LATTICE DESIGN OF A SYNCHROTRON RADIATION SOURCE AT TOHOKU UNIVERSITY

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Abstract

A 1.5 GeV storage ring was designed for a synchrotron radiation facility planned at Tohoku University. A stretcher-booster ring, which is now under construction, will be used as an injector. The circumference of the ring is 187 m. The beam emittance is 7 nm-rad. The ring consists of 12 double bend achromatic cells. Ten of 12 dispersion-free long straight sections are 5m long and will be used for insertion devices, RF cavities and injection. Other two are 15m long and reserved for advanced devices such as a very long undulator or a free electron laser. The present status of the project is 'waiting for approval'.

1 INTRODUCTION

To meet the strong demands for synchrotron radiation in VUV-SX region, construction of a third generation light source of 1.5 GeV was proposed at Tohoku University in Sendai, Japan [1]. The light source was planned to be constructed at the site of Laboratory for Nuclear Science (LNS) of the university, where a 300 MeV Linac is working and a 300MeV~1.2GeV stretcher-booster ring (STB) is now under construction [2]. Main purpose of STB is to convert the bunched beam from Linac to a quasi-continuous beam for nuclear studies. It also has a capability of accelerating a bunched beam up to 1.2 GeV to serve as an injector for the proposed light source. The commissioning of STB will be started in Spring, '97. Hopefully, the light source project shall be started soon after the commissioning. The present situation of the project is 'waiting for approval'.

2 OVERVIEW OF THE FACILITY

The light source will be constructed at LNS site in Sendai City, about 400 km north of Tokyo. A plan view is shown in Figure 1. The accelerator complex consists of a 300 MeV linac, a 0.3-1.2 GeV Stretcher-Booster Ring (STB) and the 1.5 GeV Light Source.

The 300 MeV linac has been working for about 30 years, for nuclear researches and also for studies on coherent infrared radiation by utilizing its very short bunch length [3]. The parameters of the Linac are shown in Table 1.

A stretcher-booster ring is now under construction and the commissioning will be started in Spring '97. The circumference is 50 m. The lattice consists of 4 double bend achromatic (DBA) cells. It has three operating modes; pulse stretcher mode, booster mode and storage mode. In the pulse stretcher mode, the 300 MeV bunched beam from Linac is converted to a quasi-continuous beam by slow extraction. In the booster mode, the injected beam is accelerated up to 1.2 GeV and is extracted to the beam transport line to the Light Source. The storage mode is for internal target experiments. The parameters of STB are shown in Table 2.

A beam transport line will be constructed between STB and the Light Source as shown in Figure 1. About a half of it will be constructed in an existing tunnel previously used for a TOF experiment.

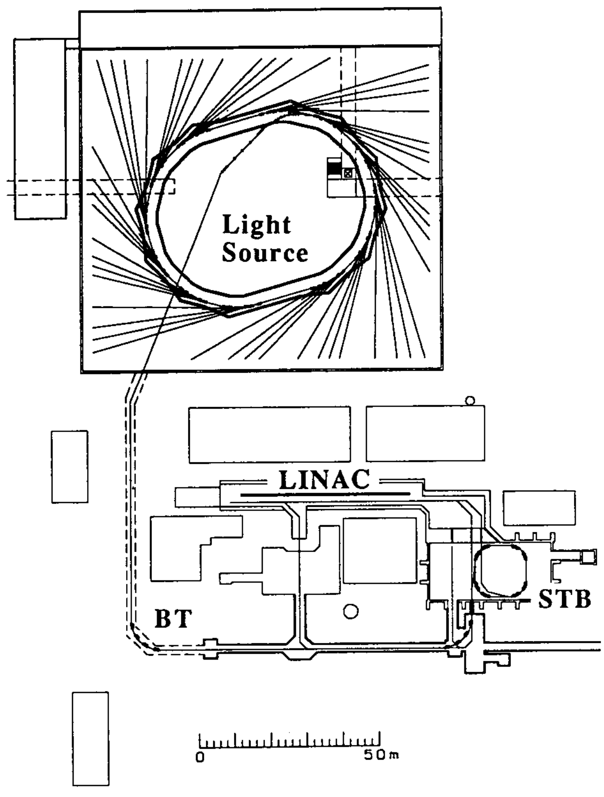

Figure 1. Plan view of the SR facility at Tohoku University.

