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INJECTOR DESIGN FOR THE 8 GEV SYNCHROTRON RADIATION FACILITY IN JAPAN

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Abstract The improved injection system consists of a 1.0 GeV linac and a 1 Hz, 8 GeV synchrotron(circumference 396 m) for the synchrotron radiation facility planned in Japan.The natural emittance of the synchrotron with a racetrack shape of lattice is about 1.95×10^{-7} m ·rad at 8 GeV, which is expected to be satisfactory for subsequent injection into the storage ring.

INTRODUCTION

The design, research and developments are under way to construct the new facility for a high brilliant synchrotron photon source in Japan[1]. The project is carried forward by Japan Atomic Energy Research Institute(JAERI) and the Institute of Physical and Chemical Research(RIKEN), under the supervision of Science and Technology Agency(STA) of our government.

The injection system was first designed on a rather large scale taking into account the future extensive use of the facilities[2]. In the meantime, the design of the injection system has been improved to be reasonable by the consideration of the injection efficiency into the storage ring and the cost. The improved injection system consists of a 1.0 GeV linac and a 1 Hz,8 GeV synchrotron (circumference 396 m).

The two basic modes of operation, the multibunch and single bunch charging of the storage ring, are considered with the loaded beam current of 100 mA and 5 mA, respectively. The injection system is capable of filling the storage ring to its full current of electrons within two minutes on the assumption that the transmission of electrons is about 30 % from the exit of the linac to the storage ring. In the case of using positrons instead of electrons, the filling time will be significantly longer than with electrons. A positron accumulating and damping ring is considered as an option to be installed.

LINAC

The linac is made up of three parts to accelerate electrons and positrons. The first section is a 50 MeV electron linac, followed by the second section of the linac to accelerate electrons up to 1 GeV for the injection into the synchrotron. The third section is a 200 - 250 MeV high-current electron linac that impinges on a converter target to generate the positrons. The positrons are focused through a pulsed solenoid magnetic field and then accelerated by the second section of the linac.

Some of the major parameters of the linac system are listed in Table 1. The pulses with a narrow width of 1 nsec are planned to be produced by a combined way of a grid pulser,a subharmonic buncher and bunchers. An option is considered for the macropulse waveform of electrons which has successive 500 pulses with the 1nsec width at every 2 nsec interval.

The linac is designed to operate at the maximum frequency of 60 Hz. The acceleration tubes are $2\pi/3$ traveling wave mode and each is about 3 m long.

An energy compression system (ECS) , made up of dipole magnets and a radio frequency cavity is planned to be attached to the end of the linac to minimize the energy spread of the electron beam from the linac.

SYNCHROTRON

The synchrotron is designed to accelerate

Table 1 Linac parameters

Energy	1.0 GeV
Repetition rate	60 Hz
Frequency	2856 MHz
Multibunch mode(e-)	
Peak current	100 mA
Pulse length	1 ms
Single bunch mode(e-)	
Peak current	300 mA
Pulse length	1ns
Multibunch mode(e+)	
Peak current	10 mA
Pulse length	10ns
Single bunch mode(e+)	
Peak current	10 mA
Pulse length	1ns

Table 2 Synchrotron parameters

Injection energy	1.0 GeV
Maximum energy	8.0 GeV
Radiation loss	11.5MeV/turn
Nominal tunes	11.73(x)/8.78(y)
Beam emittance	1.95 x 10-7 m·rad
Nat. chromaticity	-15.3/-12.7
Mometum compaction	9.51 x 10-3
Bending magnets	
field	0.85 T (8 GeV)
bending radius	31.4 m
Quadrupole magnets	
field	14.5 T/m (QF)
	12.5 T/m (QD)
Sextupole magnets	
field	201.3 T/m^2 (SF)
	162.7 T/m^2 (SD)
RF system	
frequency	508.58 MHz
harmonic number	672
voltage	17.1 MV (8 GeV)
Quantum lifetime	over 10 seconds

electrons injected from the linac at an energy of 1 GeV to the full energy of the storage ring of 8 GeV. The synchrotron lattice is based on a separated function FODO arrangement of magnets[3]. There are four dispersion-free straight sections on opposite sides of the synchrotron giving a racetrack shape. Injection is on one side and extraction on the other side. 8 rf cavities (f_{RF}= 508.58 MHz) are located in two straight sections upstream of the injection and the extraction regions (4 cavities in each region). Some of the major parameters of the synchrotron are shown in Table2.

