INJECTION SYSTEM FOR THE 8 GeV SYNCHROTRON RADIATION FACILITY IN JAPAN

H. Yokomizo, T. Harami, K. Yanagida, K. Mashiko, K. Ashida, S. Harada, H. Hashimoto, M. Iizuka,
T. Ishida, M. Kabasawa, K. Nakayama, K. Yamada, H. Konishi, S. Sasaki, Y. Suzuki, H. Kamitsubo
JAERI-RIKEN Synchrotron Radiation Facility Design Team
JAERI, Tokai-mura, Naka-gun, Ibaraki-ken, 319-11,Japan

Abstract

The injection system for the new storage ring is designed. The system is composed of a 1.5 GeV linac and a 8 GeV synchrotron which are able to accelerate the electrons and the positrons. In order to fill the positrons in the storage ring in a short time, the synchrotron is operated as the accumulation ring to store the particles at 1.5 GeV for 8 sec. The acceleration and de-acceleration in the synchrotron are operated in 0.9 sec, respectively. This synchrotron radiation facility is planned to be established in Nishiharima where is located at the western part of Japan. The design of the injection system will be improved for next two years when the research and developments will be also carried out in several components.

Introduction

The new 8GeV storage ring in Japan is planned to store the positrons and electrons[1]. The injection system of this facility has to fill the particles in the storage ring within the reasonablly short time at every reinjection. The charging time is requested to be shorter than 15 minutes in any modes of the storage ring operation. The typical cases of the operation modes considered are a multibunch mode and a single bunch mode in the storage ring with the stored beam current of 100 mA and 5 mA, respectively. In order to avoid any disorder of the experimental condition for users, it is determined to inject the particles into the storage ring at its full operating energy (full energy injection). This full energy injection may provide users the stable light position of the synchrotron radiation at every reinjection because of no need for the field swing of the storage ring magnets. This also provides the capability of two different reinjection ways, which are one or two reinjection per every day and so-frequent reinjection to keep the number of the stored particles constant. The injection system might be considered for the future extension of the facility, which means the utilization of the injection system for the other science; such as the free electron laser in the ultra-violet region, other small storage ring, positron production etc.

The injection system is composed of two accelerators; first is a 1.5 GeV linac and second is a 8 GeV synchrotron. These values of 8 GeV and 1.5 GeV are determined in consideration of the full energy injection and the future extension. Two electron guns are prepared in the linac, one is low intesity for the electron beam and one is high intensity for the positron production. The positron beam current of is low compared with the electron beam current so that the synchrotron is used as the accumulation ring of the positrons to minimize the charging time into the storage ring. Thus, this injection system does not need the positron accumulator[2] following to the linac nor a double RF system[3] in the synchrotron. This is one of merits of the 1.5 GeV linac. The acceleration and de-acceleration are slowly performed for about 2 sec in the synchrotron. The requirements for the thyristor power supplies of the synchrotron magnets become reasonable due to slow energy ramp-up.

Linac

The linac is required to provide the positrons and the electrons with the high intensity and high beam quality. The linac system is separated with three sections; an electron linac(60 MeV), a positron linac(250 MeV for the electron, positron converter, 50 MeV for the positron) and one main linac(1.5 GeV) as shown in Fig. 1. Fig. 2 shows the illustration of the macropulse waveforms for the each cases of the operation modes. These values shown in Fig. 2 are lower limits expected to be delivered into the synchrotron with the emittance of no more than 2π mm•mrad(95%) and the energy spread of no more than ±0.5%(95%). In order to provide more than 10 mA positron beam, the electron linac for the positron converter is planned to provide 10 A beam onto the tantalum target. In the case of the electron operation, the gun will provide 0.5-1 A beam for the margin in the uncertainty of the beam quality. The pulses with a narrow width of 1 nsec are planned to be

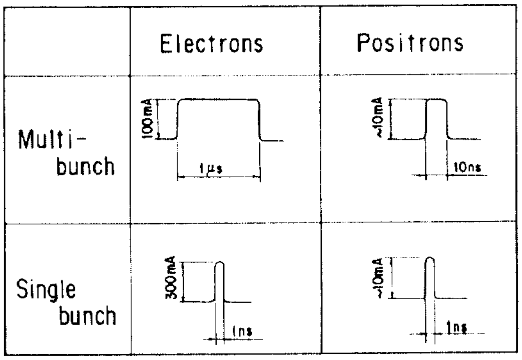

Fig. 2 Macropulse waveforms provided by the linac.

