Linac

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Introduction

The injector system of SPring-8 is composed of a 1GeV linac and a 8 GeV booster synchrotron. In order to have a reliable operation of the storage ring, a maximum energy of 8GeV is chosen for the synchrotron to provide a full energy injection of electrons or positrons into the storage ring. The energy of 1GeV for the linac was determined by taking account the easy operation of the synchrotron as well as the possibility of wider applications of the linac beam for various future sciences.

The construction of the linac was started in 1991. The injection part of the linac was already manufactured and assembled at the Tokai site of JAERI to examine the beam characteristics and to assess the hardware design. The accelerator columns and beam transport magnets were already manufactured and delivered into the site. Remaining components are under the way of fabrication.

Design of the linac

In order to produce a positron beam, an electron/positron converter is installed in the midst of the linac. Therefore, the linac consists of a 250 MeV high-current linac, the converter, and a 900 MeV main linac. The electron is able to be accelerated up to an energy of 1.15 GeV by means of extracting the converter from the beam line. Two operation modes in the storage ring are considered; a multi-bunch mode and a single bunch mode with a stored current of 100mA and 5mA, respectively. The charging time to store the full current into the storage ring is within 1 min. in the case of electron operation, and it becomes about 20 min. in the case of positron operation. To shorten the charging time in the case of positron operation, a space is prepared between the linac and the synchrotron to install a positron accumulating/damping ring(PAR), or an energy compressing system(ECS) as an option. At the same time a further effort will be continued to increase a production efficiency of the positron beam. The linac RF-frequency is 2856MHz, and a repetition rate of operation is 60Hz. The design parameters of the linac are shown in Table 1.

Table 1. Linac Design Parameters

Energy	Positron	0.9 GeV
	Electron	1.15 GeV
Repetition rate		60 Hz
RF frequency		2856 Mhz
Total length		140 m
Beam Current	Positron	10 mA
	Electron (1ms)	100 mA
	Electron(1ns)	300 mA
Emittance	Positron	< ± 1.0%
	Electron	< ± 1.5%
Electron gun	Cathode assembly	Y796
	Voltage	200 kV
Accelerator column	Number	26
	Structure	Traveling wave
	Mode	$2\pi/3$
	Cell number	81
	Length	2.835 m
	Input power	26 MW
	Energy gain	45 MeV
Converter	Target	Tungsten
	Thickness	7 mm
	Electron energy	250 MeV
LSBT	Length	39 m
	Deflection angle	15 degree

The electron beam is generated by a dispenser cathode assembly; model Y796 (EIMAC) with a cathode area of $2cm^2$. It is able to produce 20A pulsed beam current at an extraction voltage of 200 kV. This electron gun is operated in two modes; one is a high current mode for positron production, and the other is a relatively low current mode for electron use. The beam current is controlled by varying the emission current from a gun, and also by physically defining the beam size using an iris that is placed just behind the gun. Three types of grid pulsers are prepared to generate different pulse length. A long pulse of more than 1 msec is generated by a line type pulse generator, and a short pulse of 10-40nsec is generated by a nanosecond pulser, and a single pulse of 1 nsec pulse is generated by a high voltage modular pulse source (HMPS) combined with a short stave. These three types of pulses are required to provide electrons or positrons into multibunches or a single bunch in the storage ring. Two prebunchers are used with a gap voltage of 20kV and 30kV, respectively. A buncher has a standing-wave structure with 13 gaps. The drift distances are 220mm, 142mm, between the first and second prebunchers, and the second prebuncher and a following buncher, respectively. 68% of the beam is bunched into 50 degrees phase spread at the entrance of the buncher, and it becomes bunched into 5 degree at the exit of the buncher. The initial beam is confined along a solenoidal field produced by 8 Helmholtz coils. The former four coils are able to produce 400 Gauss, and the latter are able to produce 800 Gauss.

