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

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I. Introduction

Presented in this paper is a lattice for a third-generation VUV and soft X-ray light source[1], which is a future project of the Institute for Solid State Physics (ISSP) of the University of Tokyo and is being designed in close collaboration with the Photon Factory of KEK. The storage ring has an energy of 2 GeV, a circumference of about 400 m, an emittance of less than 5 nm rad, four 13 m long straight sections and twelve 7 m semi-long straight sections. We first present the lattice design of the ring, the chromaticity correction and the dynamic aperture, and next present a new lattice which is now under study to improve the performance.

II. Lattice Design

Table 1 shows the fundamental parameters of the ring, which has a circumference of 374.14 m and an emittance of 4.88 nm. The ring consists of 16 DBA cells. Each cell has two straight half-sections for insertion devices at both ends. The number of the straight sections are 16. Four of them are 13 m long and twelve of them are 7 m long. The 13 m long straight sections are arranged with a four-fold symmetry. A cell with 7 m semi-long straight half-section is called *Normal Cell* and a cell with 13 m long straight half-section at one end is called *Long Cell* (see Table 2). The lattice configuration of a Long Cell is the same as that of a Normal Cell except for three quadrupole magnets (Q1L, Q2L, Q3L), which is used for matching of the betatron functions in the 13 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	N_S	4
Circumference	C [m]	374.14
semi-long straight section		7m x 12
long straight section		13m x 4
Natural emittance	ε_{x0} [nm rad]	4.878
Energy spread	σ_ε/E	6.66×10^{-4}
Momentum compaction	α	7.13×10^{-4}
Horizontal tune	ν_x	18.410
Vertical tune	ν_y	9.800
Horizontal natural chromaticity	ξ_x	-49.98
Vertical natural chromaticity	ξ_y	-17.75
Horizontal damping time	τ_x [msec]	23.26
Vertical damping time	τ_y [msec]	23.35
Longitudinal damping time	τ_ε [msec]	11.69
Revolution frequency	f_{rev}[MHz]	0.80128
RF voltage	V_{RF} [MV]	1.4
RF frequency	f_{RF} [MHz]	500.0
Harmonic number	h	624
Synchrotron tune	ν_s	0.007
Bunch length	σ_z [mm]	4.04
RF-bucket height	(ΔE/E)	0.028

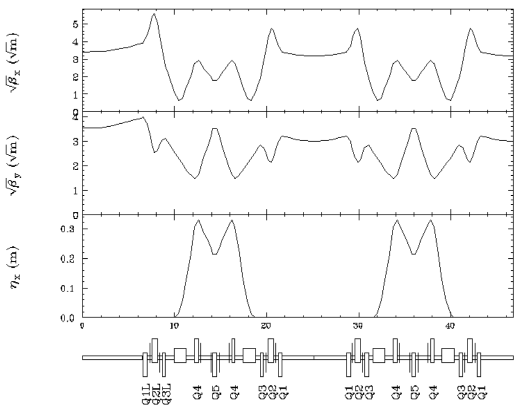

Fig 1: Optics for an octant of the ring.

IV. Chromaticity Correction and Dynamic Aperture

The horizontal chromaticity of the ring is -49.98 and the vertical one is -17.75. The chromaticities have been corrected by using chromatic sextupoles (SF0, SD0) located in the dispersive region of the cell. The strengths of these sextupoles are B''=498 [T/m^2] for SF0 and B''=-392 [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 harmonic sextupoles (SF1, SD1, SF1L, SD1L) have been incorporated in the dispersionless region of the lattice. The horizontal dynamic aperture must be larger than the 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 the half height of the vacuum chamber (10 mm) for an insertion device. A wide momentum aperture (≈±3%) is

