DESIGN OF A SMALL STORAGE RING IN JAERI

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Abstract

A small storage ring (JSR) is under construction to be installed into a present linac. The main purposes of JSR are the studies of the accelerator physics and the tests of some new ideas for aiming at the development of a high brilliant synchrotron radiation facility(6∿8 GeV). The ring size is limited by the available space of the linac building, so that the circumference of JSR becomes ∿20.5 m. However, even in this small ring, one straight section with the length of ∿1.5 m, where the dispersion is free, is provided for the insertion device study. JSR is an acceleration and storage type ring. The injection energy is 150 MeV and the stored energy is slowly increased up to 300 MeV. The beam current is ∿100 mA. The superperiodicity is 3 and the harmonic number is 8. JSR will come into operation on March, 1989.

Introduction

The brilliance of the synchrotron radiation source is required to be higher for the various advanced studies such as the material, chemistry, biology, medical science et al. A large synchrotron radiation facility with the electron energy larger than 6 GeV is planned to be constructed during next several years in Japan. The design studies of a low emittance ring have been started in our institute, and a small storage ring JSR is under construction to be installed into the linac[1] in order to study the accelerator technologies as well as to examine the new ideas such as the beam position control and the insertion devices for aiming at the next generation storage ring.

Basic Design Requirements

JSR must be located inside the linac building and its structure must be simple because of a small budget. The construction of JSR is required to be completed as soon as possible because this device is a studying machine for accelerator engineers who will work for the construction of the large synchrotron radiation facility. The available space for JSR is ∿10 m x ∿10 m in the linac building as shown in Fig. 1. Power supplies and some experimental equipments must be installed in the same room. The length of 1∿2 m is necessary around JSR for the experimental space so that the size of the ring itself should be about 7 m x 7 m or less. JSR is required to include a straight section without dispersion for the study of the insertion device and its length is preferable as long as possible. The lifetime of the stored electron beam is requested to be long enough to study the insertion device so that more than 1 hour is set for the requirement. The electron beam is supplied by the present linac with the energy of ∿150 MeV. In order to obtain the lifetime of 1 hour, the stored energy is increased up to ∿300 MeV in JSR after the accumulation.

Lattice Comparison

Several Lattices are compared for the candidate of JSR. Fig. 2 depicts six examples. (a)∿(c) are doublet-bend achromatic cell type (Chasman-Green type

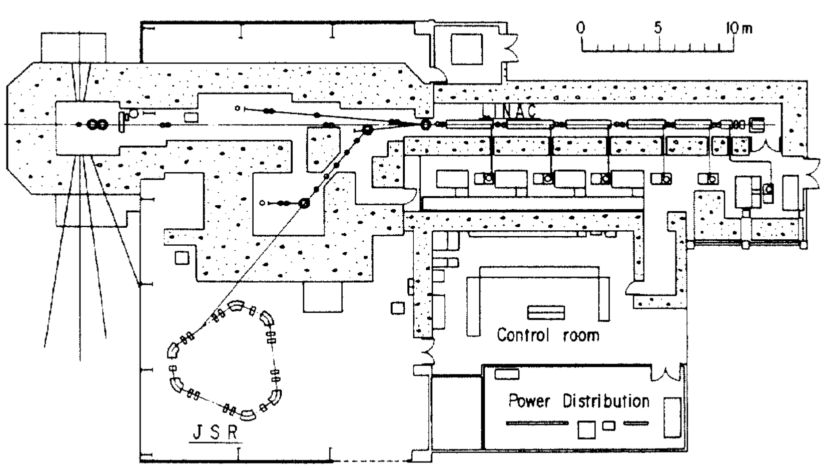

Fig. 1 Layout of the linac building.

