FEASIBILITY STUDY ON INTRODUCING A SUPERCONDUCTING WIGGLER TO SAGA LIGHT SOURCE

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Abstract

Numerical studies on the effect of a superconducting wiggler (SCW), which was developed at National Institute of Radiological Sciences (NIRS), to Saga light source (SAGA-LS) have been performed. The three dimensional magnetic field of the SCW was calculated to evaluate the effect on beam optics.

It was found that the tune correction was needed to reduce a deformation of the vertical beta function. The dynamic aperture shrank to about 70 % on horizontal plane. However these effects are considered to be tolerable at the SAGA-LS.

INTRODUCTION

SAGA-LS is the first synchrotron radiation (SR) facility which is established and operated by a Japanese local government, Saga Prefecture. The purpose of the facility is to apply the SR to science and technology in Kyushu area. The facility consists of a 1.4 GeV storage ring and a 250 MeV injector linac [1].

The facility has a plan to install an SCW for responding to hard X-ray users. Instead of fabrication a new SCW, we are discussing a possibility of installation of the SCW, which has been developed as a test model for a medical project [2] at NIRS. The SCW is close to supposed SCW in SAGA-LS project.

As the first step we investigated the effect of the NIRS-SCW on the lattice of SAGA-LS. In the following section, we report (1) on the SCW specification, (2) on the magnetic field calculation, (3) on multipole expansion of the field and (4) on the effect of the field to the lattice.

SUPERCONDUCTING WIGGLER

The specification of the NIRS-SCW is shown in Table 1 [3]. The SCW consists of a main pole and two side poles. Each pole is composed of a racetrack-shaped coil and an iron core. The SCW has already been tested as a stand-alone system at NIRS. The magnetic field of the main pole was achieved about 7 T [3].

The SR spectrum with SCW whose main pole field is 7 T at SAGA-LS is shown in Figure 1. The critical energy is 4.5 times larger than that from the bending magnet.

MAGNETIC FIELD CALCULATION

We employed Radia [4] to calculate three dimensional magnetic filed of the SCW. The magnet model of the field calculation is shown in Figure 2.

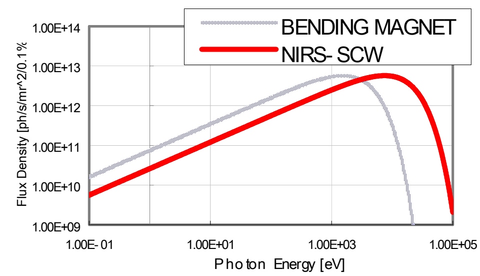

Figure 1: Spectra of the SCW and the bending magnet at SAGA-LS.

Table 1 NIRS SCW Specification

Dimension W×L×H	840mm×1184mm× 1150mm
Field of pole	
Main pole	7 T
Side poles	4 T
Materials of poles	
Main coil	Nb_3Sn
Sub coil	NbTi
Operating Current	208 A
Radiation Power	5.5 kW@SAGA-LS
Critical Energy	9 keV@SAGA-LS

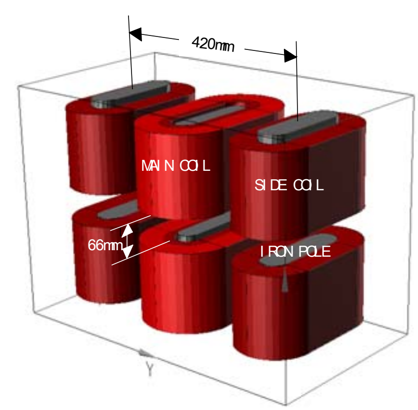

Figure 2: Field calculation model of the SCW.

The calculated and measured [3] distributions of the vertical magnetic field along the longitudinal axis of the SCW are shown in Figure 3. There is a good agreement

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between the calculation and the measurement within a range of 10^{-2}.

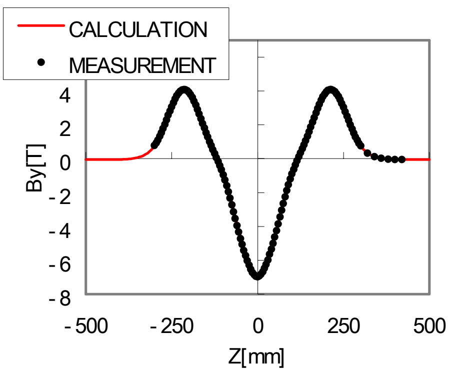

Figure 3: Calculation and measurement of the SCW vertical magnetic fields.

