A LATTICE FOR THE FUTURE PROJECT OF VUV AND SOFT X-RAY HIGH-BRILLIANT LIGHT SOURCE

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Abstract

Presented in this paper is a lattice for a third-generation VUV and soft X-ray light source, which is a future project 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 about 5 nm•rad, four 14.3 m *"long"* straight sections and twelve 7.0 m "*semi-long"* straight sections for insertion devices. Three different optics were studied in the same lattice configuration. It was proved that this lattice configuration has large flexibility and the basic optics has a sufficiently large dynamic aperture.

1 INTRODUCTION

The University of Tokyo has a future project to construct a third-generation VUV and soft X-ray light source in Kashiwa[1]. The "third-generation" light source is characterized by the low emittance and the long straight sections for insertion devices. To realize these characteristics, a Double Bend Achromat (DBA) lattice was adopted for our storage ring.

Since it is preferable to have small beam size divergence for undulators, the basic optics has high betatron functions at the long straight sections ("high-beta mode").

Two optional optics were also designed in the same lattice configuration. One is "hybrid mode" where the betatron functions are less than 2 m ("low-beta") at the RF-cavity in order to increase the threshold current of the coupled-bunch instabilities. This mode also enables to place wigglers instead of undulators, because the RF-cavity occupies only one of four "low-beta" long straight sections and it is important to have small beam size for wigglers. Another one is "very low emittance mode" which dose not hold the achromatic condition of DBA.

In following sections, we report the lattice configuration and these optics.

Table 1: The element lengths of the *Normal Cell* and the *Long Cell*.

*1: the center of the 7 m "*semi-long*" straight section.
*2: the center of the 14.3 m "*long*" straight section.

Normal Cell		Long Cell	
Element	L [m]	Element	L [m]
*1	–	*2	–
	3.50		7.156667
Q1	0.40	Q1L	0.40
	0.20		0.20
SF1	0.15	SF1L	0.15
	0.20		0.20
Q2	0.60	Q2L	0.60
	0.20		0.20
SD1	0.15	SD1L	0.15
	0.20		0.20
Q3	0.40	Q3L	0.40
	0.50		1.00
B	1.30	B	1.30
	0.90		0.90
Q4	0.60	Q4	0.60
	0.20		0.20
SF0	0.20	SF0	0.20
	0.80		0.80
SD0	0.20	SD0	0.20
	0.20		0.20
Q5	0.40	Q5	0.40
	0.20		0.20
SD0	0.20	SD0	0.20
	0.80		0.80
SF0	0.20	SF0	0.20
	0.20		0.20
Q4	0.60	Q4	0.60
	0.90		0.90
B	1.30	B	1.30
	0.50		0.50
Q3	0.40	Q3	0.40
	0.20		0.20
SD1	0.15	SD1	0.15
	0.20		0.20
Q2	0.60	Q2	0.60
	0.20		0.20
SF1	0.15	SF1	0.15
	0.20		0.20
Q1	0.40	Q1	0.40
	3.50		3.50
*1	–	*1	–

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2 LATTICE CONFIGURATION

The storage ring consists of 16 DBA cells with a circumference of 388.45 m. Each cell has two long straight sections for insertion devices at both ends. The number of these long straight sections are 16. Four of them are 14.3 m long and twelve of them are 7 m long. The 14.3 m "*long*" straight sections are arranged to be four-fold symmetry. A cell with 7 m "*semi-long*" straight sections at both ends is called *Normal Cell* and a cell with the "*long*" straight section at one end is called *Long Cell* (see Table 1). The lattice configuration of the *Long Cell* is the same as that of the *Normal Cell* except for the three quadrupole magnets (Q1L, Q2L, Q3L), two sextupole magnets(SF1L SD1L) and the drift space between B and Q3L.

3 HIGH-BETA MODE

The basic optics is a "high-beta mode", where horizontal and vertical betatron functions are around 10 m at the long straight sections. The betatron and dispersion functions in a quadrant of the storage ring is shown in Fig. 1. In this figure, both ends represent the center of the "*long*" straight sections. The fundamental parameters

Table 2: Fundamental parameters of the storage ring in the "high-beta mode"

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		14.3m x 4
Natural emittance	ε_{x0} [nm•rad]	5.10
Energy spread	σ_E /E	6.66x10^{-4}
Momentum compaction	α	6.87x10^{-4}
Horizontal tune	ν_x	18.84
Vertical tune	ν_y	9.55
Horizontal natural chromaticity	ξ_x	-47.78
Vertical natural chromaticity	ξ_y	-18.45
Horizontal damping time	τ_x [msec]	24.17
Vertical damping time	τ_y [msec]	24.25
Longitudinal damping time	τ_z [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	$(\Delta E/E)_{RF}$	0.028

Table 3: The condition of random errors (r.m.s.)