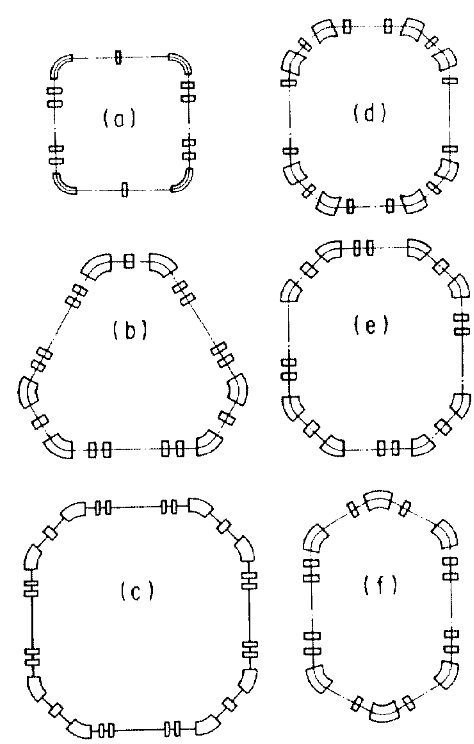

Fig. 2 Comparison of six different lattices. (a)∿(c) are CG-type with the superperiodicity of 2∿4. (d) and (e) are modified CG-type, and (f) is TBA-type.

[2]) with the superperiodicity of 2∿4, respectively. One cell needs about 7 m to include a free straight section, so that (c) becomes too large to be installed in the available space. The Touschek lifetime of (a) is short compared with the requirements. (d) is a modified type of (c) to reduce the circumference by means of using the gradient rectangular bending magnets instead of the defocusing quadrapole magnets. The circumference of (d) becomes small. But Q-magnets are all focusing type so that the tune control is restricted. The initial installation is also not easy due to the gradient bending magnets. (e) is also a modified type of (c), which is eliminated one set of doublet Q-magnets per each cell. The tune is relatively easy to be controlled, however the beta function becomes large and its shape is not symmetric at the center of the straight sections. (f) is triple-bend-achromatic cell type with the superperiodicity of two. The emittance is large and divergence of the beam size is large at the straight section in the case of (f). Finally (b) is selected for JSR lattice among several candidates. The triangle lattice is discussed before in other report[3]. The main features are that the size is tolerable to keep the experimental space around the ring, the emittance is relatively low, the Touschek lifetime is long, three straight sections without dispersion are provided for the installation of the beam injection devices, of a RF-cavity and of the insertion device, respectively. The lattice parameters of JSR are listed in table 1 and the plane view is shown in Fig. 3. The optical functions are plotted in Fig. 4. The beam cross section is small ∿0.5 mm at the straight section and smaller elsewhere. The dispersion function is easily controlled by a focusing quadrupole magnet located at the center of two bending magnets, and the tune is controlled by the doublet of the quadrupole magnets independently of the dispersion function. Fig. 5 shows the tie diagram around the operation region with keeping the dispersion function constant.

Linac

The linac is S-band type, and the output energy is 50-190 MeV. The accelerator tube is a traveling-wave disc-loaded type with the constant gradient,operating in the 2π/3 mode. There are two accelerator tubes with 2 m length, three tubes with 3 m length, and one buncher with 0.7 m length. Six klystrons are able to supply 110 MW peak power in total into the linac. The peak current is obtained 6 A at the pulse width of 20 nsec (600 pps) and 0.6 A at 1 μsec. The energy resolution of the output electron beam is achieved ∿1 % at the condition of the peak current ∿30 mA,the energy 135 MeV and the pulse width 1 μsec. In order to improve the energy resolution, the installation of a small aperture at the center of the beam transport system and some modifications of the linac power supply system are now under consideration.

Injection

The injection system is composed of a septum magnet and a kicker magnet which are located at the same straight section with ∿0.95 m separated each other. The kicker magnet generates the pulsed dipole field about 0.04 T with the pulse width of ∿0.5 μsec. The electron beam is kicked by 3 mrad and the displacement of the bump orbit is ∿22 mm at the

