THE INJECTOR LINAC FOR SPring-8

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Abstract

The Japanese project of the large synchrotron radiation source, named SPring-8(Super Photon ring 8GeV), is in progress now. SPring-8 consists of the injector linac, the synchrotron, and the storage ring. A creation of the site was started last year, and a part of the linac will be constructed from this year. This paper reports the design of the linac. The detail of the gun and the bunching system will be described elsewhere[1].

Introduction

The linac consists of major four parts(Fig.1); the high current linac(HL), the positron linac(PL), the electron linac(EL) and the main linac(ML). HL produces high current beams from a large cathode electron gun to bombard the target for positron production. PL has a converter target and a pulsed solenoid to focus and accelerate the positrons to 120MeV. EL lies on the side of PL, and accelerates the electrons to 120MeV. ML follows EL/PL and accelerates the electrons and the positrons to 1GeV. Two different linac lines, HL and EL, are provided due to the differences in the electron gun performance between EL and HL. The linac is about 200m long and three switch yards are provided in ML to supply beams for other fields of scientific research. Major parameters of the linac, the synchrotron[2] and the storage ring[3] of SPring-8 are listed in Table 1.

TABLE 1
Major Parameters of the Linac
and the Synchrotron

Linac

Energy		1.0 GeV
Repetition rate		60 Hz
Radio frequency		2856 MHz
emittance		1.5 πmm-mrad
(long pulse of positrons)		
	current	10 mA
	pulse width	10 ns
(long pulse of electrons)		
	current	100 mA
	pulse width	1us
(short pulse of positrons)		
	current	10 mA
	pulse width	1ns
(short pulse of electrons)		
	current	300 mA
	pulse width	1ns

Synchrotron

Injection Energy	1.0 GeV
Maximum Energy	8.0 GeV
Circumference	396 m
Repetition time	1 sec
Natural emittance	192 nm-rad
Number of cells	40
Periodicity	2
Radio frequency	508.58 MHz
Harmonic number	672
Radiation loss(8GeV)	11.55MeV/turn
Accelerating voltage(8GeV)	17.1MV
Quantum lifetime	over 10 sec

Storage ring

Energy	8.0 GeV
Circumference	1436 m
Natural emittance	6.9 nm-rad
Number of cells	48
Periodicity	4
Radiofrequency	508.58 MHz
Harmonic number	2436
Radiation loss in bending magnet	9.04 MeV
RF voltage	12.7 MV
Quantum lifetime	over 1 day

The linac design is dictated by the requirements of the beam parameters which are established to insure acceptance by the booster synchrotron.

Four Components

EL

EL has a low emittance thermoionic electron gun which is driven in different two modes. One is a long pulse mode (100mA, 1us pulse width), and the other is a short pulse mode (300mA, 1ns pulse width) to adapt the synchrotron operation of a single bunch mode. The cathode assembly model Y646B supplied by EIMAC will be used and the electrodes are designed of a low perviance for the low emittance. The electron beam extracted from the gun is bunched into 50 degrees phase spread on the first-pass through two prebunchers which are reentrant resonant cavity type of 2856MHz. These 50 degree bunches enter the buncher when the RF phase is near null, and the bunch length becomes 5 degree width. Three accelerator sections accelerate the bunches to 120MeV.

HL

The electron gun of HL is required to be able to deliver of high current above 20 Ampere because of a low e+/e- conversion ratio and transport efficiency. This gun

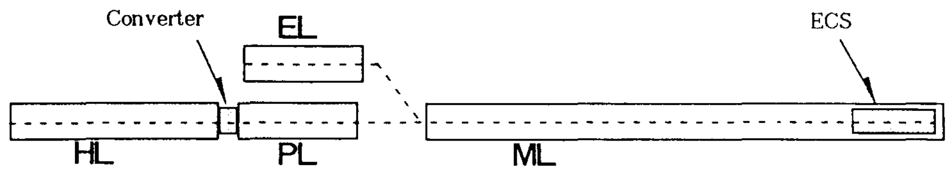

Fig.1 Conceptual view of the linac.

