PRESENT STATUS OF THE INJECTOR SYSTEM FOR THE SPRING-8 PROJECT

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Abstract

Injector system of the SPring-8 Project was reinvestigated to reduce construction cost, while keeping the basic parameters of 1 GeV linac and 8 GeV synchrotron. In this paper the injector system with recent modifications is described.

Introduction

After several years for design study and research and development, the construction of the SPring-8 Project started this year. The whole system of accelerator complex, storage ring, preinjector linac and booster synchrotron as well as buildings and utilities is coming to final design in detail. So far a lot of works have been performed in designing each part of the facilities, and before finalizing the design consistently in keeping the initial purpose of the project, thorough reinvestigations have been implemented. Especially efforts have been made to reduce construction cost of the whole system. In this paper the injector system with recent modifications are presented.

The injector system composed of a 1 GeV linac and an 8 GeV synchrotron is capable for the full energy injection of electron and positron beam into the storage ring. The total lengths of the linac and the transport from the linac to the synchrotron were reduced substantially to 140 m and 35 m, respectively. The direction of the linac was rotated about 120 degrees to be parallel to the straight section of the synchrotron for beam injection. The circumference of the synchrotron was kept the same as before, but the straight section of the racetrack structure of the synchrotron was extended to install all RF cavities in one straight section instead of two. Vacuum system of the synchrotron and the beam transport from the synchrotron to the storage ring were reduced in the number of the components. The buildings for the accelerators, power supplies, control room and utilities were reduced considerablly.

Linac

The linac can provide a 10 ns positron beam and 1 microsec electron beam for multi-bunch operation in the storage ring, and also a 1 ns positron and electron beam for single bunch operation. The linac comprises a high current linac (HL), a main linac (ML) and an energy compression system (ECS). Between the HL and the ML an electron-positron converter is placed. A high current electron beam of the HL accelerated to 250 MeV is collided to a target to produce a positron beam, which is accelerated to 900 MeV in the ML. When the target is removed, an electron beam moderated to 10∼100 mA by a slit can be accelerated to 1.15 GeV. Expected emittance

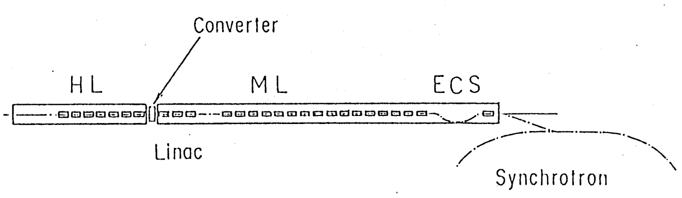

Fig.1 Schematic layout of linac.

Table 1 Parameters of linac.

Energy	1.0	GeV
Repetition rate	60	Hz
Frequency	2856	MHz
Accelerator section		
Structure	traveling wave	
Mode	$2\pi/3$	
Number of cells	81	
Length	2.835	m
Energy gain per section	40	MeV
Klystron operating power	26	MW

and energy spread at the end of the ML are 1.5(1.0) mmmrad and ± 1.5(1.0) %, respectively, for the positron (electron) beam. The energy spread can be reduced by the ECS to about 1/5, which will increase injection efficiency into the synchrotron. Parameters and schematic layout of the linac are shown in Table 1 and Fig.1.

A 10 A electron beam generated by a triode electron gun with a cathode erea of 2 cm^2 is accelerated to 200 kV. The pulse length of the beam is determined by a short pulse applied to the grid of the triode. The repetition of the pulse is 60 Hz. The beam is confined along a solenoidal field produced by a Helmholz coil. Two prebunchers are used efficiently to bunch the beam of 66 % into 40 degrees in RF phase of accelerating frequency of 2856 MHz. The beam is further bunched into 5 degrees in the phase and accelerated to about 6 MeV with an energy spread of ± 1.7 % by a following buncher. The beam is further accelerated by accelerator sections. Initial part of the linac is shown in Fig.2.