Table 1 List of Parameters

Stored energy		300 MeV
(Injection energy		150 MeV)
Circumference		20.546 m
Average radius		3.27 m
Revolution time		68.5 nsec
Available straight section		1.45 m
Number of bending magnets		6
Property of bending magnet		sector magnet
Bending radius		0.835 m
Bending magnet field		1.2 T
Number of quadrapoles		15
Strength of quadrupole field		$6.8\ m^{-2}$
		$4.1\ m^{-2}$
		$-5.6\ m^{-2}$
Natural emittance		1.1×10^{-7} m•rad
Natural chromaticity	x	-1.81
	y	-4.54
Tune	x	2.25
	y	1.25
Damping time constant	x	58 msec
	y	48 msec
	s	22 msec
Momentum compaction factor		0.044
Energy loss per turn		0.86 keV/turn
RF frequency		116.7 MHz
Harmonic number		8
Peak voltage		30 kV
Synchrotron phase		8.8 degree
Phase oscillation frequency		34.6 kHz
RF power		2 kW
Natural bunch length		1.6 cm
Touschek lifetime		∿2 hours

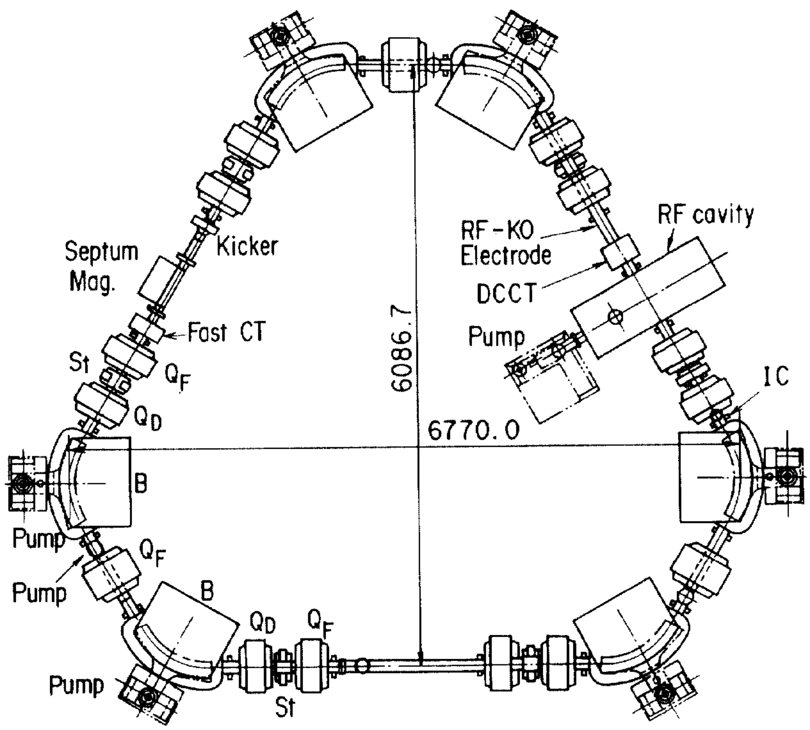

Fig. 3 JSR storage ring with ∿20.5 m circumference. The superperiodicity is three. B: bending magnet, Q_F: focusing quadrupole magnet, Q_D: defocusing quadrupole magnet, St: steering magnet, IC: ion clearing electrode.

injection point of the septum magnet. The septum magnet deflects the injector beam by 15 degree with the field of 0.89 T and the length of 148 mm. The electron beam is supplied by the linac with the pulse width of ∿0.5 μsec, which corresponds to the 8-turn length of the JSR circumference. The electrons in 3∿5-turn length are expected to be captured in JSR. Assuming that electrons of 1-turn length are stored in JSR with the peak current of 3 mA, then the ring current increases ∿3 mA per each injection. The synchrotron damping time of the horizontal direction is ∿0.5 sec at the energy 150 MeV. The injection from the linac will be repeated every 1 sec to accumulate electrons in the ring. It will take ∿33 sec to accumulate 100 mA in the ring if there is no beam loss mechanism. After the accumulation of electrons at 150 MeV, the electron energy is gradually increased up to 300 MeV. Because the bending magnets are iron block type, the speed of the acceleration is limited by the eddy current effects in the magnets. It will take a few minutes to increase the stored energy from 150 MeV to 300 MeV.