The 1.5 GeV light source has a circumference of 187 m. Because the space is limited, a careful consideration was given to the configuration of the storage ring, as shown in Figure 1, to keep spaces for SR beam lines as much as possible. About 50 beam lines can be constructed in the experimental hall. Various kinds of insertion devices including a superconducting wiggler will be installed at ten straight sections to cover the wide spectral range.

Table 1. Parameters of Linac

Beam Energy	300 MeV
Repetition Rate	300 Hz
Pulse Length	2 μsec

Table. 2. Parameters of STB (Booster Mode)

Circumference	49.8 m
Lattice	DBA x 4 cells
Beam Energy	0.3~1.2 GeV
Emittance	170 nm-rad@1.2GeV
Repetition Rate	0.2 Hz

Table 3. Parameters of Light Source

Circumference	187 m
Lattice	DBA x 12
Straight Sections	5 m x 10, 15 m x 2
Beam Energy	1.2~1.8 GeV
Emittance	7.3 nm-rad@1.5GeV
Betatron Tunes	(12.20, 3.15)
Natural Chromaticity	(-46.8, -14.2)
Momentum Compaction	0.00145
Momentum Spread	6.60×10^{-4}
Harmonic Number	312
RF frequency	500 MHz
RF voltage	1 MV
Synchrotron Tune	0.0067
Natural Bunch Length	0.43 cm

3 LATTICE

The lattice of the Light Source was designed (1)under the space limitation, (2)to realize the beam energy higher than 1.5 GeV, (3)emittance smaller than 10 nm-rad, (4) number of straight sections for insertion devices as many as possible, and (5)to keep some options for developments of advanced light sources such as an FEL or a long undulator.

Comparing various lattice structures, DBA was selected for normal cell structure. The ring consists of 12 DBA cells. The lengths of the dispersion free straight sections are 5 m except for two 15 m long ones that are reserved for advanced light sources. The racetrack shape of the ring was selected to make use of the limited space of the site effectively.

The beam energy is 1.2 GeV at injection and is ramped up to the nominal energy of 1.5 GeV. The maximum energy will be 1.8 GeV to meet the demands for X-rays.

The emittance as small as 7 nm-rad can be achieved at 1.5 GeV. The emittance growth due to intrabeam scattering was estimated to be less than a few percent. Even smaller emittance by a factor of 2 can be obtained by violating the achromatic condition. This possibility will be kept as an option.

Magnets will be short in lengths and strong in fields (Table 4), to keep the spaces for straight sections and other accelerator components (Table 4). In addition, steerers and skew-quadrupoles will be integrated in sextupoles, utilizing the auxiliary windings.

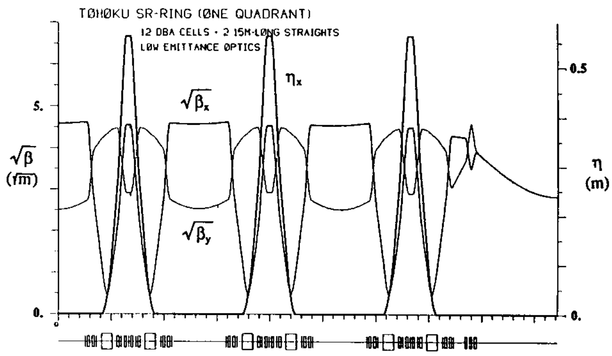

Figure 2. Optical functions of the light source. One quadrant of the ring is shown.

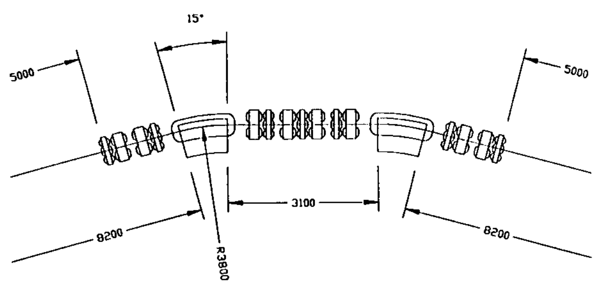

Figure 3. Magnetic lattice of a normal cell of the light source

Table 4. Parameters of the magnets of Light Source (in case of 1.5 GeV)

