THE DESIGN OF THE 8GeV SYNCHROTRON AND THE BEAM TRANSPORT SYSTEM

T.Shimada, M.Kabasawa, K.Nakayama, H.Hashimoto, T.Harami and Y.Suzuki
JAERI-RIKEN Synchrotron Radiation Facility Design Team
Honkomagome 2-28-8, Bunkyou-ku, Tokyo, 113, Japan

Abstract

The synchrotron and the beam transport lines(linac-synchrotron, synchrotron-storage ring) have been designed. These are used as a part of the injection system for the 8GeV storage ring of SPring-8 facility. To keep high injection-efficiency into the storage ring, the emittance of the beam is designed to be smaller than 200nm·rad and transverse phase-space matching is made at the injection point of the ring. The calculation about the beam transport lines and the synchrotron is performed using the code SYNCH.

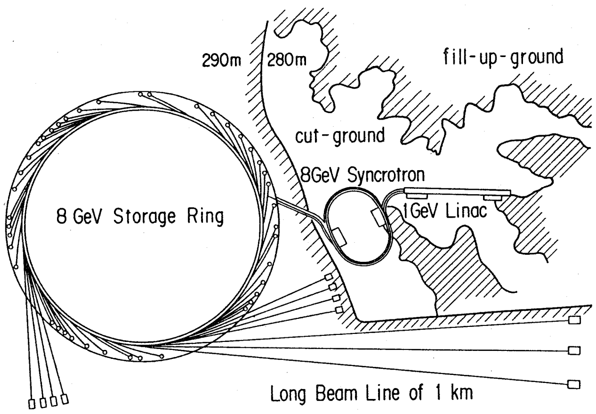
Introduction

Japan Atomic Energy Research Institute(JAERI) and The Institute of Physical and Chemical Research(RIKEN) are planning to construct an 8GeV synchrotron radiation facility(nicknamed SPring-8) at Nishi-harima in Kansai area.

The machine of this facility consists of an 8GeV storage ring and an injection system which is composed of a 1GeV linac, a 1Hz,8Gev synchrotron and beam transport lines. These machines accelerate and store positrons and electrons.

The design goal of the injection system is that the storage ring is filled up with 100mA positron or electron beam within 10minutes. Since the intensity of the positron beam from the linac may not be large enough, the beam is designed to be transported and accelerated without significant loss from the linac to the storage ring. Particles may be lost mainly at injection into the ring, therefore, it is necessary that transverse phase-space matching is achieved and that the emittance of the beam is small enough to be accepted into the ring. In addition, the injection system is designed to be simple, low-cost and easy to operate.

Fig.1 Layout of SPring-8



The layout of the machines is shown in Fig.1. The site for SPring-8 is being prepared by cutting-off or filling-up the ground. All machines will be constructed on the cut-off ground which is firmer than the filled-up area. The altitude of the storage ring is 10m higher than that of the injection system. The layout of the synchrotron and the linac is determined to keep the site for future extensions and to avoid the building of synchrotron interfering with the straight line of the linac.

In this paper, the design of the synchrotron and beam transport lines are described.

Linac to Synchrotron Beam Transport(LSBT)

The function of the LSBT line is to transport the beam of 1GeV from the end of the linac into the injection point of the synchrotron. In addition, the line serves to provide transverse phase-space matching of the linac beam to the acceptance of the synchrotron. The LSBT line includes a discursive section that is used both to characterize the injection energy of the beam and to define the full momentum spread of the beam transported to the synchrotron. This ensures that the synchrotron is injected with a beam whose energy spread is small enough that no significant distributed beam losses occur, thus minimizing the requirement for synchrotron shielding.

