LATTICE DESIGN OF SAGA SYNCHROTRON LIGHT SOURCE

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Abstract

The SAGA Synchrotron Light Source is a compact third generation synchrotron light source with a 1.4GeV electron storage ring, and being constructed in Tosu City, Saga prefecture Japan. A distributed dispersion system, the dispersion function is non-zero in long straight section, is adopted for the lattice design to make the ring to be compact. At the typical working point (5.796, 1.825) the emittance without insertions is 25nm-rad and the beam size at the middle of the long straight section is about 0.58 mm in horizontal and 0.13mm in vertical (10% coupling is assumed). One of merits of distributed dispersion system is reduction of sextupole strength required for chromaticity correction. Consequently, a large dynamic aperture can be obtained. We have performed beam dynamics studies by using TRACY2 to estimate tolerable magnetic errors and magnetic misalignments and found that the designed lattice has an enough dynamical aperture to operate the ring.

INTRODUCTION

SAGA Synchrotron Light Source is the middle-scale light source with 262MeV linac and 1.4GeV storage ring [1]. The construction started from the fall of 2001. We will start the commissioning in October 2004. Active X CA based control system will be applied from the commissioning phase [2]. The light source will be opened March 2005. Since the budget and space is tightly restricted, it is reasonable to design the ring with existing accelerator technologies.

The lattice was designed to satisfy the maximum number of user requirements. The number of beamline is more than twenty. A high brightness and wide range of wavelength (from infrared [3] to hard X-ray [4]) of the synchrotron light is required. So, the energy of the stored electron beam and circumstance of the electron storage ring was chosen as 1.4GeV and 75m respectively. We adopted eight symmetries to the electron storage ring to install more than twenty beamlines. Each cell has two bending magnet (DB). Among eight long straight sections, two sections are used for the injection and RF cavity, and six sections are used for insertion devices. In order to make a high brightness synchrotron light, we first examined the Chasman-Green (DBA) type lattice. Optimizing the arrangement of the magnets and strengths of quadrupoles, we found a working point of which natural emittance was lower than 30nm-rad. However, we also found that the natural chromaticity was large and the small dispersion in the chromaticity correction section at that working point. Furthermore the interference with sextupole magnet and beamline was problem. Therefore, a distributed dispersion system, the dispersion function is non-zero in insertion device section, was examined, because several distributed dispersion type machines have been designed and operated with low chromaticities and low emittances [5].

In this paper, we will describe the design of the distributed dispersion lattice for SAGA-SL and the beam dynamics studies on it.

LATTICE DESIGN

The design of the distributed dispersion lattice has been done as following procedure: At first, we roughly defined the physical sizes of magnet (bending, quadrupole and sextupole). The number of magnet was determined to that two family quadrupole for the tune control and 1 family quadrupole for dispersion control just as Chasman-Green lattice. Two family sextupole were also employed for the chromaticity correction. The next step, we arranged them to keep the length of the long straight section as long as possible. Then, a linear optics calculation was performed to evaluate the machine function. To optimise the machine function, above procedure was iteratively repeated and we obtained acceptable arrangement. After that, the magnets were designed to generate an enough magnetic field with proper accuracies. Then, a fine tune of the magnet arrangement and the linear and non-linear calculations were performed. TRACY2 [6] was used for these calculations. Figure 1 shows the lattice structure of the half cell and the machine parameters at a typical working point are listed in Table 1. It is noted that the horizontal and the vertical beta functions of below 20 m are achieved. However, the dispersion function reaches to be 0.6 m at the long straight section. This will cause the emittance growth from the insertion devices. Preliminaly calculations show that the 7.5 T superconducting wiggler enlarge the emittance to 47nm-rad, which is still small enough for the SAGA users.