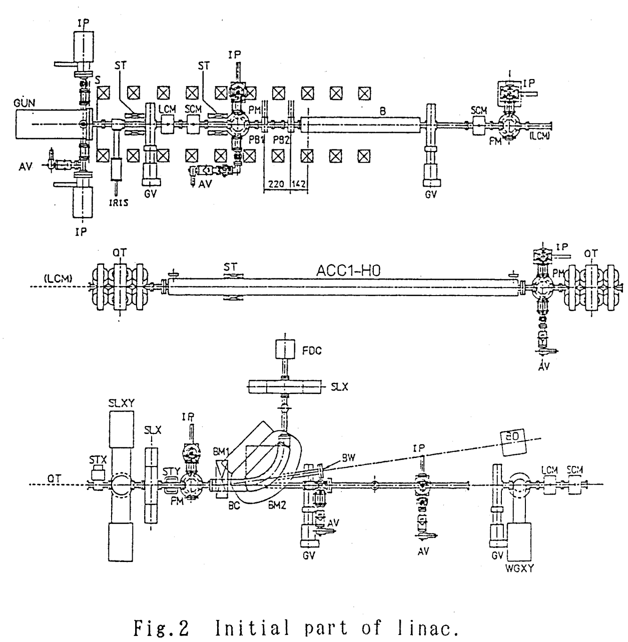

Fig.2 Initial part of linac.

The accelerator section is a disk loaded type composed of 81 cells with a total length 2835 mm, and operates at 2856 MHz in the $2\pi/3$ mode with a constant gradient field. The number of accelerator sections is 7 in the HL, 19 in the ML and 1 in the ECS. Each section is fed by 26 MW from a 35 MW klystron, which produces an acceleration field of 16 MV/m or 45 MeV per section. A low level microwave of 2856 MHz generated by a stable master oscilator is amplified by a booster klystron and distributed to the high power klystrons. The RF phase in each accelerator section is controlled in low level before the high power klystron. Power dissipation in one unit of the linac, modulator, klystron, accelerator section, dummy load and beam load, is 30 kW at most as shown in Fig.3.

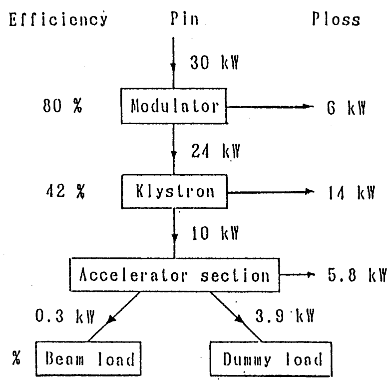

Fig.3 Power flow in one acceleration unit with 35 MW, 5 microsec, and 60 Hz for accelerator section

The 250 MeV 10 A electron beam with a size of 3 mm in diameter impinges a target to produce a positron beam with a large energy and angle spread. Among these, a positron beam with an energy of 5∼15 MeV and an angle less than 200 mrad is captured in the following accelerator section through a pulsed and a DC solenoidal field. An expected conversion efficiency of 0.001∼0.002 results in a beam current 10∼20 mA with an emittance about 1.5 mmmrad at 900 MeV.

The ECS is composed of four bending magnets and an accelerator section. The magnets produce an energy dispersion, and the particles with different energy travel different path length, and then they pass the accelerator section in different phase of accelerating voltage. Thus the energy spread is compressed, and also the beam energy is automatically adjusted.

Various kinds of beam monitors have been designed, and some of them are under development. Alignment of accelerator sections and quadrupole magnets for beam focusing is to be performed by using a laser beam. Recent study revealed a problem that a laser beam drifts more than 0.1 mm at a distance about 50 m. The linac is computer-controlled by a distributed network system using VME bass method. Software of the system is under development. There are several uncertain factors about the positron production and capture efficiency. A prototype of the system was constructed and investigations are under way. The initial part of the linac from the gun to the buncher was ordered and its performanec will be tested next year.

Synchrotron

The synchrotron accelerates the beam from 1 GeV to 8 GeV at a repetition of 0.5 Hz. Figure 4 shows the lattice of the synchrotron, which is composed of 40 FODO cells. There are 30 normal cells, two straight sections composed of three cells each, and four dispersion suppression cells with missing bend. Two kinds of quadrupole magnets and two kinds of sextupole magnets are used. Magnet arrangement in a normal cell is shown in Fig.5. The number of bending magnets was decreased from 68 to 64, and the emittance increased a little to 230 nmrad, which is expected not to reduce injection efficiency into the storage ring. RF cavities are installed in one straight section near beam injection section. Design parameters of the synchrotron are shown in Table 2.