Fig.2 shows a schematic layout of the LSBT line. The LSBT line is about 80m long and consists of 7 dipoles and 26 quadrupoles. Total bending angle is 116 degrees. The LSBT line is split into three sections on function. In the first section, the use of two quadrupole doublets ensures that horizontal and vertical focuses can be achieved at the collimator(SA), independent of the properties of the linac beam. In the second section, the direction of the beam is turned to 90 degrees leaving zero-dispersion. A dipole magnet(B1) switches the beam from the straight beam line to the LSBT line. B1 and B2 act as dispersion elements. Momentum selection and analysis are carried out downstream via a variable horizontal collimator(SA). Since the beam emittance from the linac is expected to be 1.5mm·mrad[1], the momentum resolution of 0.06% is accomplished by the horizontal β-function of 4m and the dispersion-function of 4m at SA. In the last section, transverse phase-space matching to the acceptance of the synchrotron is provided by tuning quadrupoles(Q19~Q22). The final part of this section forms a Chasman-Green lattice of B7 and the septum magnets (MS,PS) of the synchrotron, and makes the dispersion free at the injection point of the synchrotron.

The results of the calculation of β-function and dispersion-function in the LSBT line are shown in Fig.3.

Synchrotron

The synchrotron is used to accelerate the 1GeV beam from the linac to the nominal 8GeV operating energy of the storage ring. The cycle rate of the synchrotron is 1Hz. The natural emittance is about 200nm·rad at 8GeV. The synchrotron has two dispersion-free straight sections on opposite sides of the ring giving a racetrack shape. In these straight section, RF cavities and pulse operated magnets for injection and extraction are installed. Table 1 shows the major parameters of the synchrotron.

Table 1 Major parameters of Synchrotron

Injection energy	1.0 GeV
Maximum energy	8.0 GeV
Circumference	396 m
Repetition rate	1 Hz
Natural emittance (8GeV)	192 nm·rad
Momentum spread (8GeV)	0.122 %
Radiation loss (8GeV)	11.55 MeV/turn
Number of cells / Periodicity	40 / 2
Nominal turn ($\nu x/\nu y$)	11.73/8.78
Natural chromaticity ($\xi x/\xi y$)	-15.3/-12.7
Momentum compaction	9.53×10^{-3}
Resonant frequency	508.58 MHz
Harmonic number	672
Accelerating voltage (8GeV)	17.1 MV
Quantum lifetime	over 10 seconds

In the following, the lattice[2], magnets, the vacuum system[3] and RF system[3] of the synchrotron are briefly described.

Fig.4 shows the configuration of magnets. The lattice is based on a separated function. The synchrotron has 40 FODO cells including 32 normal cells. The dispersion suppressor cells are configurated one by one on both sides of the straight section. The horizontal and vertical tunes are 11.73 and 8.73. Fig.5 shows the β-function and dispersion-function for this tune around the straight section. The natural emittance at 8GeV is 192 nm rad, which is expected to be quite satisfactory for the efficient injection into the storage ring. The natural chromaticities of this lattice are ξx=-15.3 and ξy=-12.7. To correct the chromaticities, 16 focusing and 32 defocusing sextupoles are placed near focusing quadrupoles and defocusing quadrupoles, respectively. As injection process, on-axis injection and off-axis injection with accumulation are considered.

The major magnets of the ring consist of 68 dipoles, 80 quadrupoles and 48 sextupoles. The core of these magnets is assembled by laminated 0.5mm thick silicon steel sheets to block eddy current in 1Hz operating. The shape of the cross section of the dipole is C-type, which is easy to access the beam duct in comparison with H-type. Table 2 shows the parameters of the synchrotron magnets.

The vacuum system of the synchrotron ring is designed to satisfy the following requirements; maintain a pressure of less than 1×10^{-6} Torr with a 8GeV 10mA beam electrons to give a life-time of more than 10 seconds due to gas scattering. The vacuum chamber in the dipole is devised to weaken the eddy current effect. The inside dimensions of the duct are 34mm height and 72mm width. There is clearance enough for the beam injected by the off-axis mode passing through the duct.

The RF system is designed to adopt a frequency of 508.58 MHz because of the availability of high power klystrons at KEK. The same RF frequency is used for the storage ring. The λ/2 resonant cavities is shaped nose cone type to optimize the shunt impedance. There are 5 cells per cavity coupled with each other through the slots. The effective shunt impedance is 21MW/m. The rated dispersion power per cavity is evaluated to be about 220kW. A minimum of 8 cavities may be required to satisfy the synchrotron design parameter specifications.