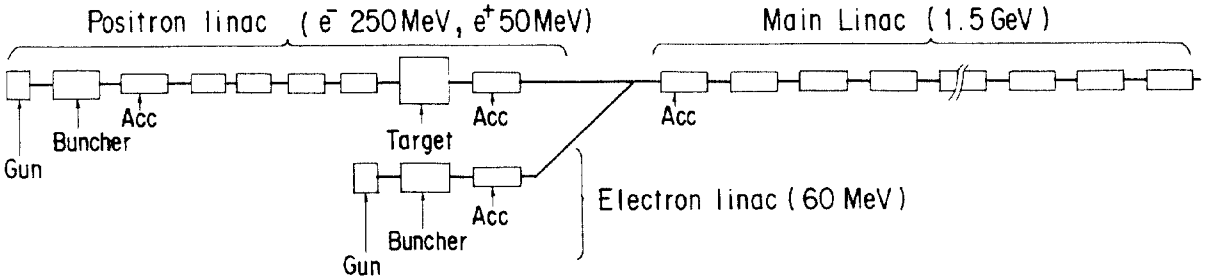

Fig. 1 Illustration of the linac. Acc means the acceleration tube.

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produced by a combined way of a grid pulser, a subharmonic buncher and bunchers. One option is considered for the macropulse waveform, which has successive 500 pulses with the 1 nsec width at every 2 nsec interval (so called a burst beam). This is one of the future developments.

The frequency of the RF acceleration is presently chosen to be 2856 MHz. This frequency is under consideration in relation to the storage ring RF frequency which is presently chosen to be 508.6 MHz. In the case of the multibunch operation, the ratio of the RF frequencies for the linac and the storage ring is better to be integer, because the number of particles is easily achieved to be almost constant in each bucket. In order to provide the high quality beam(especially the low energy spread), the RF frequency stability, the output power of the klystrons and the temperature of the accelerating waveguides must be carefully controlled in the narrow windows. The linac is presently designed to operate at the maximum 60 Hz repetition which will be decided consistently in consideration of the operation scinario. The acceleration tubes are $2\pi/3$ traveling-wave mode with constant field gradient, except the first section just after the gun, and each is about 3 m long. The types of the structure of the acceleration tube are now considered by comparison of two typical cases of the disc-loaded waveguide and the higher-shunt-impedance waveguide[4]. The capabilities of these waveguides will be evaluated in the laboratory. Every acceleration tube is planned to be excited by each powerful klystron with the power of more than 30 MW, which will produce the field gradient of about 17 MV/m.

Synchrotron

The FODO type lattice is chosen for the synchrotron to obtain the low emittance and the small dispersion function. There are four dispersion-free straight sections in the lattice. One straight section is composed of three cells in which the bending magnets are missing as shown in Fig. 3. Two straight sections are dedicated to the RF acceleration system, the rests are used for injection and extraction of the beam. There are 36 normal cells and 48 cells in total included in the lattice. 72 sextupole magnets are installed for the correction of the chromaticities and 36 correcting magnets which have the vertical and horizontal field coils are prepared to correct the closed orbit displacement.

The betatron functions are 17 m at the maximum and 3 m at the minimum in both vertical and horizontal directions. The maximum dispersion function is 0.84 m, which is one of the key parameters to decide the lattice because the value of the dispersion function affects to the vacuum chamber size at the injection from the linac. The synchrotron parameters are listed in Table 1. The tune values are chosen to achieve the dispersion free at the center of the straight section.

