THE LATTICE DESIGN OF THE SUPER SOR LIGHT SOURCE

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Abstract

The Super SOR light source is 1.8 GeV electron storage ring proposed for the third generation vacuum ultra violet (VUV) and soft X-ray light source, where is going to be constructed at Kashiwa campus of the University of Tokyo. The lattice design of the ring is going to be fixed due to the results of the particle tracking simulation for the chromaticity correction and the evaluations for the strength and the alignment error of the magnets.

INTRODUCTION

The Super SOR light source [1] is 1.8 GeV electron storage ring to be constructed at Kashiwa campus of the University of Tokyo. The main parameters of the ring are shown in Table 1, and the plan view in Figure 1. The circumference of the ring is about 280 m. The nominal emittance is 7.26 nm·rad at an energy of 1.8 GeV. The brilliances of the photons are over 10^{19} photons/sec/mm^2/mrad^2/0.1%b.w., as shown in Figure 2. The flux are over 10^{16} photons/sec/0.1%b.w..

In this paper, we present the lattice design of the Super SOR light source and the simulation results of the particle tracking for the chromaticity correction and the error correction.

Table 1: Parameters of the ring

		normal	hybrid
Energy	GeV	1.8	
Circumference	m	280.55	
Emittance	nm rad	7.26	6.7
Energy Spread		6.68E-04	6.68E-04
Momentum Compaction		1.00E-03	1.00E-03
Betatron Tune			
horizontal		14.12	15.85
vertical		5.18	5.7
Chromaticity			
Horizontal		-43.277	-55.139
vertical		-19.442	-31.525
Magnetic Field of Bend.	T	1.12	
Critical Photon Energy	keV	2.42	
Energy Loss / turn	keV/rev	173.7	
Radiation Damping Time			
horizontal	msec	19.319	19.319
vertical	msec	19.4	19.4
longitudinal	msec	9.721	9.721
Revolution Frequency	MHz	1.0686	
RF Frequency	MHz	500.1	
Harmonic Number		468	
RF Voltage	MV	1.4	
Synchrotron Tune		0.00759	0.00759
Bunch Length	mm	3.935	3.935
RF Bucker Hight		0.0293	0.0293

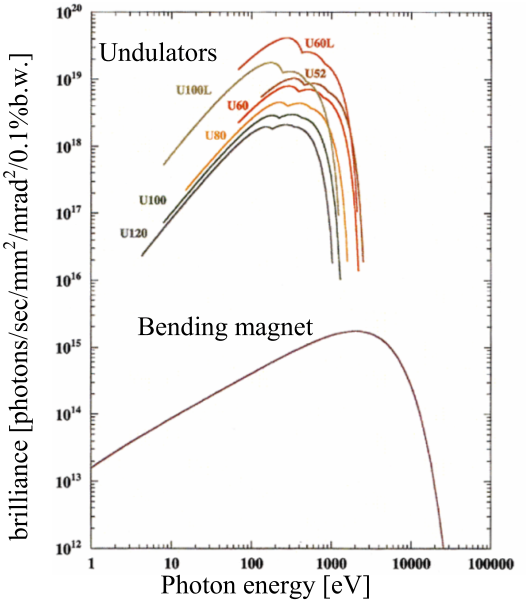


Figure 2: The brilliances of the photons

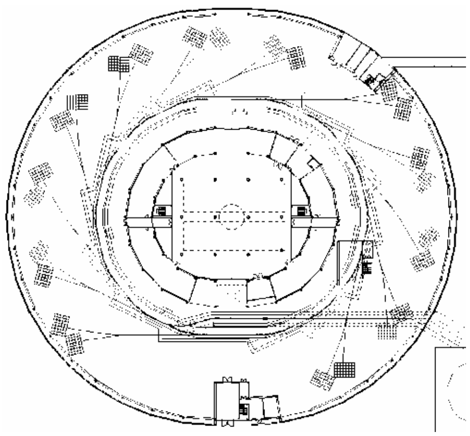
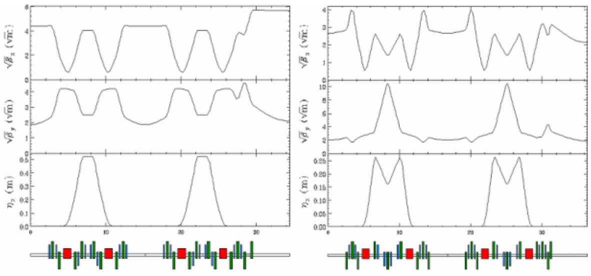


Figure 1: Plan view of the main ring

DESIGN STRATEGY OF LATTICE

We have several conditions to design the lattice of main ring storage ring; the length of straight sections is over 6 m for the normal insertion device of 5 m and over 17 m for the longer one of 15 m, and number of the devices is over 10, and so on. Under the conditions, we designed so that the lattice of the ring has two long and twelve normal straight sections considering with the sections for the RF cavities and injection components. In addition, we have to consider the circumference of the ring because the area of the campus and the budget of the construction are limited. We adopted, therefore, the structure of 14 double bend achromat (DBA) cells in the lattice configuration.

