# Design Study of High Brilliant 1 GeV Compact SR Ring

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## Abstract

1 GeV compact SR ring with a circumference of 42 m and an emittance of 76 $\pi$ nmrad has been designed. This SR ring has two straight sections for the insertion devices. If we use 7 T superconducting wigglers, we can get the brilliance of $3x10^{13}$(Photons/mm$^2$/mrad$^2$/0.1%b.w.) at the photon energy of 12.65 KeV, which is K absorption edge of Se and is useful for biological sciences. The lattice of this ring is obtained by removing 4 straight sections from 6 period Chasman-Green lattice in order to make it compact. The injection energy is determined to be 300MeV considering radiation damping time which is sufficiently fast to repeat the injection more than 3 times per second. The injector of this energy is the microtron which we have designed previously for the angiography system. The study of the effects of 7T superconducting wiggler on the beam dynamics is under progressing. At present, the tune shift of betatron oscillation due to the wigglers has been calculated and is tolerable. However, the superconducting wiggler must be excited after ramping up the ring to 1GeV from injection energy.

## 1 Introduction

Compact SR rings AURORA using superconducting magnet[1] and AURORA-2S using 2.7T high field normal conducting bending magnet[2] have been designed and constructed by Sumitomo Heavy Industries, Ltd. The critical energy of sychrotron radiation from AURORA series is about 1 keV as they are designed for X-ray lithography. For the scientific application, AURORA-2D, which is a modified version of AURORA-2S and has two straight sections for undulators, has constructed at Hiroshima University as HiSOR[3].

Recently, the needs of compact SR ring generating more than 10 keV X-ray are increasing. In particular, the X-ray at 12.65 keV, which is a K absorption edge of Se, is useful for the analysis of protein. This will be satisfied by 1 GeV electron storage ring with a high field super-conducting wiggler. Here, we have assumed a 7T superconducting wiggler which is actually constructed and tested by AURORA-2D. The spectrum of SR light is shown in Fig.1. The brilliance of SR light from wiggler is $3x10^{13}$ (Photons/mm$^2$/mrad$^2$/0.1%b.w.) at 12.65 keV.

In order to design a high brilliant compact SR ring, we have modified six period Chasman-Green lattice by removing four straight section. And there remained two straight section for insertion devices. The effect of superconducting wigger on lattice is calculated and proved to be tolerable. Dynamic aperture is calculated to be sufficiently large with the five set of sextupoles correcting X/Ychromaticities and harmonics. But, in our case, there are no large difference in dynamic aperture between with harmonic correction and without harmonic correction. The calculation of dynamic aperture with superconducting wiggler is under progressing.

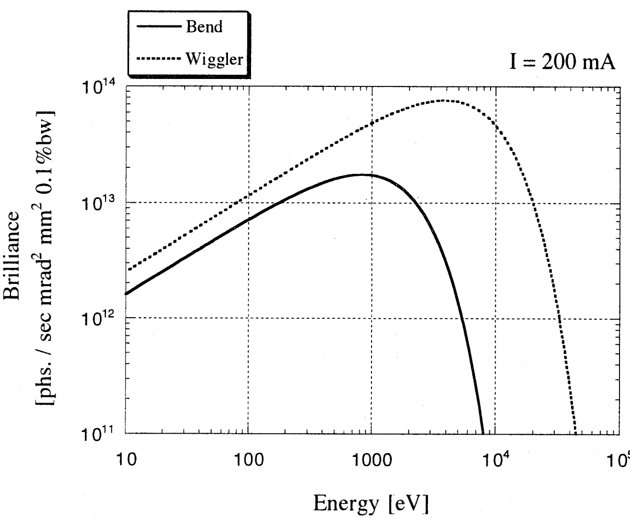


Fig. 1 Spectrum of SR light from bending magnet and superconducting 7T wiggler.

## 2 Storage Ring

The ring is shown in Fig.2. There are two dispersion free short straight sections where we place two superconducting wigglers. An RF cavity, an inflector for beam injection and a kicker are placed at the space between bending magnet and quadrupole magnets in the dispersion free straight section. Main characteristics are shown in Table 1. The circumference is about 42 m. Emittances and Touschek lifetimes were calculated by ZAP considering intra-beam scattering. The emittance at the stored energy is 76 $\pi$ nmrad without wiggler and 64 $\pi$ nmrad with wigglers. For the beam injection, radiation damping times are too large at the beam energy of 150 MeV whereas they are sufficiently short at 300 MeV and it is possible to repeat beam injection at the rate of a few times per second. When we use a microtron as an injector, the repetition rate is essentially important as the peak beam current of microtron is about 10 mA which is small compared with linac. Short radiation damping time will also have good effects on the suppression of beam instabilities. By these reasons, 300 MeV microtron is used as an injector.