The dynamical aperture with the bare lattice is shown in Figure 2 and one can see that the dynamical aperture is quite large for the distributed dispersion lattice. It could be emphasized that the natural emittance is 25.1nm-rad

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Table 1: Machine parameters and magnets strengths
*10% coupling was assumed

Energy[GeV]	1.4
Circumference[m]	75.6
Superperiod	8
Bending Radius[m]	3.2
Betatron Tunes[ν_x,ν_y]	5.796, 1.825
Synchrotron Tune	0.0093
Momentum Compaction	0.0134
Energy Spread	6.7×10^{-4}
Longitudinal Damping Time[ms]	3.346
Horizontal Damping Time[ms]	6.563
Vertical Damping Time[ms]	6.649
Natural Chromatisity[ξ_x,ξ_y]	-6.54, -9.64
Natural Emittance[nm-rad]	25.1
Horizontal Beam size[mm]	0.58
Vertical Beam size[mm]*	0.13
QF[T/m]	25.1
QD[T/m]	-24.4
QFA[T/m]	18.4
SF[T/m^2]	80.5
SD[T/m^2]	-115

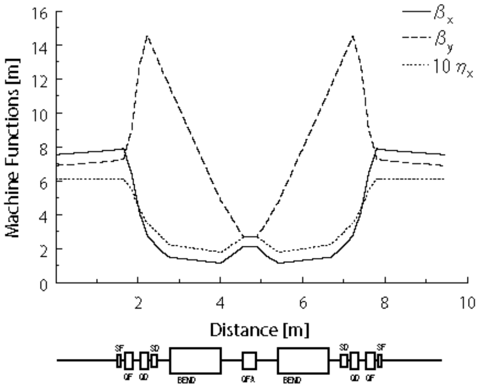

Figure 1: Machine functions and magnets arrangement.

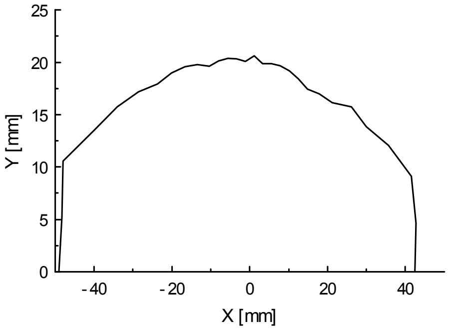

Figure 2: Dynamical aperture of the bare lattice.

We also calculated the beam lifetime using ZAP [7]. The required lifetime is 5 hours with 300mA stored current. The lifetime at the working point is dominated by Touschek half-life and 15hours lifetime was obtained at 500kV RF voltage.

MISALIGNMENT AND MULTIPOLES

The designed lattice satisfies several demands on the SAGA-LS. However, the effect of misalignment of the magnets should be evaluated, because we will use the usual alignment technique. The maximum transverse tilt of the bends of 0.2mrad and the maximum transverse shift of each quadrupoles of 0.2mm were achieved without special alignment technique. Moreover, magnetic field imperfection, dipole strength error of $2\text{x}10^{-4}$, quadrupole error of $1\text{x}10^{-3}$, and sextupole strength error of $3\text{x}10^{-3}$, should be taken into account for the COD evaluation. TRACY2 was used for the evaluation of the COD. The optimum steering position was also investigated for the COD correction at the same time. Figure 3 shows the COD distribution calculated by TRACY2. We can see the maximum 4 mm in horizontal and 10 mm in vertical CODs. Using the 40 steering magnets, 32 combined steerings in the sextupoles and 8 normal steerings, the COD can be suppressed less than 10µm both in horizontal and vertical. At the COD correction, maximum 1mm-rad

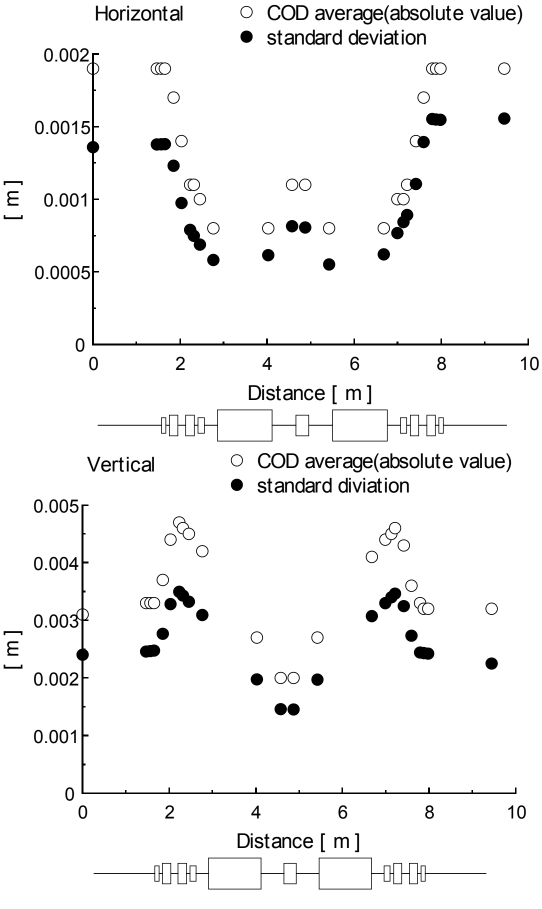

Figure 3: Horizontal and vertical COD distribution.

