harmonic sextupoles (SF1, SD1, SF1L, SD1L) have been incorporated in the dispersionless region of the lattice (6 families correction). The design goal is, the horizontal dynamic aperture must be lager than half width of the vacuum chamber (40 mm) at the position where the horizontal betatron function is maximum, while the vertical dynamic aperture must be lager than half height of the vacuum chamber (8 mm) for an insertion device, and a wide momentum aperture (~ ±3%) is also required to obtain a long Touschek lifetime. By optimizing the harmonic sextuples, we have obtained a sufficiently large dynamic aperture as shown in Fig. 2. Here the dynamic aperture is defined as the stable region in which a particle can circulate the ring over 1000 turns. The momentum-dependent tune shift is shown in Fig. 3. Horizontal and Vertical amplitude-dependent tune shifts are also shown in Figs. 5 and 6.

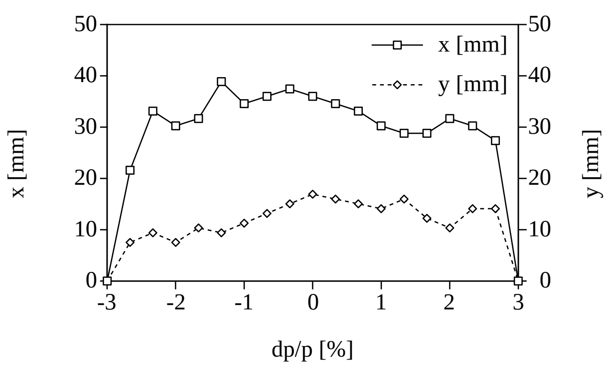

Fig 2: Dynamic aperture versus momentum deviation

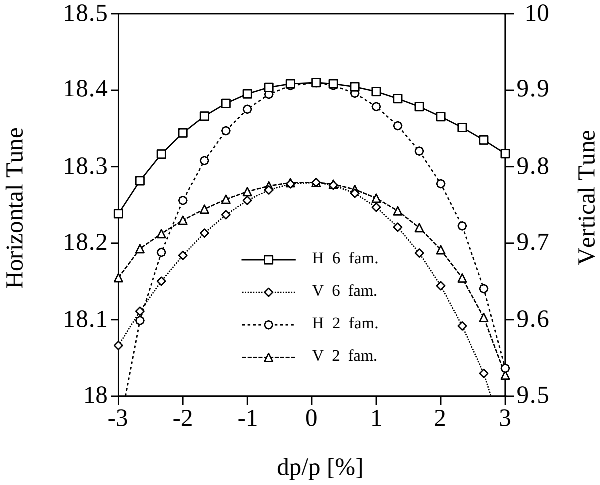

Fig. 3: Momentum-dependent tune shift

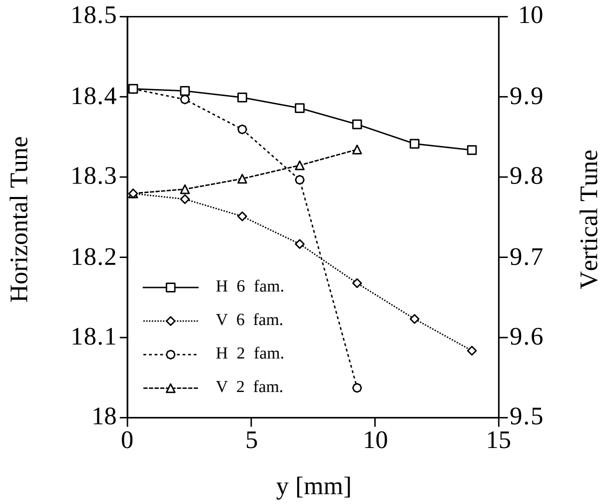

Fig. 5: Vertical amplitude-dependent tune shift

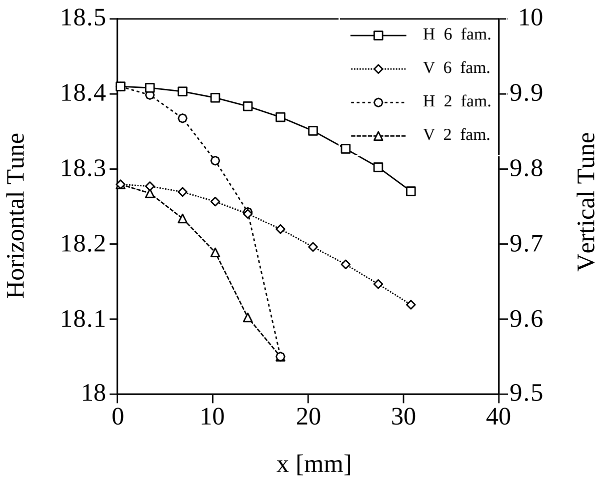

Fig. 4: Horizontal amplitude-dependent tune shift

REFERENCES

[1] Y. Kamiya et al., "A Future Project of VUV and Soft X-ray High-Brilliant Light Source in Japan", Proceedings of European Particle Accelerator Conference (London) 1994, p639.

[2] SAD is developed by KEK accelerator group.