## 3 Effects of Superconducting Wigglers

The betatron tune shift due to wigglers at the stored energy is small as in Table 1. The effect on betafunction is

Table 1 Main parameters of SR ring. The value of a blank space is equal to left side value.

| | | | | |
|---|---|---|---|---|
| Insertion devices | No insertion device | | | Two 7T wigglers |
| Beam energy | 1 GeV | 0.15 GeV | 0.30 GeV | 1.0 GeV |
| Beam current | 200 mA | | | |
| Circumference | 41.623 m | | | |
| Superperiodicity | 2 | | | |
| RF voltage | 250 kV | 50 kV | 100 kV | 250 kV |
| Harmonic number | 28 | | | |
| RF frequency | 201.672 MHz | | | |
| Energy aperture | 0.8717% | 1.154% | 1.151% | 0.8212% |
| Energy loss | 40.227 keV/turn | 0.02 keV/turn | 0.326 keV/turn | 56.076 keV/turn |
| Synchrotoron frequency | 0.05696 MHz | 0.06620 MHz | 0.0662 MHz | 0.05652 MHz |
| Momentum compaction factor | 0.05687 | | | 0.05672 |
| Betatron tunes Horizontal/Vertical | 3.728/2.711 | | | 3.728/2.789 |
| Natural chromaticities Horizontal/Vertical | −5.968/−7.016 | | | −5.968/−8.877 |
| Emittance | 75.88 $\pi$ nmrad | 147.71 $\pi$ nmrad | 40.72 $\pi$ nmrad | 63.74 $\pi$ nmrad |
| Energy spread | 0.0714% | 0.155% | 0.0773% | 0.0848% |
| Radiation damping time | | | | |
| Horizontal | 4.091 msec | 1212.3 msec | 151.533 msec | 3.314 msec |
| Vertical | 6.903 msec | 2045.3 msec | 255.657 msec | 4.952 msec |
| Longitudinal | 5.258 msec | 1557.9 msec | 194.733 msec | 3.288 msec |
| Bunch length | 33.99 mm | 63.63 mm | 31.81 mm | 40.62 mm |
| Beam size at wiggler (1%emittance coupling) Horizontal/Vertical | 0.365/0.024 mm | 0.511/0.034 mm | 0.269/0.018 mm | 0.334/0.025 mm |
| Beam divergence at wiggler Horizontal/Vertical | 0.206/0.031 mrad | 0.289/0.043 mrad | 0.152/0.023 mrad | 0.189/0.026 mrad |
| Touschek lifetime | 8.11 H | 0.834 H | 0.453 H | 7.288 H |
| Quantum lifetime | 2.5E+24 H | > 1.0E+32 | > 1.0E+32 | 2.164E+12 |

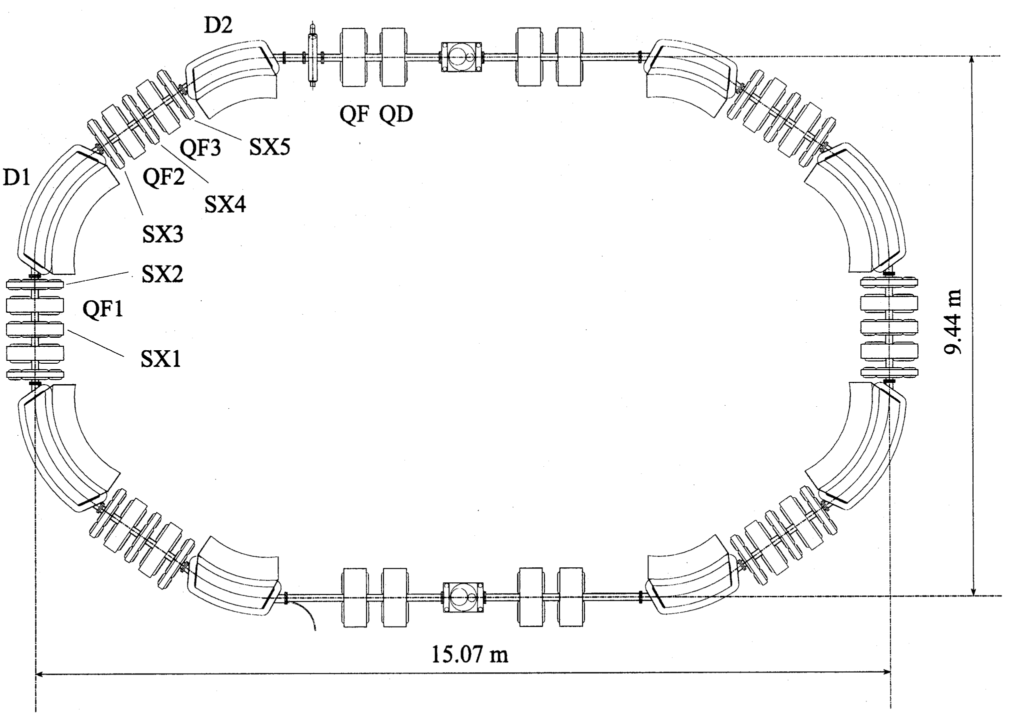


Fig. 2 Layout of storage ring.