kick angle was assumed. Figure 4 shows the dynamical aperture after the COD correction. The dynamic aperture is clearly recovered with the COD correction.

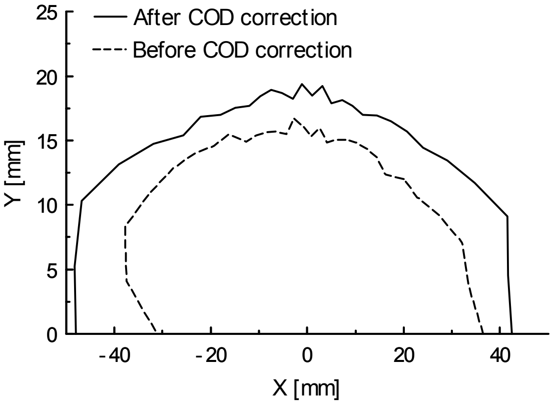

Figure 4:Dynamical aperture before COD correction and after COD corrections.

Under the realistic condition, the multipole effect will be shrink the dynamical aperture. We can define *n*-th multipole component β_n as the coefficient of Talyor expantion for the field on the mid-plane. The vertical components of the multipole field α_n can also be expressed in the cylindrical coordinate. The relation between them is express as $\beta_n = \alpha_n/r^n$, where *r* is the distance from the central orbit. By using cylindrical coordinate, the condition to the multipole can be expressed simply and convenient to compare to the experimental data. Table 4 illustrates the multipole conditions for α_n.

BEND	$\alpha_n/\alpha_0 < 2\times10^{-4}$
QUAD	$\alpha_n/\alpha_1 < 1\times10^{-3}$
SEXTU	$\alpha_n/\alpha_2 < 3\times10^{-3}$

Table 4:Multipole conditions expressed in the ratio to the main component.

We examined the multipole effect to the dynamic aperture by using TRACY2. Figure 5 shows the result of the calculation with the multipole conditions illustrated in the table 4. It is clear that the distortion of the dynamic aperture is appeared in the horizontal axis. However, the survived dynamical aperture it is still large enough for the ring operation. The required magnetic construction accuracy is achievable with a standard magnet manufacturing technique. Therefore, we can conclude that the designed lattice has an enough multipole tolerance for the operation.

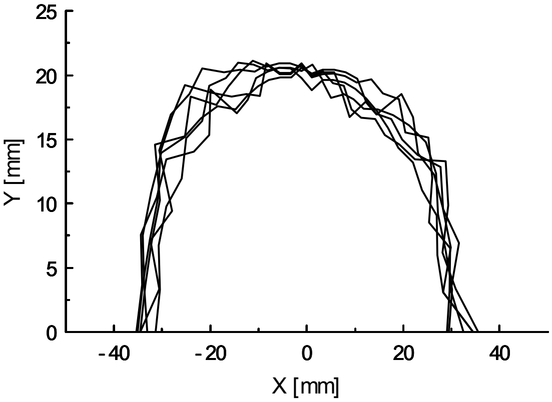

Figure5:Dynamical aperture including systematic multipoles

CONCLUSION

We have designed the lattice of SAGA Synchrotron Light Source electron storage ring. A distributed dispersion system is adopted to make the ring be compact. Optimising the magnet arrangement and searching working point, the natural emittance is obtained to be 25 nm-rad with a bare lattice. We found that the dynamic aperture is still large with achievable misalignments and multipole components.

Since a 7.5T superconducting wiggler will be installed in near future, preliminary calculations have been performed to evaluate the effect of the wiggler. The result shows the emittance grows up to 47nm-rad and it is small enough for user requirements in this facility. The dynamical aperture is also recovered by a tune correction which is executed by quadrupoles located both end of the wiggler.

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