DESIGN OF A 1.5 GEV STORAGE RING FOR THE INTEGRATED PHOTON SOURCE PROJECT AT TOHOKU UNIVERSITY

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Abstract

An integrated photon source project has been developed at Tohoku University [1]. The project will be able to utilize the photons over wide energy range: far-infrared, VUV, X-ray and hundreds MeV. Based on the existent accelerator facility, Laboratory of Nuclear Science (LNS), a new injector linac and a light source storage ring are designed. The storage ring is considered to be operated in the energy range of 1.2 to 1.8 GeV. Two of six short straight sections are used for an RF cavity and beam injection, the others for insertion devices including a couple of superconducting wigglers for x-ray generation. The storage ring should be small, because of the limitation in budget and site area. Therefore multipole magnets will be employed which produce both quadrupole and sextupole magnetic fields. The beam injection from a booster ring will be done by a conventional way to make a bump orbit using three bump magnets. The 1.2 GeV booster ring (STB ring) [2] has already been operated at LNS. The design of the storage ring is described here.

INTRODUCTION

In the photon source project, a 150 MeV injector linac and a 1.5 GeV light source storage ring will be newly constructed. The injector linac may contain a thermionic RF gun, which allows us to operate an infrared FEL. The storage ring is designed to realize relatively low emittance and capability of inserting a couple of superconducting high-field wigglers for x-ray generation. A storage ring FEL is also considered to provide coherent higher harmonic photons and high energy γ-rays via intracavity Compton backscattering. Thus the project will utilize the photons over the very wide energy range; far-infrared, VUV, X-ray and hundreds MeV.

STORAGE RING

Outline of Storage Ring Design

A planned layout of the storage ring is shown in Fig. 1. The storage ring is considered to be operated in the energy range of 1.2 to 1.8 GeV. The lattice is composed of eight Chasman-Green cells with two long straight sections. A circumference of the ring is 99.5 meters. In the lattice design, an availability of superconducting 7 T wiggler has also been considered. Since a vertical betatron function in the straight section of the normal cell is so small as to be 0.8 m, distortion of the lattice function due to the wigglers is sufficiently small and can be corrected by modifying the excitation currents of the nearby multipole magnets slightly [1]. One of two 8.3 m long straight sections will be dedicated to the SRFEL device. The lattice functions in a normal cell are shown in Fig. 2, and the main parameters are listed in Table 1.

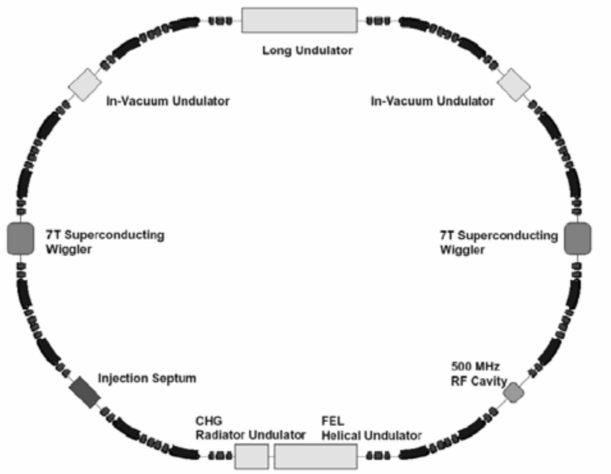

Figure 1: Layout of a 1.5 GeV storage ring.

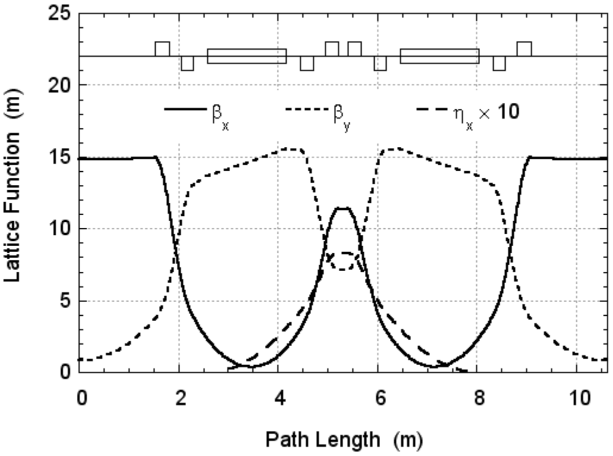

Figure 2: Lattice functions in a normal cell.