Table 2 Parameters for Synchrotron magnets

Dipole magnet	
number	68
pole length	2870 mm
pole gap	46 mm
pole width	150 mm
yoke type	C type
edge	rectangular
strength (8GeV)	0.8502 T
tolerance limit of field	0.05 %
Quadrupole magnet	
number	80
pole length	570 mm
bore radius	40 mm
strength F/D (8GeV)	14.598/-12.382 T/m
tolerance limit of field	0.1 %
Sextupole magnet	
number	48
pole length	150 mm
bore radius	50 mm
strength F/D (8GeV)	204.0/-162.8 T/m^2
tolerance limit of field	1 %

Synchrotron to Storage ring Beam Transport(SSBT)

The function of the SSBT line is deliver the 8GeV beam extracted from the synchrotron to the injection point of the storage ring. For the efficient injection, the transfer line provides a zero-dispersion and transverse phase-space matching to the ring acceptance at the injection point. The design concept of the SSBT line is similar to the case of LSBT.

The schematic layout of SSBT is shown in Fig.6. The SSBT line is about 330m long. Furthermore, the height of the storage ring are different from that of the synchrotron. Most part of the SSBT line is under the ground in order to lead the beam line to the inside of the storage ring. The lattice is mostly FODO arrangement. SSBT is divided into seven sections on function. In SS1, the phase-space of the beam from the synchrotron is transformed into that to be suitable one for the SSBT line. In SS2, SS4 and SS6, the beam is bent leaving zero-dispersion. SS3 is a long straight section. In SS5, the beam ascends from the synchrotron level to the storage ring level. SS7 ensures the transverse phase-space matching at the injection point of the storage ring. The final part of SS7 forms CG-lattice to cancel momentum dispersion. Thus, SSBT can cope with the variation of the operating mode of the synchrotron or the storage ring by tuning only SS1 or SS7 with SS2~SS6 fixed.

The calculated β-function and dispersion-function are shown in Fig.7.

Conclusion

The synchrotron and the beam transport lines have been designed. To keep high injection-efficiency, the emittance of the beam into the storage ring is smaller than 200nm·rad and transverse phase-space matching is made at the injection point of the ring.

The R&Ds for the injection system are planned to establish the design of components[4].