will be made of a large diameter cathode assembly Y796 of EIMAC. The preliminary calculated emittance is 181 mm-mrad at the point of 150 mm from the gun cathode. This value will become better as modifying the shape of the wehnelt and the anode. HL has a subharmonic buncher which is a quarter-wave reentrant resonant cavity with the frequency of 238MHz. This frequency and the drift space are discussed still now, and they will be optimized in the near future. Through HL, bunches of 10 Ampere, 1ns are accelerated up to 300 MeV. In this project, we suppose the positron use, and the efficiency of the positron yields is one of the most significant issue, because the positron yields ratio depends on the high current and the high energy on the target. Moreover, the beam must achieve a 3 mm-diameter spot size including the chromatic effects of the transport system.

PL

For the high density positron beam, it is important how many positrons are accelerated after the target. We are carrying out two experiments about the target structure to aim of a high conversion ratio. One is a conventional type of the combined pulsed solenoid, and the other is a RF gun type. High current beams from HL bombards the target, and the pulsed solenoid coil and the helmholtz coil are used to converge produced positrons. The collected positrons have a wide energy spread. Thus, the beam transport line must have a large acceptance. PL is set to accept positrons with an energy of 10±5 MeV, and the solid-angle acceptance of this line is defined by a pulsed solenoid, placed immediately downstream of the target, and by matching the positron-accelerator section with the dc solenoid. The pulsed solenoid has a field strength of 1-2 T and is 10 cm long. Positrons produced within the angle of 200 mrad in each transverse plane are captured in the acceptance aperture of the dc solenoid. The loss factor in the accelerating sections of PL is assumed to be 50 percent, and PL will finally provide a 10 mA positron beam to ML.

ML

ML receives either electron beams from EL or positron beams from PL at 120MeV. At first, there is a small angle bending section to separate the positron beam from electrons when the positron beam is used. The beams are focused by three quadrupole triplets placed between every other accelerator section. 23 accelerator sections accelerate beams from 120 MeV to 1 GeV. For the consideration of the energy spread of positron beams, the energy compression system is placed at the tail of ML. This energy compression system has a low compression factor because of a large acceptance for positron beams.

Accelerator section

The accelerator section of this linac has to achieve high performance. This performance is determined by the shunt impedance, the Q-value, the material, the operating vacuum level and so on. Anyhow, reliability is most important to the injector linac for many users of SPring-8. A conventional disk-loaded wave guide of 2856 MHz, $2\pi/3$ traveling-wave mode with a constant-field gradient was chosen. Each section is 2.835m long and containing 81 cells. Several kinds of the iris diameter of the disk are mixed to prevent from a cumulative beam break-up. we are now discussing about the modified type accelerator secitions. The cross sectional shape is modified, shown in Fig.2, for high shunt impedance 65 MOhm/m. These accelerator sections will be made by electric welding method. The first test tube was made already, and has been tested on JAERI-linac. The adoption of this modified type accelerator section depends on the results of the test.

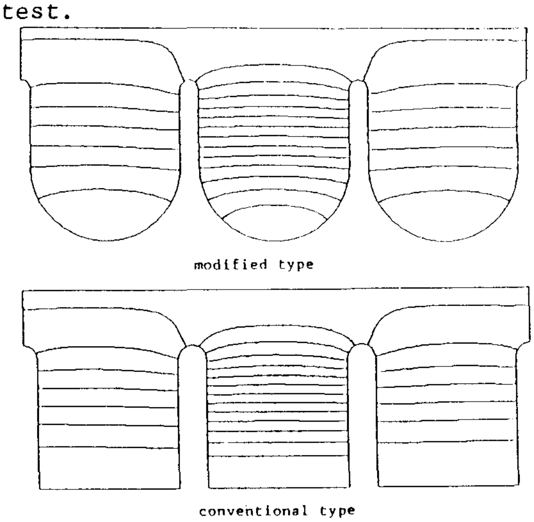

Fig.2 Cross sectional view of cells of a accelerator section.