Table 1: Machine Parameters

Beam energy	**1.5 GeV** **(1.2 ~ 1.8 GeV)**
Circumference	**99.503 m**
Lattice structure	**Chasman-Green,** **8-cell racetrack**
Straight section	**3.06m×6, 8.33m×2**
Horizontal emittance	**26.9 nmrad @1.5GeV**
Betatron tune	**(7.80, 3.72)**
Momentum compaction factor	**0.00644**
Chromaticity	**(-20.9, -13.2)** **--> (2, 2)**
Relative energy spread	**0.000645**
Radiation loss / turn	**112 keV**
Damping time (dipoles only)	**(8.77, 8.88, 4.47) ms**
RF frequency	**500.14 MHz**
RF power & voltage	**120 kW & 700 kV**
Harmonic number	**166**
Synchrotron frequency	**26.7 kHz**
Natural bunch length	**24.7 ps (7.43 mm)**
Beam current	**400 mA @ 1.5 GeV** **200 mA @ 1.8 GeV**

Since multipole magnets are located at the high-beta positions, the strength of sextupole component is not so large. As a result, a large dynamic aperture is secured.

For a relatively low energy ring, Touschek lifetime becomes significant. Assuming that the total beam current of 400 mA distributes over 166 RF buckets uniformly, Touschek lifetime is about 7 hours for the 1 % coupling, which is comparable to the lifetime due to 1 nTorr vacuum pressure. At present, a cure by introducing a harmonic cavity is considered to improve the Touschek lifetime.

Multipole Magnets

One significant feature of the ring is to employ multipole magnets which produce both quadrupole and sextupole magnetic fields. This type of magnets has been already constructed and operated in MAX-II ring [3]. The basic specifications are listed in Table 2.

Table 2: Basic Specifications for multipole magnets

	Focus	Defocus
Quadrupole (T/m)	**16.053**	**-13.655**
Sextupole (T/m^2)	**55.242**	**-91.288**
Pole length (cm)	**28**	**24**
Bore radius (mm)	**> 30**	**> 30**
Effective region (mm)	**±25**	**±25**
Uniformity	**$<1\times10^{-4}$**	**$<1\times10^{-4}$**

Pole-face shape of the magnet is basically given by an equipotential line including the quadrupole and sextupole components, except for some shim work to decrease the higher multipole components and to get the proper dipole and sextupole components.

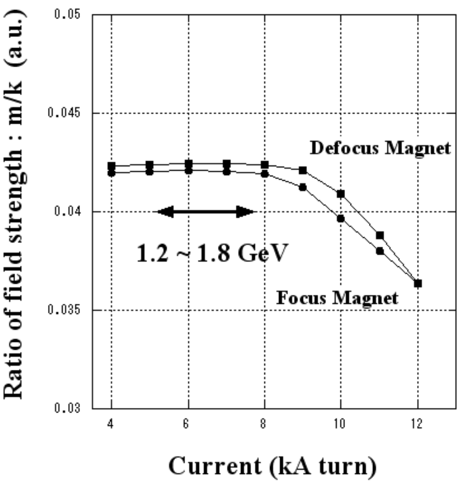

Figure 3: Ratio of field strength vs. excitation current.

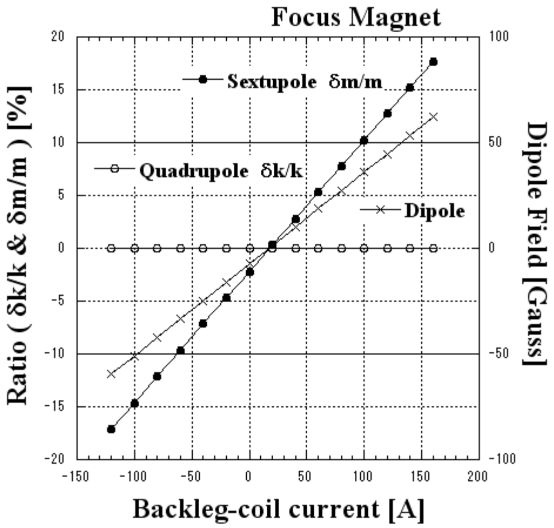

Figure 4: Dependence of field components on the backleg coil current.

Fig. 3 shows ratios of the sextupole component to quadrupole vs. excitation current calculated by 2D POISSON calculation. Over 9 kAturn, the differences from the proper value due to saturation effect is obvious. However, in the region corresponding to 1.2 ~ 1.8 GeV, the ratios are quite constant for both magnets.