Fig.2 Layout of the LSBT line

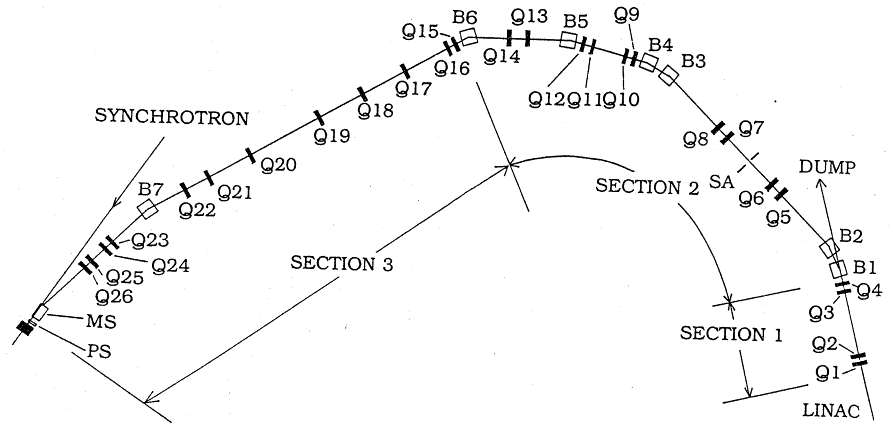


Fig.3 Optics of the LSBT line

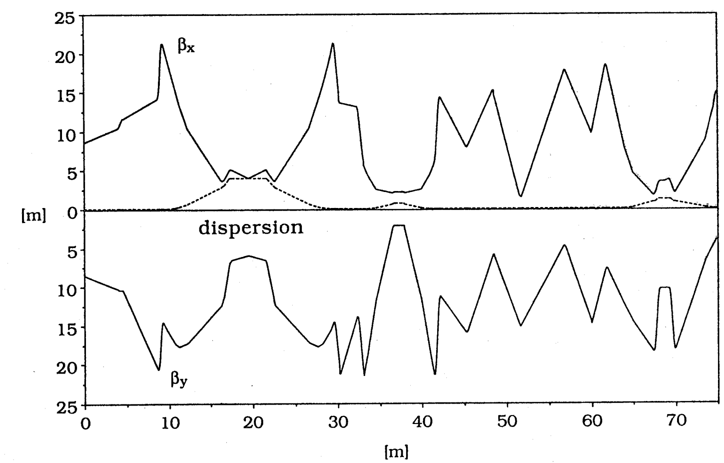


Fig.4 Layout of the synchrotron

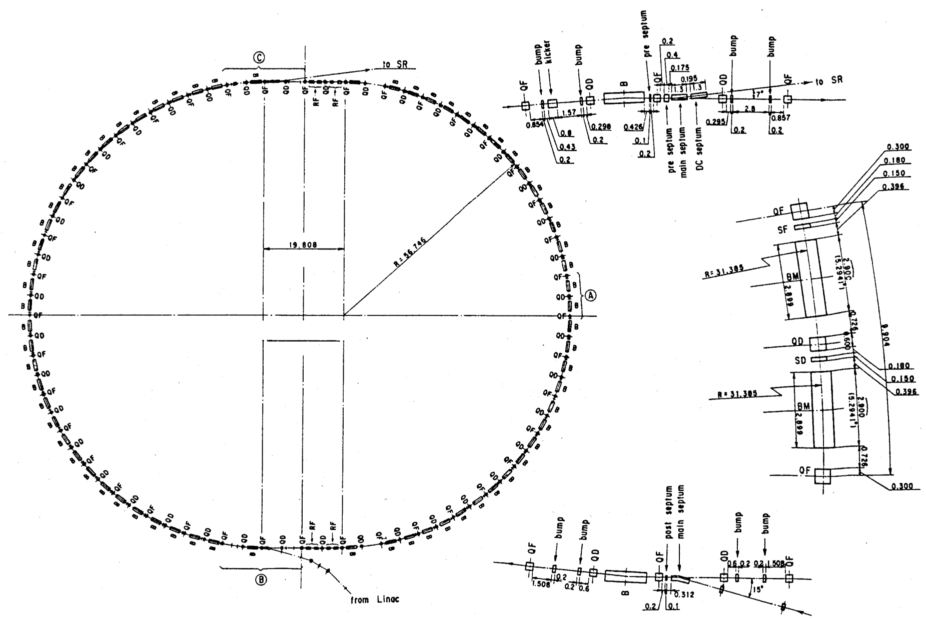
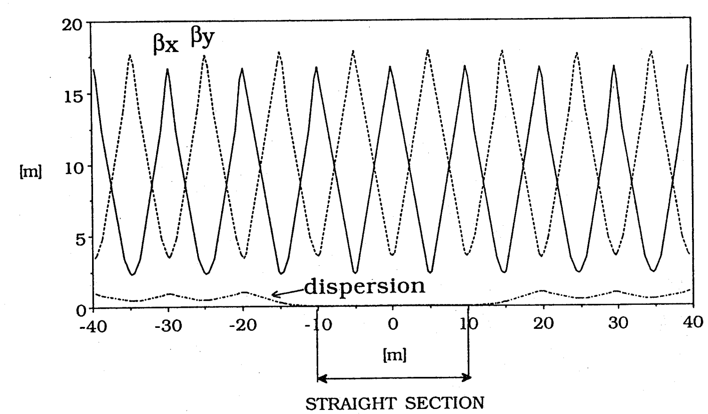