In the strategy of the normal cell, we compared the structure of two types; Type I is composed of B-QD-QF-QF-QD-B, and Type II of B-QF-QD-QF-B in the configuration of magnets of the cell. The large difference of two types appears in the shape of dispersion functions, as shown in Figs. 3. The function of Type I has the shape of Λ type and the flat region near the centre of cell. On the other hand, the shape of V type is formed in the function of Type II. The advantage of Type II is that small emittance is realized by the shorter length of cell. By adopting this Type, we can achieve the theoretical minimum emittance of DBA structure. However, it is hard to correct the chromaticity in this type because the dispersion function at sextupole magnets is quite small in spite of larger chromaticity. Thus, the dynamic aperture tends to narrow. Actually, it was very severe to ensure enough dynamic apertures in our simulations. In the case of Type I, though the length of cell tends to become longer, the chromaticity correction was easier than that in the case of Type II. We adopted, consequently, the structure of Type I. Including various boundary conditions for the ring components and the required conditions, we designed the lattice of the ring. The length of normal cell is about 18 m, and the circumference of the ring is about 280m. The nominal emittance at beam energy of 1.8 Gem is 7.26 nm·rad. Though the theoretical minimum emittance is 3.5 nm·rad, practical minimum emittance of the ring may be about 5 nm·rad. The betatron tunes of one cell are (ν_{nx}, ν_{ny})=(0.9743, 0.3653). To reduce the emittance, the horizontal tune ν_{nx} becomes close 1.0. The tunes of cell in the matching section for 17 m long straight section are (ν_{lx}, ν_{ly})=(1.214, 0.3984), and finally tunes of the ring are (ν_x, ν_y)=(14.12, 5.18).


(a) Type I

(b) Type II

Figures 3: Two types of DBA cell

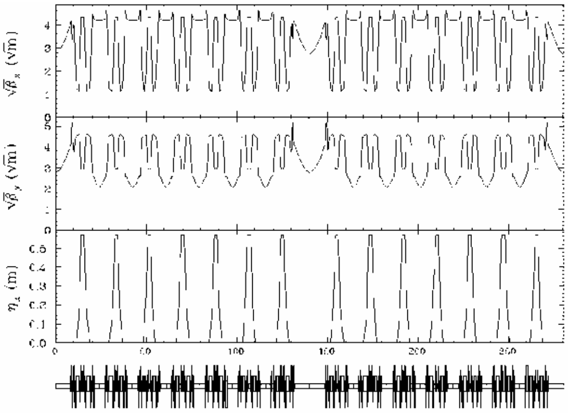


Figure 4: The optics of the normal mode

The present optics of the ring is shown in Fig. 4. Because of two long straight sections, the optics has 2-fold symmetry.

NONLINEAR EFFECTS AND DYNAMIC APRTURES

We use four families of the sextupole magnets; two of them are for the chromaticity correction, and the others for the harmonic correction of avoidable nonlinearities produced by the chromaticity correctors. The latter magnets called harmonic sextupoles. The effects of them on the momentum dependent tune shift are shown in Figure 5. It is clear that the dynamic aperture may be limited by the resonance lines ν_x=14 and ν_y=5 without them. Using the harmonic sextupoles, however, the momentum dependent tune shift is drastically improved. The tunes of particles with large momentum deviation takes away from these resonance lines, As a result, the dynamic apertures is much expanded as shown in Figures 6.

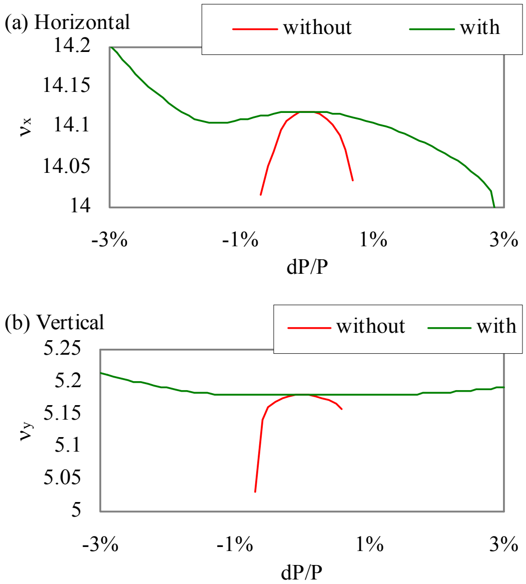
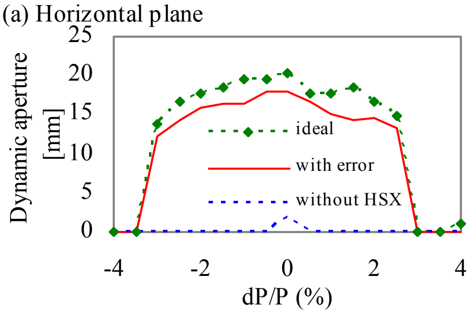