Backleg-coil in the multipole magnet is usually used to decrease dipole component and to get proper sextupole component. In other words, if the dipole component is small enough and an allowable level for COD correction, the backleg-coil can be used to adjust the sextupole component. Fig. 4 shows the dependence of each field components on the backleg-coil current. The backleg-coil can change the sextupole component linearly, while it keeps the quadrupole component at constant. The change of ±15% in the sextupole component corresponds to ±2.0 change in the chromaticity, while the dipole component of about 100 Gauss causes the COD of about 6mm in maximum as shown in Fig. 5. This COD, however, can be corrected to less than 70 μm without any additional steering magnets.

So far 2D POISSON code was used for the field calculations. In the actual magnet, however, existence of some leakage field at the magnet end may affect to the previous calculations. To estimate this effect, a 3D calculation code RADIA [4] has been applied. According to the preliminary result, there is a 10 % discrepancy between RADIA and POISSON in the sextupole component. At present, more details about the calculations are studied, and the investigation by constructing a prototype magnet will be done.

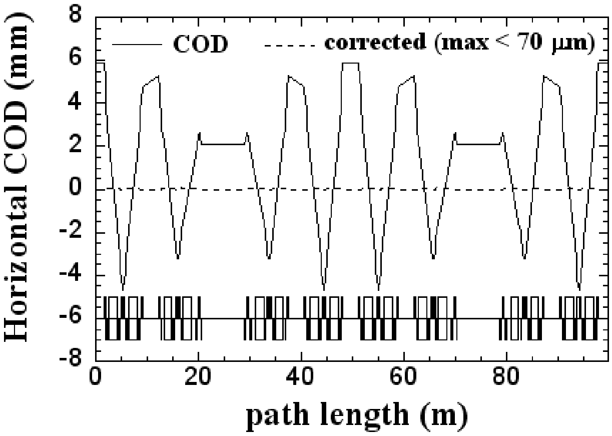

Figure 5: Horizontal COD due to dipole components in the multipole magnets.

Beam Injection

The beam injection from the booster synchrotron (STB ring) will be done by a conventional way to make a bump orbit using three kicker magnets that allows us to make multiple injections. The Twiss-parameters of the beam are fitted by the transport line to be almost the same as for the ring-parameters at the injection point. Incoming beam emittance is around 170 nmrad and which gives a 2.5σ beam of about 4.0 mm. The pulse length is assumed to be 100 nsec and the pulse current about 30 mA. It is desirable to limit the injection section to one straight section of the ring, but the straight section in our ring is too short to install bump magnets. Therefore the injection elements are distributed over three straight sections. The injection bump is shown in Fig. 6.

The amplitude of the injection bump is assumed to be 15 mm by taking into account of the above incoming beam size, the 5σ beam size (3.3 mm) of storage ring and thickness of the septum conductor. The maximum strength of the bump magnets to make the injection bump is 2.4 mrad. The bump magnets will be excited by half-sine wave with duration less than 2 μs.

Incoming beam is guided by two septum magnets; the downstream magnet (Sep-A) is excited by half-sine wave and the upstream (Sep-B) DC current. The main parameters are listed in Table 3.

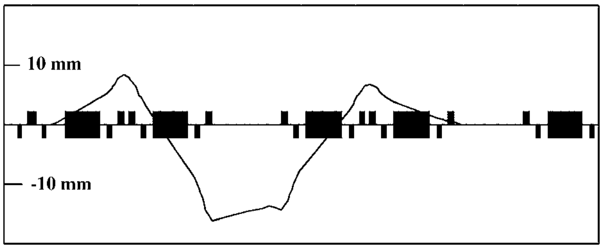

Figure 6: Closed bump orbit for the beam injection.

Table 3: Main parameters of septum magnets

	Sep-A	Sep-B
Pole length (m)	**0.6**	**1.0**
Pole gap (mm)	**10**	**14**
Field strength (T)	**0.63**	**1.08**
Current (A)	**5000**	**2000**
No. of turns × coils	**1×1**	**3×2**
Excitation	**Half-sine**	**DC**

Due to nonlinear effects by the sextupole components in the injection section, the relative excitation level of the bump magnets are bump-amplitude dependent. This effect will cause the residual oscillations of the beam. A dynamical tracking calculation including time-dependent strength of the bump magnets has to be done to estimate this effect.

SUMMARY

An integrated photon source project has been developed at Tohoku University to utilize the photons over wide energy range. A basic design of a light source storage ring has been constructed. At present, the design work proceeds for further details. Especially, some key issues like a multipole magnet are going to be soon investigated by fabricating prototypes.

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