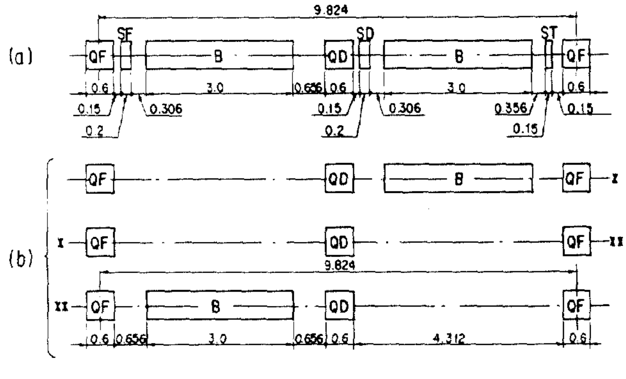

Fig. 3 Synchrotron lattice. (a) Normal cell, (b) Straight section with three cells.

Table 1 List of synchrotron parameters.

Injection energy		**1.5GeV**
Maximum energy		**8GeV**
Maximum beam current		**10mA**
Beam emittance horizontal		**1.19×10^{-7} (m·rad) (K=0)**
vertical		**1.2×10^{-8} (m·rad) (K=0.1)**
Energy spread at maximum energy		**1.1×10^{-3}**
Circumference		**471.552m**
Repetition rate		**0.1Hz**
Radiation loss per turn		**9.5MeV/turn**
Number of cells / Periodicity		**48 / 4**
Nominal tunes($\nu x/\nu y$)		**13.735/10.735**
Natural chromaticities($\xi x/\xi y$)		**-17.5/-14.5**
Momentum compaction		**6.79×10^{-3}**
Bending magnet		
Number of magnets		**80**
Magnet field		**0.69866T**
Length		**3.00m**
Bending radius		**38.197m**
Quadrupole magnet		
Number of magnets(QF/QD)		**48/48 Total 96**
	QF :	**14.43T/m**
	QD :	**-12.683T/m**
Length		**0.6m**
Sextupole magnet		
Number of magnets(SF/SD)		**36/36 Total 72**
	SF :	**92.3T/m²**
	SD :	**-149.62T/m²**
Length		**0.2m**
Damping time($\tau x/\tau y/\tau \varepsilon$)	**1.5GeV**	**407.9ms/402.5ms/199.9ms**
	8GeV	**2.7ms/2.7ms/1.3ms**
(βx)max/(βy)max/(ηx)max		**16.7m/17.4m/0.84m**
RF system related parameters		
Resonant frequency		**508.6 MHz**
Harmonic number		**800**
Accelerating voltage		**14.2MV at 8GeV**
Over voltage factor		**~1.5 at 8GeV**
Synchrotron frequency		**22.5kHz at 8GeV**
Beam lifetime		
Quantum lifetime		**over 5 min at 8GeV**
Touschek lifetime		**over 5 min at 10mA 1.5GeV**

The bending magnet field is 0.7 T which is selected for the reason of lowering the radiation power in the bending magnets. The radiation loss is 9.5 MeV per one turn. The RF system is phase locked at the same frequency 508.6 MHz as one in the storage ring. The cavities with multi-cells will be developed to provide the stable operation with the type of the structure coupled by the peripheral slots[5]. One cavity has five cells, and each cell length is half of the wavelength. 8 cavities are planned to be installed in two straight sections, and they are able to provide the total power of 1 MW. The maximum beam current is assumed to be 10 mA in the synchrotron. The required powers are estimated to be 100 kW for the beam loading and 800 kW for the wall loading.

The vacuum chambers are made from 1.5 mm thick stainless steel tubes formed to the racetrack cross section. The inside dimensions are 30 mm height and 60 mm width in any place as shown in Fig. 4 except in the injection and extraction regions. The eddy currents occured in the chamber at the acceleration phase are estimated to be small enough to be ignored compared with the effects due to the COD. Two small ion pumps are equipped at each cell to maintain the vacuum pressure less than 10^{-6} psi. The turbomolecular pumps are used to start the evacuation of the vacuum chamber.

Operation scenario

In the case of the electron operation, the current of the electron beam from the linac is high enough to fill the particles in the storage ring in a short time of less than 1 min. The linac provides one macropulse into the synchrotron and the synchrotron immediately accelerates the electrons from 1.5 GeV to 8 GeV for 0.9 sec and transfers them to the storage ring. The repetition of this charging procedure is 0.5 Hz on the both cases of multibunch and single bunch modes. These acceleration and de-acceleration speed are chosen to keep the requirements for the magnet power supplies in the reasonable specifications.