Estimated beam stay clear at quadrupole magnets is 36 mm horizontally and 17 mm vertically, for which the aperture of vacuum chamber and the gap of magnet poles are provided.

Since the radiation damping time is about 1 sec at 1 GeV, eight pulses of electron or positron beam are injected in series at 60 Hz by on-axis method. For this purpose fast kicker magnets with a rise and a fall time

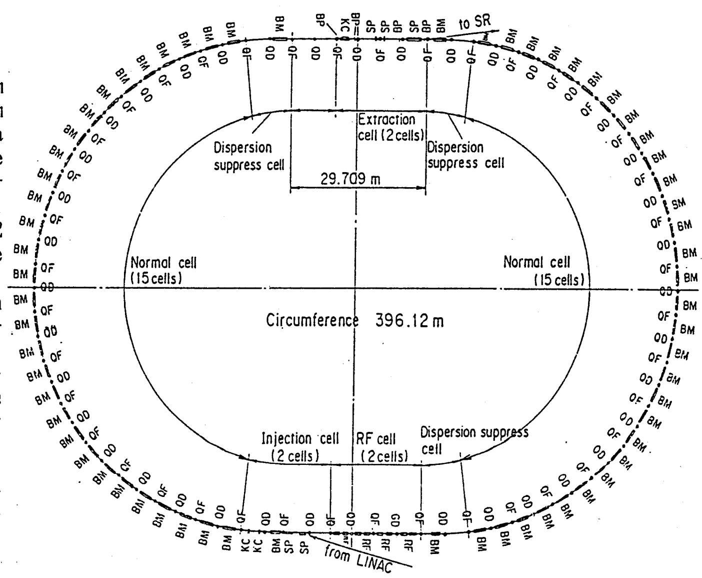

Fig.4 Lattice of synchrotron.

Table 2 Parameters of synchrotron.

Injection energy	1.0 GeV
Maximum energy	8.0 GeV
Circumference	396.12 m
Repetition time	2 sec
Natural emittance	230 nm.rad
Number of cells/periodicity	40/2
Nominal tune ($\nu x/\nu y$)	11.73/8.78
Natural chromaticity ($\xi x/\xi y$)	-14.4/-11.5
Radiofrequency	508.58 MHz
Harmonic number	672
Radiation loss (8GeV)	12.27 MeV/turn
Accelerating voltage (8GeV)	18.1 MV
Quantum lifetime	over 10 sec

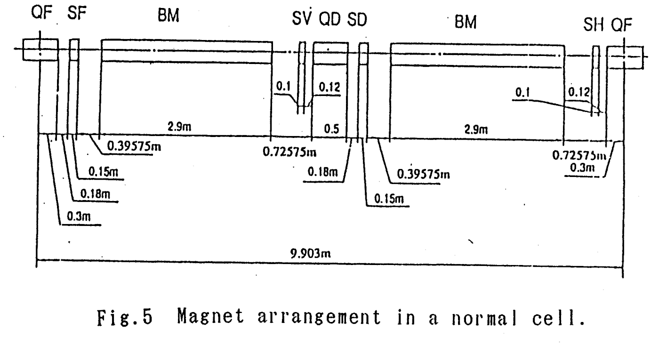

Fig.5 Magnet arrangement in a normal cell.

less than 100 nsec are used. Similarly the pulsed beam accelerated to 8 GeV is extracted at 60 Hz with fast kickers and bump magnets.

RF voltage is 19 MV at 8 GeV for a quantum lifetime about 10 sec, for which an RF power of 1.8 MW is fed from two 1 MW klystrons, instead of four klystrons, into 8 five-cell cavities. Meanwhile RF voltage is 8 MV or less at 1 GeV for matching to the energy spread of injected beam, for which 0.3 MW is needed. However, the dynamic range of the klystron power does not cover the above range, so the voltage variation is performed by changing the RF phases between two klystrons while keeping the power constant.