Figure 5: The effect of the harmonic sextupoles

HYBRID OPTICS

In order to suppress the effect of the higher order mode produced by the RF cavities and avoid various coupled bunch instabilities, we hope that the beta functions at a place of RF cavities are small as possible while the horizontal beat function at a place of injection section is large. Thus we prepared the hybrid optics where the

(a) Horizontal plane



(b) Vertical plane

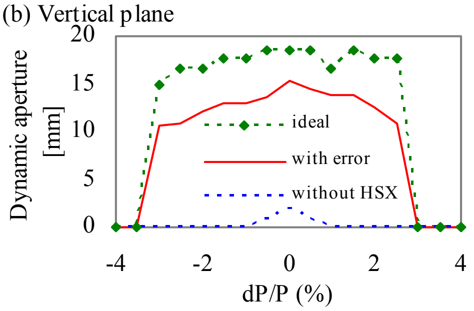


Figure 6: The dynamic apertures of the normal mode.

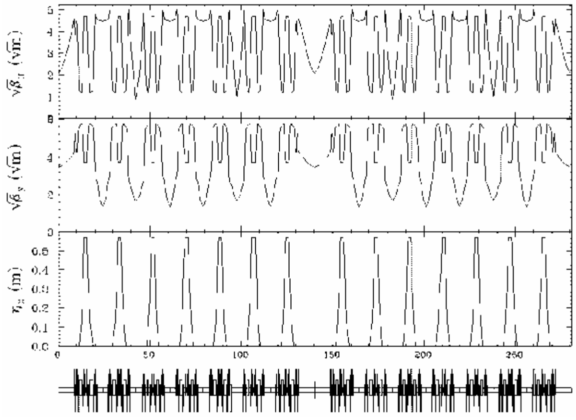


Figure 7: The optics of the hybrid mode.

normal cells with very small beta functions (low beta cells) are symmetrically arranged in the ring. The configuration of the low beta cell in the half part of the ring is the following,

(17m) – H – L – H – H – L – H –,

where H indicates the ordinary (high beta) normal cell and L the low beta cell, as shown in Fig. 7. For the low beta cell, the beta function at the centre of 6.2 m long straight section is about 1 m for both horizontal and vertical planes. Since we plan that the strength of all the quadrupoles and sextupoles can be independently changed, we have great flexibility in the adjustment of the optics and the chromaticity correction. However, the dynamic aperture of the hybrid mode has large asymmetry in the horizontal plane and especially small for the negative amplitude. In the next step, we are going to simulate the hybrid-optics increasing a number of families in the harmonic sextupoles to improve the dynamic aperture.

EFFECTS OF MAGNETIC ERRORS

We simulate the effect of the magnetic errors and the COD correction for the normal mode. The assumed magnetic errors are the alignment errors of 100μm, the field error of 0.1% and the rotation error of 400μrad for the bending, quadrupole and sextupole magnets. The number of the beam position monitors is 140 and that of the steering magnets 112. We adopt the eigenvalue method for the COD correction and the number of the used eigenvalues is 50. We calculate ten random error seeds and take the average. The RMS and maximum values of the COD and dispersion function distortion (Δη) are shown in Table 2. The dynamic aperture after the COD correction is shown in Figure 6.

When the beam current is 400mA, the XY coupling 1%, the physical half aperture 25mm, and the vacuum pressure 1 nTorr, the estimated beam lifetime results in about 8 hours.

Table 2: The magnetic errors

		COD X max (mm)	$\Delta\eta_x$ max (mm)	COD X rms (mm)	$\Delta\eta_x$ rms (mm)
horizontal	before	11.282	301.22	5.509	129.78
	after	0.189	64.33	0.072	34.63
vertical	before	15.012	348.4	8.010	135.5
	after	0.252	160.2	0.083	71.3

SUMMARY

The lattice design of the Super SOR light source is presented. Because of the two 17 m long straight section, the optics has 2-fold symmetry. The effective use of the harmonic sextupoles, however, enables us to keep the large dynamic aperture and we achieve the beam lifetime of 8 hours with the beam current 400mA and the coupling 1%.

Besides the normal optics, we prepare the hybrid optics. The beta functions are about 1 m in the low beta cells and eight low beta cells are configured symmetrically in the ring. The further optimization of the harmonic sextupoles is needed to get the large dynamic aperture of the hybrid optics and this is the next step.

REFERENCES

[1] Design Report, Sep. 2002