Quadrupole alignment error	0.1 mm
Sextupole alignment error	0.1 mm
Dipole tilt error	5 x 10^{-4} rad
Quadrupole tilt error	5 x 10^{-4} rad
Sextupole tilt error	5 x 10^{-4} rad
Dipole filed error	5 x 10^{-4}
Quadrupole filed error	5 x 10^{-4}
Sextupole filed error	5 x 10^{-4}

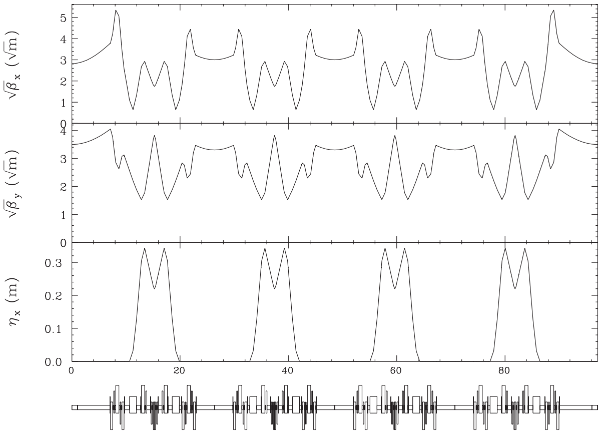

Fig. 1: The "high-beta mode" optics in the quadrant of the storage ring.

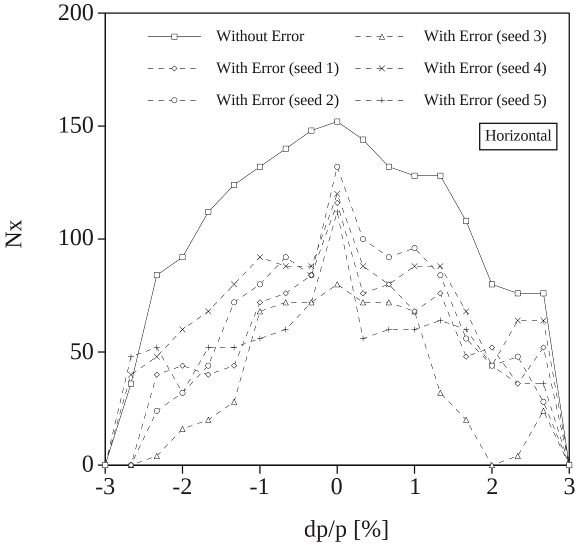

Fig. 2-a: The horizontal dynamic aperture versus momentum deviation in the "high-beta mode".

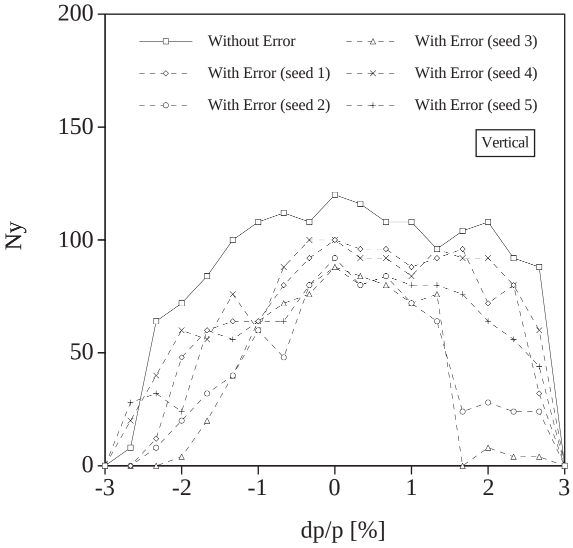

Fig. 2-b: The vertical dynamic aperture versus momentum deviation in the "high-beta mode".

of the storage ring are shown in Table 2. The natural emittance is 5.10 nm•rad. We have used SAD[2] code for the calculation.