Fig.5 Optics of the synchrotron



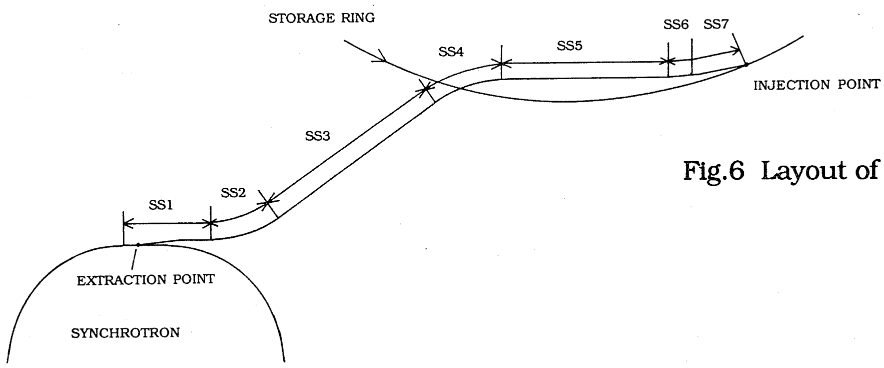
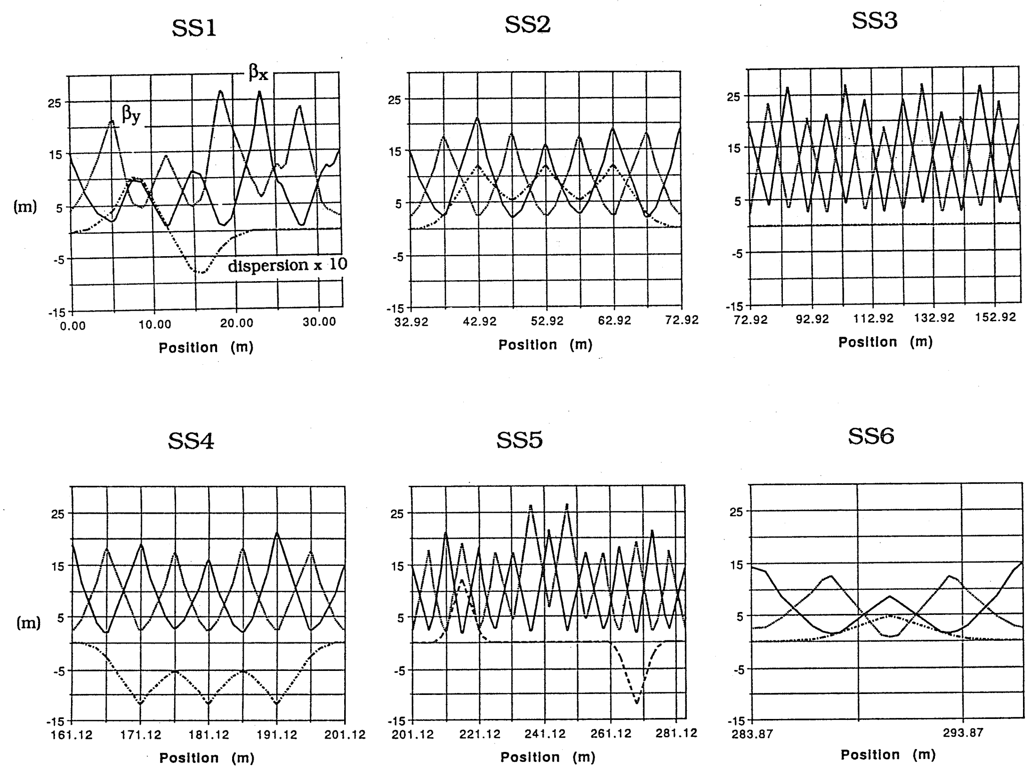
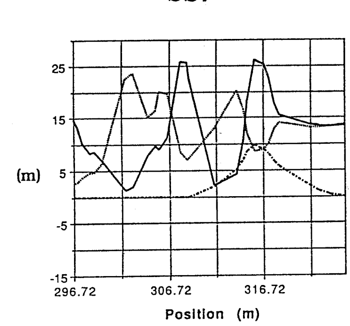


Fig.6 Layout of the SSBT line

Fig.7 Optics of the SSBT line





References

1. H.Suzuki, *et al.*, Proc. of The 7th Symp. on Accelerator Science and Technology, Osaka, Japan (1989).
2. M.Kabasawa, *et al.*, JAERI-M 89-109, Japan Atomic Energy Research Institute (1989).
3. T.Harami, *et al.*, Proc. of The XIV International Conference on High Energy Accelerators, Tsukuba, Japan, August 22-26, (1989), to be published.
4. H.Ohtsuka, *et al.*, Proc. of The 7th Symp. on Accelerator Science and Technology, Osaka, Japan (1989).