In the case of the positron operation, however, the intensity of the positron beam from the linac is so small that the sophisticated charging procedure is required to fill the positrons in the storage ring within a reasonablly short time. The eight bunches are injected at the equally spaced positions in the synchrotron. The present synchrotron has 800 harmonics, so that each bunch locates at every 100 harmonics which means that it takes 196 nsec for one bunch to move to the next bunch location. The bump magnets which creates the field to perform the bump orbit for injection are excited for 200 nsec with the flat top of 40 nsec as shown in Fig. 5. The bump field should be de-excited within 80 nsec before the next bunch reaches the location of the bump magnets to avoid the next bunch hit the wall of the septum magnet. After the injected beam size becomes small by means of the radiation damping, the positron beam is added in each bunch to increase the number of the positrons in the synchrotron. The radiation damping time is 0.4 sec at 1.5 GeV in this synchrotron so that the injection into one particular bunch is planned to be repeated at every 0.5 sec interval during 8 sec period as shown in Fig. 6. The acceleration and de-acceleration sequence is same as the case of the electron operation. The same sequence as shown in Fig. 5 is used for the extraction at 8 GeV on the case of the single bunch mode. In the case of the multibunch mode, the duration time at the flat top phase is requested to be longer(1600 nsec). Using this injection scenario, it is estimated to take 12 min and 3 min to fill the positrons in the storage ring in the both cases of the multibunch and the single bunch modes, respectively.

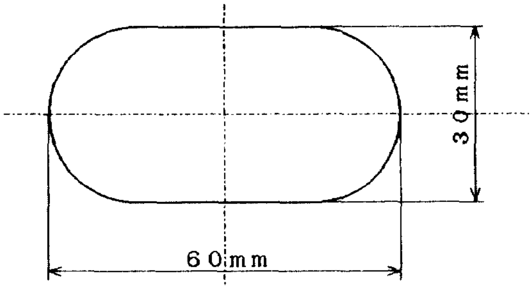

Fig. 4 Cross section of the vacuum chamber.

Arrangement

The injection system is located outside of the storage ring to keep the capabilities for the future extension. The beam transport lines between each accelerator become long, 100 m for the line between the linac and the synchrotron, and 200 m for the line between the synchrotron and the storage ring. These long beam transport lines, however, are tolerable for the future extension utilizing the injection accelerators.

Schedule

This new synchrotron radiation facility is now on the design work until 1990. The construction will be started in 1991, and the commisioning is planned in 1995. The design described in this paper will be revised and improved for next two years. The research and developments are also planned to be carried out in several major components at the same time.

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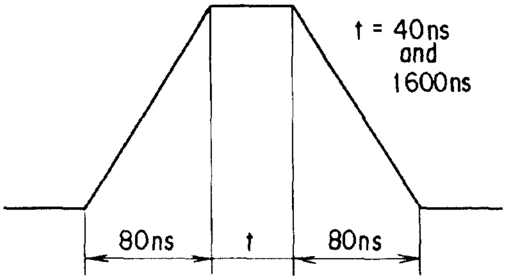

Fig. 5 Waveform of injection and extraction magnets. t=1600ns is used for the injection of 1 μsec macropulse and for the extraction of the multibunch modes.

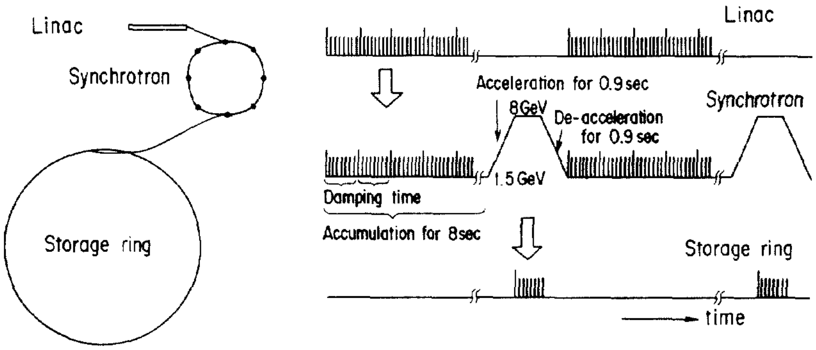

Fig. 6 Operation scinario in the case of the positron operation.