The beam orbit was calculated by solving numerically electron motion. The current correction of the subcoils was iterated until the ejection angle and transverse position of the beam at the exit of the SCW coincide with the design orbit of the storage ring. Obtained beam orbit is shown in Figure 4. Maximum displacement from the design orbit is about 17.1 mm. The path length becomes longer than that of the orbit without the SCW by 1.3mm.

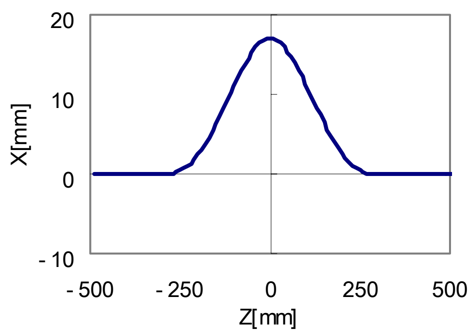

Figure 4: Beam orbit in the SCW section. Horizontal and vertical axis show the longitudinal and transverse direction on the design orbit, respectively.

MULTIPOLE EXPANSION

The SCW field is generally considered to have rather complex distribution. It is important to understand the each effect of multipole components, such as quadrupole and sextupole. We expanded the field to the multipole components in perpendicular to beam orbit. The schematic figure of the multipole expansion is shown in Figure 5. The distribution of the vertical field along w axis in Figure 5 was calculated by Radia, and the multipole components were obtained by polynomial fitting to the field distribution. The multipole field was expanded to 14 pole whose contribution was negligible.

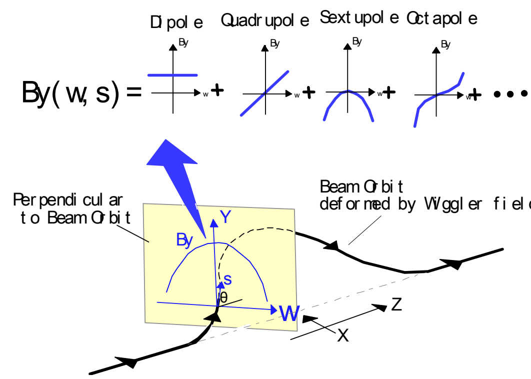

Figure 5: Schematic view of multipole expansion along beam orbit.

Quadrupole and sextupole components are important from the viewpoint of effects on a tune shift and a dynamic aperture shrink, respectively. The components are shown in Figure 6.

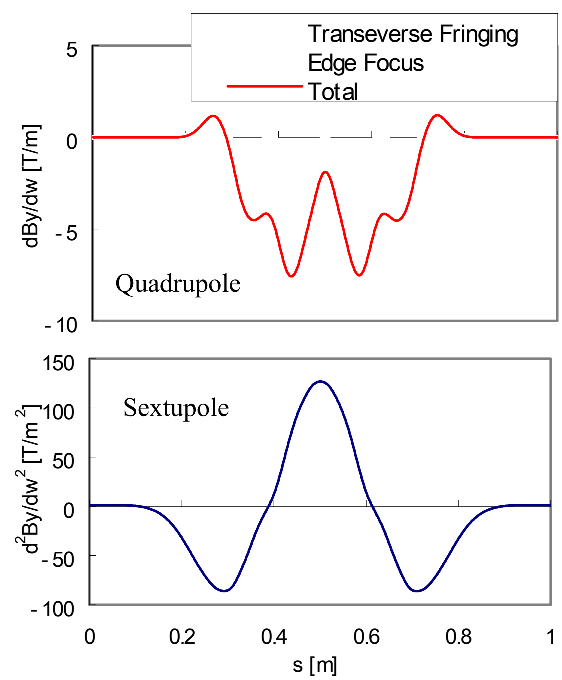

Figure 6: Quadrupole (up) and Sextupole (down) distributions along beam orbit. Quadrupole is decomposed to two contributions due to the SCW transverse fringing field and edge focus.

The quadrupole component can be further expanded to two components, which are due to transverse fringing field and edge focus. For small angle θ between the beam orbit and the longitudinal axis of the SCW, the quadrupole component along the axis w in Figure 5 is approximately given by

$$\frac{dB_y}{dw} \approx \frac{\partial B_y}{\partial x} - \theta \frac{\partial B_y}{\partial z} . \tag{1}$$

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First and second terms of right side in equation (1) correspond to the transverse fringing field and the edge focus, respectively. These components are also shown in Figure 6. The GL values of from the fringing field and the edge focus were values of –1.6 T and –0.2 T, respectively. The edge focus was dominant and the contribution of the fringing field was about 10 % in the quadrupole component.