Vacuum system was reduced in the number of components. The system is pumped by 72 ion pumps (40 l/s), 10 ion pumps (400 l/s) and 19 turbo molecular pumps (50 l/s), and seperated by 11 valves and additional three valves in RF section. Vacuum chamber is made of stainless steel, and expected pressure is less than 10^{-6} Torr.

Beam transport from the synchrotron to the storage ring is shown in Fig.6. The number of bending and quadrupole magnets was reduced substantially. The beam is injected from the inside of the storage ring. Total length of the transport line is about 300 m, and the level difference between the synchrotron and the storage ring is 9 m.

So far several R and D's have been performed. Model magnets of the synchrotron, bending, quadrupole, sextupole, septum and kicker magnets, were constructed, and their performance is under test. A prototype of RF system was constructed and a high power test of a five-cell cavity has been performed. A vacuum system including a vacuum chamber for a unit cell was constructed and tested.

Control system of the whole facility including the storage ring is under discussion.

Buildings and Utilities

Expected total power dissipation is 1.5 MW for the linac and 8.1 MW for the synchrotron. Electric power capacity is 3.7 MVA for the linac and 24 MVA for the synchrotron, and the capacity for the buildings of the linac and the synchrotron is 4.2 MVA. The buildings for the linac, the synchrotron and their power supplies as well as utilities are shown in Fig.7. A control room locates near the crossing point of the linac and the synchrotron, and used for both the accelerators.

Acknowledgement

Design works for the injector system have been performed by the members of JAERI group in collaboration with RIKEN group, to whom the author is obliged.

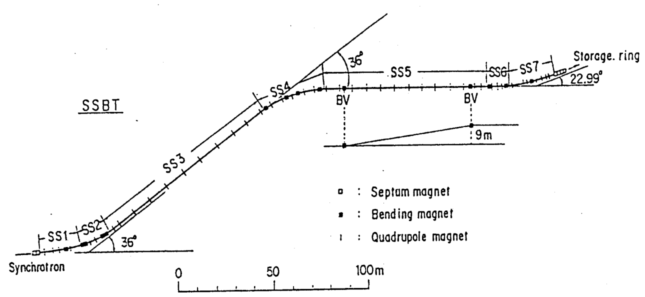

Fig.6 Beam transport from synchrotron to storage ring.

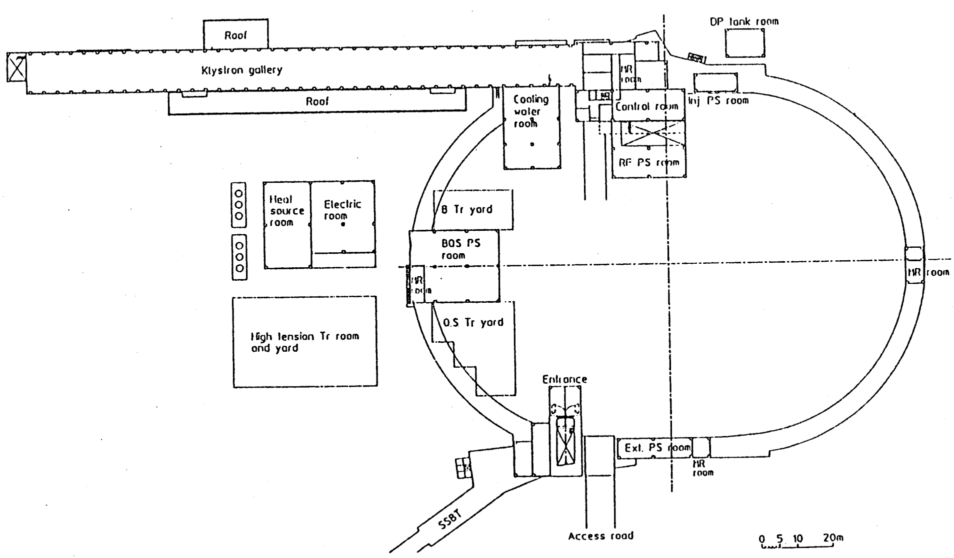

Fig.7 Buildings for injector system.