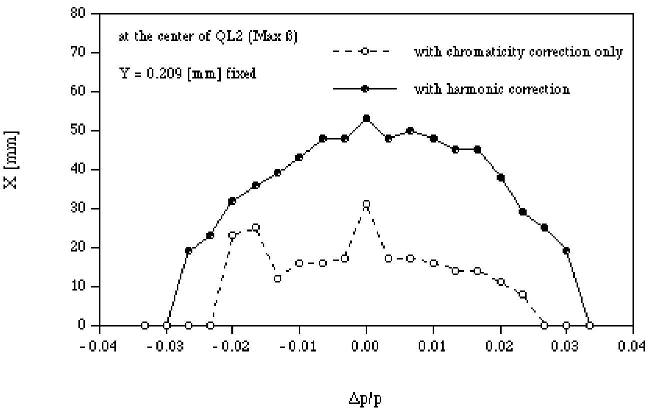

Fig. 2-a: Horizontal dynamic aperture versus momentum deviation

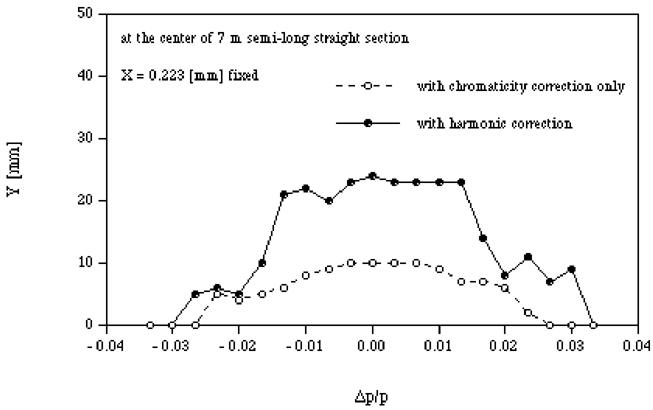

Fig. 2-b: Vertical dynamic aperture versus momentum deviation

Table 2: The lattice of the Normal Cell and Long Cell. The element lengths of the new lattice different from those of the old one are listed in the table. *1 is the symmetric point of 7 m insertion section, *2 the mirror symmetric point of the normal cell, *3 the symmetric point of 12.5 m insertion section. *4 the point where the long cell is connected to the mirror symmetric point of the normal cell.

Normal Cell			Long Cell		
Element	L [m]		Element	L [m]	
	old	new		old	new
*1	-	-	*3	-	-
	3.5	3.3		6.62	6.26
Q1	0.4		Q1L	0.4	
	0.15	0.2		0.15	0.2
SF1	0.15		SF1L	0.15	
	0.15	0.2		0.15	0.2
Q2	0.6		Q2L	0.6	
	0.15	0.2		0.15	0.2
SD1	0.15		SD1L	0.15	
	0.15	0.2		0.2	0.2
Q3	0.4	0.6	Q3L	0.4	
	0.5	0.95		0.95	0.95
B	1.3		B	1.3	
	0.9			0.9	
Q4	0.4	0.6	Q4	0.4	0.6
	0.15	0.2		0.15	0.2
SF0	0.2		SF0	0.2	
	0.9	0.7		0.9	0.7
SD0	0.2		SD0	0.2	
	0.15	0.2		0.15	0.2
Q5 (half)	0.2		Q5 (half)	0.2	
*2	-	-	*4	-	-

also required to obtain a long Touschek lifetime. By optimizing the harmonic sextupoles, 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 revolve the ring over 1000 turns.

V. New Lattice

We are making some modification to the lattice described above to improve the following points;

(1) quadruple magnets should not be C-type,

(2) the access to the BPM should be easier.

For (1), Q3 and Q3L have been shifted away from bending magnets not to touch the beamlines for the synchrotron radiation (see Table 2). For (2), every drift space between a quadrupole magnet and a sextupole magnet has been lengthened from 0.15 m to 0.2 m.

In order to keep of the betatron functions of 7 m semi-long straight sections to almost the same values as in the old lattice and to obtain a flexibility of optics for long straight sections, the polarities of the quadrupole magnets (Q1, Q2, Q3) have been changed. Since this change causes the magnetic field of Q3 to be saturated, the lengths of Q3 is increased from 0.4 m to 0.6 m.

With these modifications, the circumference of the ring has become from 374.14 m to 388.45 m, the harmonic number from 624 to 648. However long straight sections have become a little bit shorter; from 13 m to 12.5 m for long straight sections and from 7 m to 6.6 m for semi-long straight sections. The new parameters of the ring are listed in Table 3. The betatron and dispersion functions for an octant of the new ring are shown in Fig. 3.

The dynamic aperture for this lattice is now under study. So far, the horizontal dynamic aperture is 30 mm at the maximum position of horizontal betatron function, while the vertical dynamic aperture is 13 mm at the center of the insertion device. It is expected that the dynamic aperture is further improved.

VI. 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.

Table 3: New 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		6.6m x 12
long straight section		12.5m x 4
Natural emittance	ε_{x0} [nm rad]	4.582
Energy spread	σ_ε/E	6.66×10^{-4}
Momentum compaction	α	6.87×10^{-4}
Horizontal tune	ν_x	19.410
Vertical tune	ν_y	11.200
Horizontal natural chromaticity	ξ_x	-44.1
Vertical natural chromaticity	ξ_y	-42.9
Horizontal damping time	τ_x [msec]	24.17
Vertical damping time	τ_y [msec]	24.25
Longitudinal damping time	τ_ε [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	(ΔE/E)	0.028

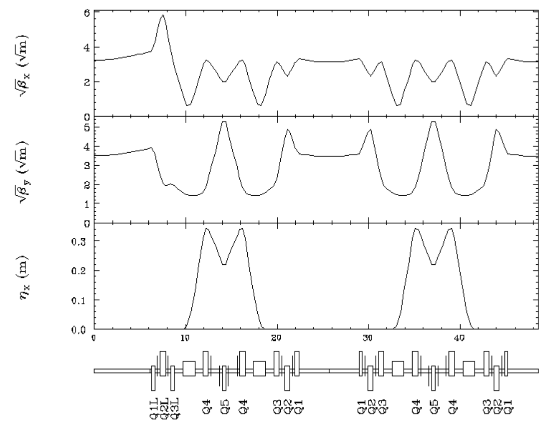

Fig. 3: New optics for an octant of the ring