TABLE 2
Characteristics of
the modified accelerator section

Frequency	2856 MHz
Structure	disk-loaded type
Accelerating mode	$2\pi/3$
Tube length	2.835 m
Number of cell	81
Range of iris dia.	26-20mm
Energy gain	40MeV
Input power	25MW
Shunt impedance	65 M-Ohm/m
Energy gain	40 MeV

RF system

Klystron and modulators

RF power is fed to each accelerator section from a single klystron. The maximum power of those klystrons is 35MW, and they are used around 30MW in average. Each klystron amplifier is provided with a line-type modulator rated at 85 MW peak and 20 kW average power, at a pulse length of 5us, and a maximum pulse repetition rate of 60pps. The pulse-forming network in the modulator is discharged through a hydrogen thyratron. Each modulator is provided with a de-Qing circuit which compares the charging voltage of the pulse network during each charging cycle to a reference voltage. When the charging voltage reaches the reference voltage, the energy stored in a charging transactor is dumped into a dissipative circuit by means of rectifier switch. If the stability of the power source, a motor generator will be used to exclude noise in the electric power provided to the modulators.

Phase control

The 2856MHz low-level output of a highly stable master oscillator will be distributed by coaxial cables and amplified by either newly developed solid state rf high power amplifiers or booster klystrons. Each amplifier provides a signal to a power klystron. The phase of the rf power is controlled by low-power phase shifters, which will be simple and reliable. The phase of the accelerator is initially adjusted by maximizing the energy of the linac and at the same time minimizing the energy spread. This phasing system uses the phase of the beam bunches as the reference phase. It is based on the principle that the phase of the beam-induced wave should be synchronized with the klystron rf phase. The relative phase difference is kept constant by a control computer.

Control system

This linac is designed to be reliable and to have minimal failures. The control system should contribute to minimizing down-time of the machine. However, it is necessary to adapt and modify devices and operating conditions. The block diagram of this control system is shown in Fig.3. There is a VME cage in each modulator and control signals are distributed to the modulator and magnet power sources near by, and monitor signals are gathered in this cage. In each component, these VME cages connect LAN by mini-MAP or ether-net. Furthermore, four LAN servers of each component are connected to the main computer of this linac by MAP or FDDI. The main computer will be used on UNIX. OS-9 or VxWorks will be used as a operating system of VME controllers.

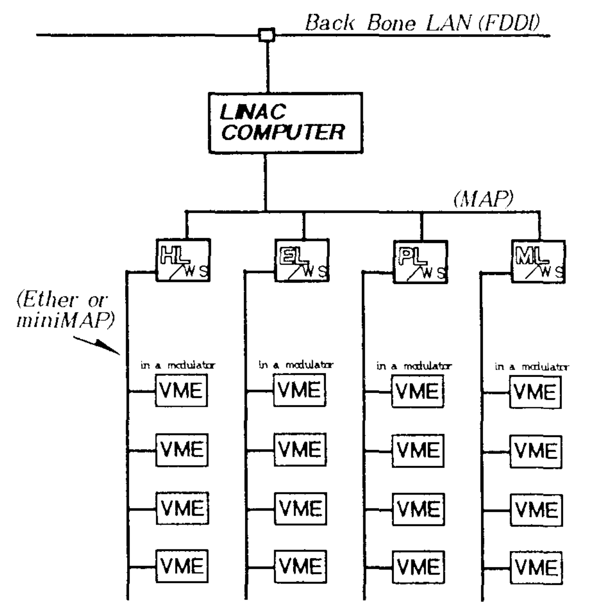

Fig.3 Block diagram of the control system.

Reference

[1]N.Nakamura, et. al. "DESIGN OF A BUNCHING SYSTEM FOR A HIGH CURRENT ELECTRON LINAC", This proceedings. (1990)
[2]T.Harami, et. al. "INJECTOR DESIGN FOR THE 8 GEV SYNCHROTRON RADIATION FACILITY IN JAPAN", Particle Accelerators,(33),63,(1990)
[3]M.Hara, et. al. "STORAGE RING DESIGN FOR THE 8 GEV SYNCROTRON RADIATION FACILITY IN JAPAN", Particle Accelerators,(33),51,(1990)