The horizontal chromaticity of the ring is -47.78 and the vertical one is -18.45. The chromaticity is corrected by using chromatic sextupoles (SF0, SD0) located in the dispersive region of the cell. The strengths of these sextupoles are 498 [T/m^2] for SF0 and –392 [T/m^2] for SD0, while the design limit of the sextupole strength is 600 [T/m^2]. These chromatic sextupoles may reduce the dynamic aperture. In order to obtain a dynamic aperture as large as possible, the harmonic sextupoles (SF1, SD1, SF1L, SD1L) has been incorporated in the dispersionless region of the lattice. The dynamic aperture should be larger than the half width of the vacuum chamber (40 mm) horizontally and lager than the half height of the vacuum chamber (8 mm) vertically. A wide momentum aperture is also required to obtain a long Touschek lifetime.

By optimizing the harmonic sextupoles, we obtained Nx ≈ 150 and Ny ≈ 130 for the dp/p (momentum deviation) = 0 as shown in Fig. 2 (solid line), where Nx and Ny are the amplitude normalized by $\sqrt{\beta_x\ \varepsilon_{x0}}$ and $\sqrt{\beta_y\ \varepsilon_{x0}}$ respectively. The horizontal dynamic aperture is 68 mm and the vertical dynamic aperture is 28 mm at the center of the "*semi-long*" straight section. Here, the dynamic aperture is defined as the stable region in which a particle can revolve the ring over 1000 turns.

The effect of the field and alignment error of magnets were also studied. The condition of random errors (r.m.s.) are listed in Table 3. After C.O.D. correction using 128 BPM and 256 steering magnets (128 for horizontal and 128 for vertical), the dynamic apertures were calculated for five different cases in Fig. 2 (dashed line). On average, we obtained Nx ≈ 100 and Ny ≈ 90 for dp/p = 0. In the large dp/p region, some cases have rather small dynamic apertures. It is caused by the large relative displacements (five or six times the standard deviation) of the neighboring magnets. We expect to reduce a such displacement by using a scheme of the grouping alignment of magnets.

4 HYBRID MODE

In order to increase the threshold current of the coupled-bunch instabilities caused by the RF-cavity, some modifications for the betatron functions was made. In this optics, both horizontal and vertical betatron functions are less than 2 m at one of "*semi-long*" straight sections in the quadrant of the ring (see Fig. 3), where the RF-cavity is placed.

The dynamic aperture for this mode is rather small in comparison with the "high-beta mode" and sensitive to the magnet alignment error. To obtain the same performance as "high-beta mode", the quadrupole and sextupole alignment errors should be kept down to 0.05 [mm]. For this mode, we need the further study.

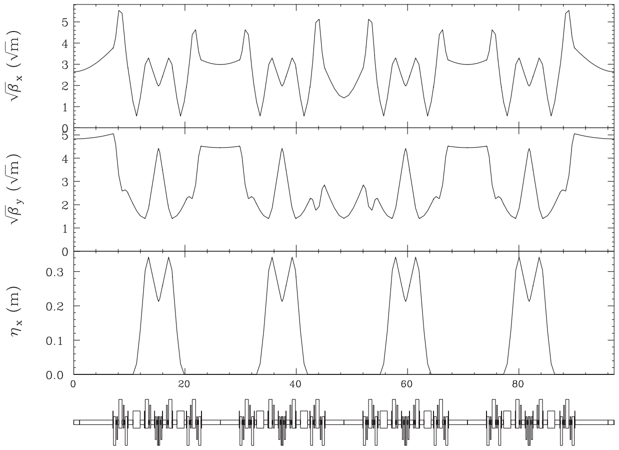

Fig. 3: The "hybrid mode" optics in the quadrant of the storage ring.

Table 4: Fundamental parameters of the storage ring in the "hybrid mode"

Natural emittance	ε_{x0} [nm•rad]	4.46
Horizontal tune	ν_x	18.84
Vertical tune	ν_y	11.55
Horizontal natural chromaticity	ξ_x	-61.43
Vertical natural chromaticity	ξ_y	-27.61

Other parameters are as same as those listed inTable 3.

5 VERY LOW EMITTANCE MODE

In this optics, the lattice configuration (shown in Table 1) is also not changed. The emittance reduction is made by breaking the achromatic condition of the DBA. The minimum achievable natural emittance is 1.0 nm•rad for our lattice configuration theoretically. This "very low emittance mode" is now under study. So far, the natural emittance is obtained around 2.5 nm•rad.

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.