Vacuum and Beam Monitors

The cross section of the vacuum chamber at the straight section is a racetrack shape as shown in Fig. 6. The inside dimensions are determined by the calculation of the closed orbit distortion times 2.5 and the beam size times 10[4]. The duct at the bending magnet section is a rectangular shape with the similar dimension as the straight section. The vacuum chamber is composed of the stainless steel SUS 316L of 3 mm thickness, which is carefully fabricated for a high vacuum operation. The average base pressure is expected ∿2 x 10^{-9} Torr. The vacuum chamber is able to be heated up to ∿150°C. The position monitors of the electron beam are installed in the vacuum chamber at the entrance of each bending magnet. One position monitor is made up of 4 electrodes and their signals are sequentially processed in the data analysis computer. The tune is measured by RF-knock out electrodes and the beam current is monitored by a DCCT and a fast CT. The injector beam is monitored by two profile monitors composed of screen targets, which are located in front of the septum magnet and in one straight section of the ring. One electrode is installed for the purpose of clearing ions and if necessary some electrodes for the position monitors will be used for the ion clearing.

Schedule

JSR program has been started early in 1988. Design will be completed in June and devices will be manufactured until the end of 1988 and the installation in the linac building will be started early in 1989. The initial beam will be injected into JSR in March, 1989.

References

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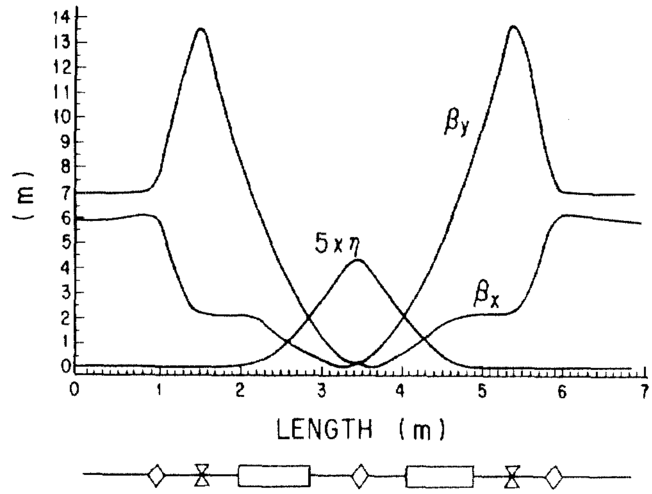

Fig. 4 Optical functions of one cell.

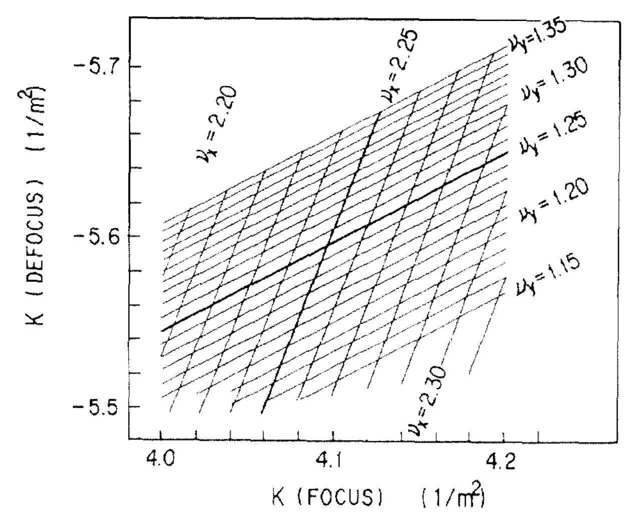

Fig. 5 Tie diagram when the dispersion function is fixed.

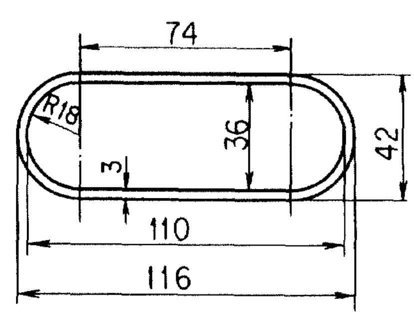

Fig. 6 Cross section of the vacuum chamber.