Lattice

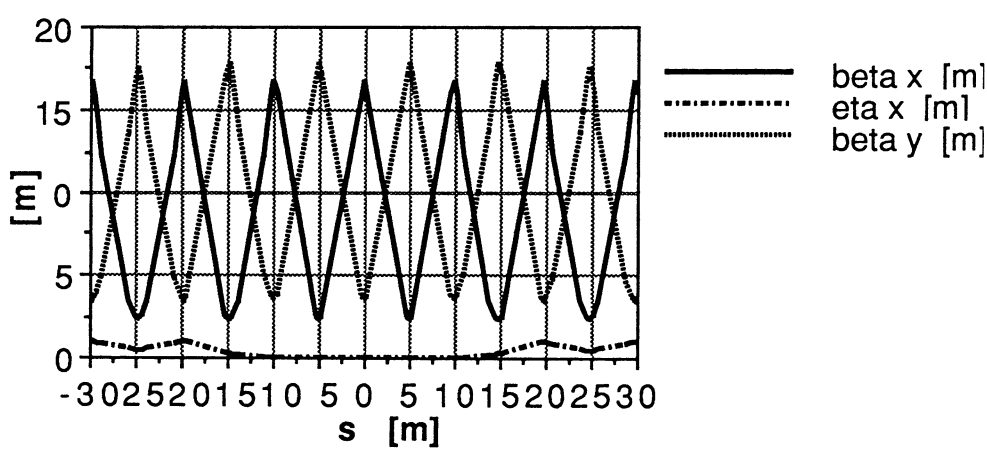
The injector synchrotron has 40 FODO cells. There are 32 normal cells in the lattice. Dispersion is suppressed by removing a bending magnet from a normal cell, followed by a full empty cell.

The horizontal and vertical tunes are, 11.73 and 8.78. Figure 1 shows the lattice functions for these particular tunes. Four dispersion-free straight sections are 4.35 m long. The natural emittance at 8 GeV is 1.95 x 10^{-7} m·rad. This value of emittance is expected to be quite satisfactory for subsequent injection into the storage ring. The natural chromaticities of the lattice are ξ_x= -15.3 and ξ_y= -12.7. To correct the chromaticities, 16 focusing and 32 defocusing sextupoles, each 0.15 m long, are placed near focusing and defocusing quadrupoles. The sextupole strength are 201.3 T/m^2 for the focusing and 162.70 T/m^2 for the defocusing sextupoles.

The lattice has a large dynamic aperture according to the calculation performed using the tracking code RACETRACK.

The incoming beam rms emittance of 1 x 10^{-6} m ·rad, the maximum β function of 16.7 m and the maximum dispersion function of 1.0 m give rms beam size of 9.1 mm at the quadrupoles

Fig. 1 β and dispersion functions for the synchrotron



in the horizontal plane.
The vertical half-height of the vacuum chamber in the quadrupoles is 18 mm which is 4.4 times the rms beam size of 4.1 mm in the vertical plane. The gap of the bending magnet is 45 mm. At injection, incoming linac macropulse is 1 nsec long. The bucket length is more than 1 nsec, which may assure an effective capture efficiency.

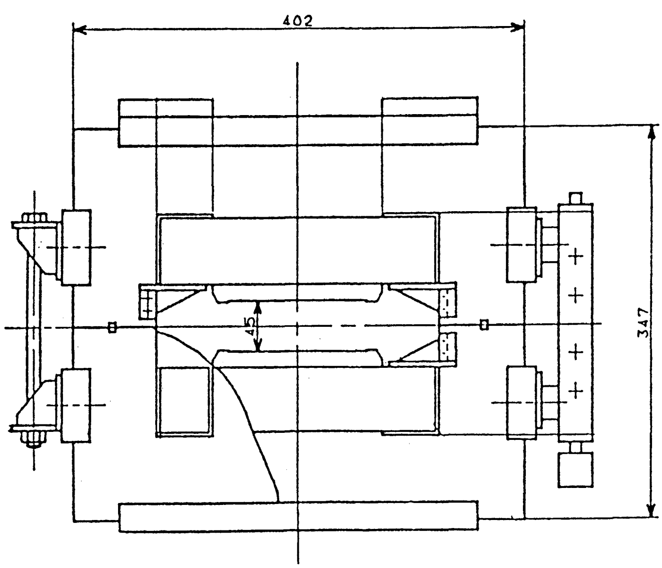
Magnets

The major ring magnets for the synchrotron consist of 68 dipoles, 80 quadrupoles and 68 sextupoles. These magnets are assembled by stacking 0.5 mm thick silicon steel laminations. The cross section of the magnets has been determined by 2D calculations using TRIM.
The dipoles are specified as H magnets. The pole profile is shown in Fig.2 The pole width is 150 mm with lateral shims 9 mm wide by 1.2 mm high. The magnetic field variations has been calculated to be $\Delta B/B = 5 \times 10^{-4}$ within an aperture of x = + 35 mm, y = + 15 mm. There are no saturation effects with the maximum magnetic field of 1.5 T throughout the yoke.
The pole tip of the quarupoles is hyperbolic (equation:$xy = (31)^2/2)$ for a total angle of 45° and continued by a linear tangent. The magnetic field is correct ($\Delta B/B < 1\times10^{-3}$) up to x = 22mm. The Bohr radius and the length of the sextupole is 42 mm and 0.2 m, respectively.