	Field	Length
Bendings	1.25 T	1.0 m
Quadrupoles	20 T/m	0.2 m
Sextupoles	500 T/m^2	0.1 m

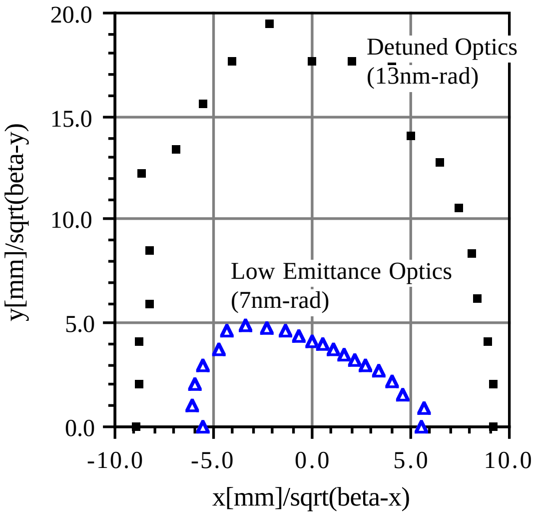

Figure 4. Dynamic aperture of the light source without machine errors. The amplitude is normalized by square root of β. In cases of the low emittance optics and the detuned one are shown.

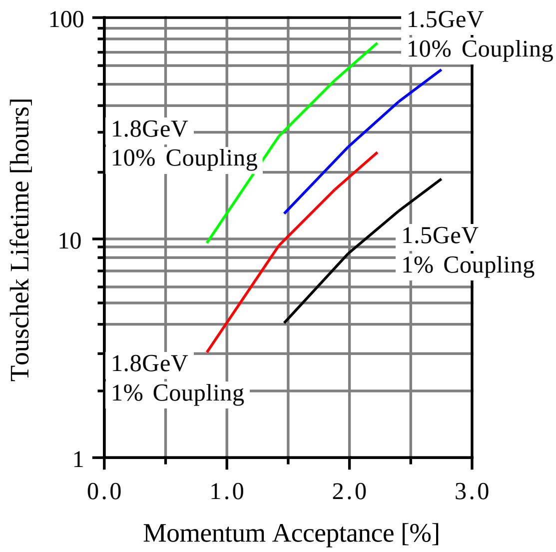

Figure 5. Touschek lifetime of the light source. Two cases for the coupling, 1% and 10%, and two cases for the beam energy, 1.5 GeV and 1.8 GeV are shown as functions of momentum acceptance.

Sextupoles are divided into four families. Two families at the dispersive sections are used for chromaticity compensation and other two at the dispersion-free sections are used for minimizing the amplitude dependent tune shifts.

The low symmetry of the lattice was expected to reduce the dynamic aperture. By now, no special consideration was given to the optics matching between normal cells and the long straight sections, to keep the dynamic aperture large.

Some results from tracking simulation are shown in Figure 4. Results for two cases of the optics, a low emittance one of 7 nm-rad and a detuned one of 13 nm-rad are shown. The dynamic aperture reduces as the emittance gets smaller. Even in case of 7 nm-rad, the dynamic aperture without machine errors is larger by a factor of two than the aperture required for injection. However, to make the commissioning smooth, the operation will be started with the detuned optics of 13 nm-rad, which has much larger dynamic aperture. After investigating the machine errors using the stored beam, the lower emittance will be tried.

The beam lifetime is strongly limited by Touschek effect as shown in Figure 5. To keep the lifetime longer than 10 hours, momentum acceptance should be larger than 2%. It can be assured by an RF voltage of 1 MV and the present sextupole correction scheme.

3 SUMMARY

A 1.5 GeV synchrotron light source was proposed to be constructed at LNS site of Tohoku University. There is a stretcher-booster ring under construction, that can be used as an injector. Its commissioning will be started in Spring '97.

The proposed light source belongs to the third generation. Emittance smaller than 10 nm-rad can be achieved. Ten straight sections are available for insertion devices. Two very long straight sections are reserved for future developments of advanced devices

Hopefully, the light source project shall be approved and be started in near future following the completion of the stretcher-booster ring.

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