shown in Fig.3 and appears only on vertical betafunction.
In oder to reduce this effect, the vertical betafunction is designed to be as small as possible at the wiggler. The effect on neck-tie diagram is shown in Fig. 4(a), which is drawn without wigglers, and Fig,4(b), which is drawn with wigglers. Parameters of these neck-tie diagrams are the field strength of quadrupole magnets QF, QD in Fig. 2. The operating point of these quadrupole magnets is 11.7 T/m for QF4 and -11.7 T/m for QD5. By the effect of wigglers, the stable region is increased.

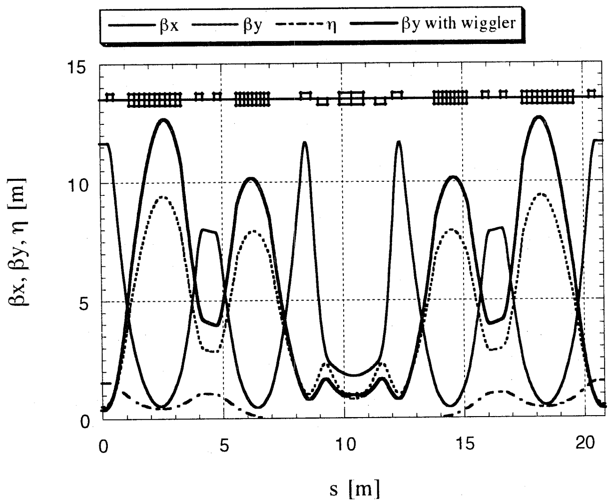


Fig. 3 Twiss parameters of a half of the ring.

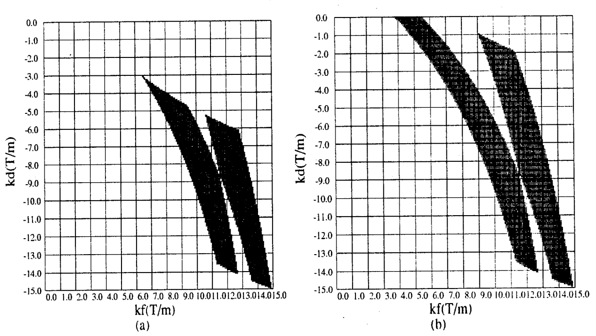


Fig. 4 Neck-tie diagram. (a): no wiggler. (b) 7T wiggler

## 4 Dynamic Aperture

There are five set of sextupoles in the ring. Therefore, we can correct not only chromaticities but also harmonics [4]. In Fig. 5, Dynamic apertures calculated by MAD are shown. In the figure, the dynamic aperture with (*) is calculated with sextupoles which are used only for chromaticities correction and is somewhat narrower than other dynamic apertures of which harmonics are corrected. However, all of these dynamic apertures are sufficiently large to make the various lifetimes long. The effect of +/- 1% momentum deviation is also small and sufficient momentum acceptance is obtained.

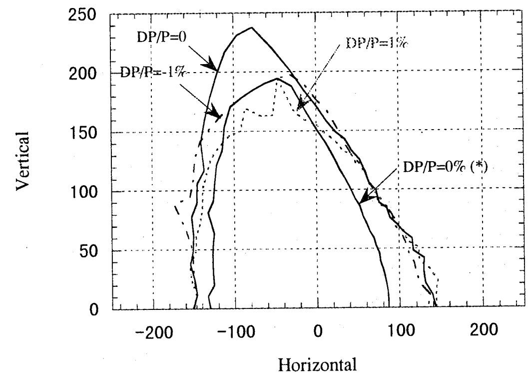


Fig. 5 Dynamic aperture. Units are $\sqrt{\varepsilon\beta_x}$ and $\sqrt{\varepsilon\beta_y}$ for horizontal and vertical indexes respectively. Here, $\varepsilon = 75.88$ $\pi$ nmrad. (*):Sextupoles are used for chromaticity correction only. Others: Sextupoles are used for chromaticity and harmonic correction.


## Acknowledgement

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## References


[1] N. Takahashi., Nucl. Instrum. Methods B24/25 425(1987).
[2] T. Hori, et al.,,"AURORA-2: Compact Advanced SR Ring as an X-ray Source", 4th Int'l Conf. On SR sources & 2nd Asian Forum on SR, Kyongju, Korea (1995)pp.148-158.
[3] K. Yoshida, et al., "Commissioning of a Compact Synchrotron Radiation Source at Hiroshima University", Proc. Of the 1st Asian Particle Acc Conf., Tsukuba (1998)653.
[4] R. Nagaoka, et al. Nucl. Instrum. Methods in Physics Research A302(1991)9-26.