The beam is accelerated by 26 accelerator columns. One accelerator column is 2.835m long containing 81 cells, and of 2p/3 traveling-wave constant-gradient type. Accelerator columns have three different types in a bore diameter of an exit iris, which are 20.0 mm, 20.5 mm and 20.95 mm, respectively. They are arranged in a manner to prevent multisection beam-breakup. The RF power is produced by thirteen klystrons with the maximum output power of 80 MW per each klystron. The RF power generated by one klystron will be divided into two accelerator columns through 3dB directional coupler. Accelerating RF power is designed to be 26 MW to each accelerator column, so that the average accelerating field is 16 MV/m, and the energy gain per each column becomes 45 MeV. The accelerator columns are designed to operate in the constant temperature of 30°C. The room temperature is planned to be controlled at 27±2°C, and the water-cooling system is planned to have a capability of adjusting the temperature within an accuracy of ±0.1°C. The beam focusing system along the linac is composed of triplet quadrupole-magnets. They are arranged to transfer the positron beam with the quality of 1.5 mm•mrad in an emittance, 1.5% in an energy spread at the exit of the linac. The total length is 140m from the electron gun to the exit of the linac including 18m for a space of the option, and a beam transport line is 39m between the linac and the synchrotron (LSBT). LSBT consists of 1 bending and 9 quadrupole magnets. The bending angle is 15 degrees.

Performance

Preinjector of the linac was tested at Tokai site to evaluate its beam quality and to examine the beam monitors. The main parameters such as beam energy, current were observed to satisfy the design values as shown in Table 2. The beam current of more than 10A was obtained with the pulse width of less than 1nsec. The maximum beam current was achieved to be more than 20A. The fluctuation of the beam current was less than 1.5%. The energy spread was less than 2%. The efficiency of the beam bunching was achieved to be about 65%. Performance of the linac preinjector is good enough to be ready for the normal operation.

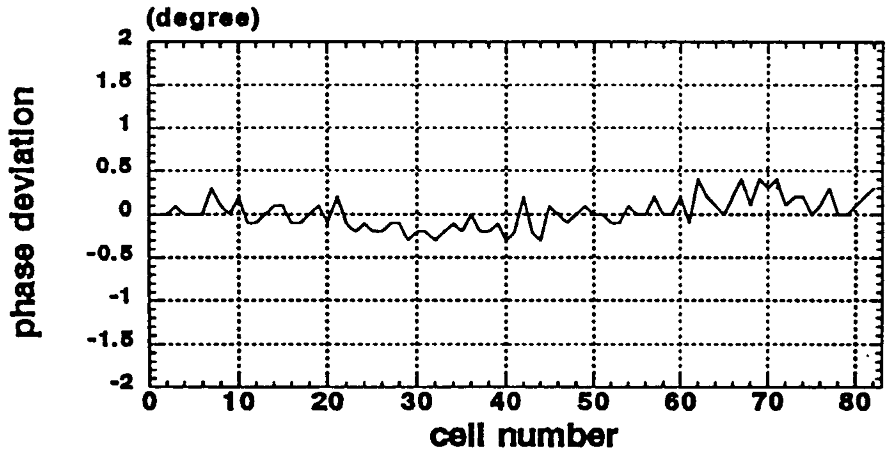

Figure 1. Phase deviation measured by Nodal shift method

Several types of beam monitors were tested in the preinjector. The beam current of a long pulse is measured by a current transformer, and that of a short pulse is measured by a wall current monitor and an amorphous-core type current transformer. The absolute value of the current is calibrated by a coaxial Faraday cup. These current monitors for a short pulse were proved to have good characteristics of the time response, less than 300psec.

The fabrication of the whole accelerator columns were completed and stored in the storage building under the condition filled with dry nitrogen gas. The phase spread of 81 cells in one accelerator column were achieved to be a good value with the fluctuation of less than 2 degrees which was the target value as shown in Fig. 1.

Table 2. Achieved Performance of Linac Preinjector

Maximum beam current	22 A
Stability of beam current	1.5 %
Pulse width	1-4 μsec
	10-40 nsec
	1 nsec
Bunching efficiency	64-65 %
Beam energy	9.1 MeV
Energy spread	± 2 %
Normalized emittance	130 mm•mrad