Vacuum system

The synchrotron ring vacuum system is designed to satisfy the following main requirement; maintain a pressure of 1×10^{-6} torr with a 8 GeV 10 mA beam of electrons to give a lifetime of more than 10 seconds due to gas scattering.
The vacuum chambers are made from 1.5 mm thick stainless steel tubes formed to a race-track shape. The inside dimensions are 36 mm height and 72 mm width. The eddy cur-

Fig. 2 End view of bending magnet for the synchrotron

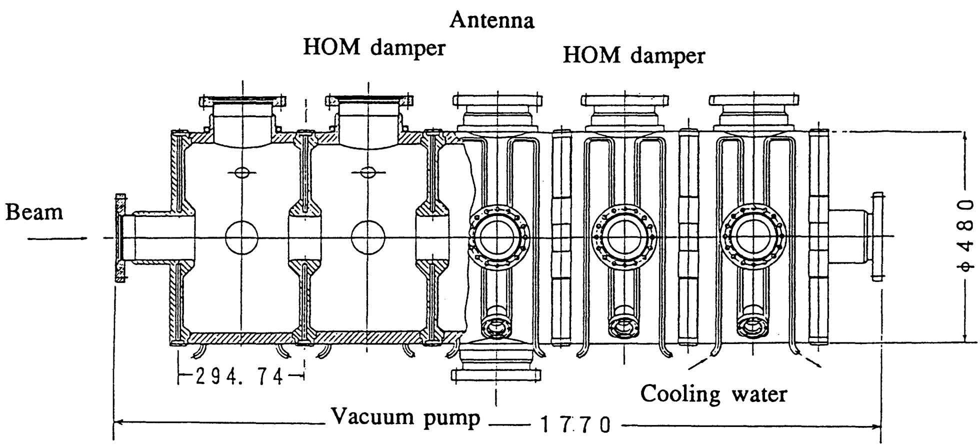


rent effect is negligible. The heating of the chamber due to synchrotron radiation requires no additional water cooling.

RF system

The rf system is designed to adopt a frequency of 508.58 MHz because of the availability of suitable klystrons at this frequency in KEK. The same rf frequency is used as for the storage ring. The 1/2 resonant cavities is shaped nose cone type to optimize the shunt impedance, shown in Fig.3. There are 5 cells per cavity coupled to each other through slots. The effective shunt impedance is 21 MW/m. The rated dissipation power per cavity is evaluated to be about 150 kW. A minimum of 8 cavities may be required to satisfy the synchrotron design parameter specifications.

Fig. 3..Side view of 5 cells rf cavity for the synchrotron



BEAM TRANSPORT SYSTEM

Figure 4 shows the layout of the injection system and the storage ring. The facility is built on the ground created in the hilly country of Nishiharima. The injection system and the storage ring are based on rock bed. The injection system is planned to be built on the lower ground by about 10 m than that of the storage ring.

The 60 m beam transfer line from the linac to the synchrotron is composed of the injection septum in the synchrotron and bending magnets and quadrupole magnets to match the dispersion function in the synchrotron and the phase-space matching between linac and synchrotron.

The transfer line between the synchrotron and the storage ring is made of three parts. The first part of the transfer line is an achromatic cell. This achromatic cell eliminate the dispersion created by the extraction hardware. The dispersion-free second part contains quadrupoles for matching the functions from the synchrotron to those of the storage ring. The third part, which includes the storage ring injection magnets, is an achromatic cell that matches the dispersion function in the ring. The total length of the transfer line is about 270 m. This long beam line can afford a place around the injection system building for the future use of the synchrotron to another application.

CONCLUDING REMARKS

The current design, research and development of the injection system was described for the 8 GeV synchrotron radiation facility in Japan. The R&D of the hardwares, magnets, rf cavities and vacuum chambers for the synchrotron is carried out this fiscal year. The test of the positron generation system is planned. The design of the injection system will be improved on the basis of these studies.

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Fig. 4 Layout of the injection system and the storage ring