EFFECT TO LATTICE

Effects of the SCW to lattice functions and dynamic aperture were calculated by the evaluated mutipoles from dipole to 14 pole. The calculation was achieved by computer code SAD [5]. The SCW position on the lattice was assumed to be center of a long strait section with a length of about 3 m. The lattice functions with the SCW are shown in Figure 7. The lattice parameters is shown in Table 2.

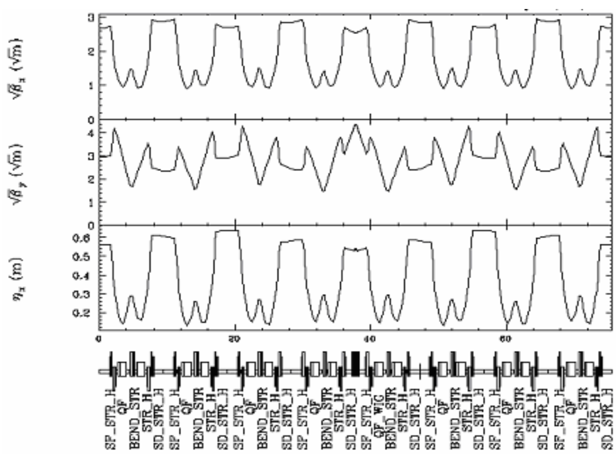

Figure 7: Beta and dispersion functions after tune correction. The SCW position is center of the lattice.

Table 2 Change of lattice parameter.

	Wiggler (tune corrected)	No Wiggler	Ratio
Tune (v x,v y)	(7.596,1.825)	(7.596,1.825)	1.00
Emittance[nmr]	45.2	25.1	1.80
Dynamic Aperure			
Horizontal [mm]	70.0	96.7	0.72
Vertical [mm]	63.1	66.3	0.95
Dispersion[m]	0.56	0.60	0.93
Radiation Loss[keV]	124	106	1.17
Quarupole (gl/ Bρ) [/ m]			
QF	1.072	1.072	1.00
QD	- 1.038	- 1.038	1.00
QF2	1.191	1.191	1.00
QFW	1.002	1.072	0.93
QDW	- 0.843	- 1.038	0.81
Sextupole (dBy2/ dx2/ Bρ) [/ m^2]			
SF	1.810	1.723	1.05
SD	- 3.560	- 3.425	1.04

As there were tune shift and deformation of the beta function, a tune correction was needed. The tune was corrected by quadrupole doublets (QFW and QDW in Table 2), which are located both sides of the SCW section.

Result of the dynamic aperture calculation is shown in Figure 8. The aperture shrank to 70 % on horizontal plane by the SCW. The measure factor in the shrink was the sextupole component.

As the SCW field will be excited after the beam injection and acceleration to 1.4 GeV, the dynamic aperture shrink will not effect the injection. In addition, the horizontal dynamic aperture is still forty times larger than the beam size. Thereby, the reduction of the dynamic aperture should be still tolerable.

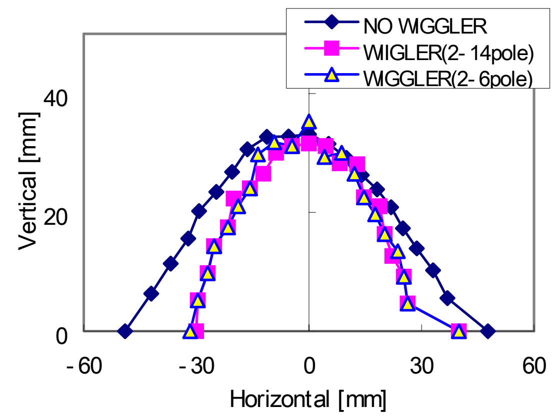

Figure 8: Dynamic aperture at center of the long strait section. Tracking turn number is 25000, which corresponds to damping time at 1.4 GeV.

SUMMARY

The SCW field calculation was in good agreement with the measurement. The multiopole components were calculated. Using the multipoles, the lattice functions and dynamic aperture was calculated. The tune correction was needed. The shrink of the dynamic aperture should be still tolerable. It is basically acceptable to install the SCW from viewpoint of the effect to the lattice.

As next step we will discuss more technical problem on installation and operation of the NIRS-SCW at SAGA-LS.

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