

THE INJECTION LINAC FOR THE 8 GeV SYNCHROTRON RADIATION FACILITY IN JAPAN

H.Suzuki, H.Yokomizo, H.Yoshikawa, K.Mashiko,
M.Iizuka, T.Ishida, N.Nakamura, K.Yamada, Y.Suzuki
JAERI-RIKEN Synchrotron Radiation Facility Design Team
JAERI, Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, Japan

ABSTRACT

The injection linac for the 8 GeV synchrotron radiation facility has been designed. It is so designed as to accelerate both electron and positron beams up to 1 GeV. The construction of the linac will be started in 1990. The research and developments are carried out in several components.

This paper describes the outline and the fundamental design of the linac.

INTRODUCTION

The new facility for a high brilliant synchrotron photon source is planned to be established in Nishi-harima, Hyogo prefecture. 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).

This facility consists of three accelerators; a 1 GeV injection linac, a 8 GeV booster synchrotron and a 8 GeV storage ring. First of all, the construction of the linac will be started in 1990, and the commissioning of the storage ring is planned in 1995.

The linac consists of three parts; a 100 MeV positron linac, a 100 MeV electron linac, and a 0.9 GeV main linac. For the future extension of the facility, several beam extraction area will be considered in the linac.

The current status of the linac design for the 8 GeV synchrotron radiation facility in Japan is described.

GENERAL DESCRIPTION

The main parameters of the linac are given in Table 1. These parameters are set by the requirements of the acceptance of the synchrotron.

A diagram of the linac is shown in Fig. 1. The electron linac consists of a 100 MeV accelerating sector and a beam transport line. The positron linac consists of a 250 MeV high-current electron linac, a converter target to generate the positrons and a 100 MeV accelerating sector. The main linac accelerates 100 MeV electrons or positrons up to 1 GeV. The linac is about 200 m long. The energy compression system (ECS) is planned to be placed after the main linac in order to achieve small momentum spread. There are four beam switchyards; the confluence of the electron linac and the positron linac (100 MeV), two branches for experimental uses (250 MeV and 500 MeV) and the end of the 1 GeV linac. The beam diagnostic system of the linac consists of beam current monitors, screen

monitors, emittance monitors, energy analyzer systems and beam loss monitors. The 20 m length beam-diagnostics transfer line is used to measure linac beam properties.

Fig.2 shows the illustration of the beam pulse waveforms for the each case of the operation modes. A long pulse mode and a short pulse mode are designed for both electrons and positrons. A burst mode which shows in Fig.3 is under consideration to shorten the accumulation time for the storage ring. For the future extension, the linac will provide its beams for other purpose, such as the free electron laser in the ultraviolet region and positron production etc.

Table 1 Linac parameters

Energy	1.0 GeV
Repetition rate	60 Hz
Frequency	2856 MHz
Momentum spread	$\pm 0.25\%$
Emittance	1.5π mm·mrad

INJECTOR

The ultimate qualities of the electron (positron) beam emerging from a linac depend on the design and operation of the injection system. We describe the fundamental design of the injection system.

The beam characteristics required for the injection system of the linac is following. The energy is 30 MeV and the maximum pulse repetition rate is 60 Hz. In the case of electron linac, one operation mode is 100 mA peak current for long pulse duration of about 1.3 μ sec, the other is 300 mA peak current for short pulse duration of about 1 nsec. In the case of positron linac, one operation mode is 10 mA peak current for long pulse duration of about 10 nsec, the other is 10 mA peak current for short pulse duration of about 1 nsec. However we take aim at more high current beam in order to shorten the accumulation time for the storage ring.

Electron linac injector

A diagram of an electron linac injector is shown in Fig.4. A beam of 100 keV electrons from a gun is initially bunched by a subharmonic buncher (which is not used in case of the long pulse mode) and prebunchers. It is further bunched and accelerated to 15 MeV in a one meter long standing-wave buncher. The beam then enters the one meter long accelerator section in which it is still further bunched into narrow phase spread and accelerated to 30 MeV. Solenoidal focusing is used along the entire length of the

injector.

The electron gun is of the triode type with 0.5 cm^2 dispenser cathode. It will be capable of producing 2.8 A of peak current at 100 kV with emittance of $6.5\pi \text{ mm}\cdot\text{mrad}$. The emission current can be pulsed for the duration of 1.3 μsec and 2-3 nsec by varying the grid voltage in the triode.

The subharmonic buncher is a quarter-wave re-entrant resonant cavity. The gun pulse beam is bunched within one half cycle of the 24th subharmonic (119 MHz) of the linac frequency (2856 MHz). This allows the beam pulse width from the gun to be 2-3 nsec long. The subharmonic buncher will deliver an electron beam of approximately 1 nsec pulse width at 100 kV to following a 2856 MHz prebuncher. In case of the long pulse mode (1.3 μsec), the subharmonic buncher is not used.

The prebuncher is a re-entrant resonant cavity (2856MHz). The velocity modulation by the prebuncher causes 70 % of the electrons to be bunched into a 50 degrees phase spread at the entrance of the buncher.

The buncher is a standing-wave structure with a varying a phase velocity. The accelerator section is standard one meter standing-wave structure. The 50 degrees bunches are caused to enter the accelerator section around the phase stable field null, become bunched to 5 degrees width, and asymptotically approach the crest of the wave as they are accelerated.

Positron linac injector

The fundamental constitution of the positron linac injector is similar to the electron linac injector. The principal difference between the two injector is specification of the gun. The gun of the positron linac injector is required high intensity for the sake of a low conversion (e^+/e^-) efficiency. The gun is of the triode type with 2.0 cm^2 dispenser cathode, and will be able to deliver 20 A pulsed beam at 150 kV. The preliminary calculated emittance is $87 \pi \text{ mm}\cdot\text{mrad}$.

ACCELERATOR SECTION

Energy gain, beam current, beam pulse width, accelerator frequency and repetition rate are the most important parameters. They lead an accelerator structures, a length of accelerator section and a klystron power.

The linac accelerator sections consist of disk-loaded waveguides operating in the $2\pi/3$ traveling-wave mode with constant field gradient. There are 25 traveling-wave sections in the main linac. Section length of 3m (effective length is 2.835m) for both electrons and positrons is a compromise between the energy gain and the brazing of long structures. The basic performance criterion is an energy gain of 36 MeV per section, with 20-25 MW input power and a field gradient of 13-15 MV/m. Each section consists of 81 elementary cavities except the two end couplers. The characteristics of the accelerator section are listed in Table 2. To achieve a satisfactory field gradient, the

vacuum and the surface processing in the accelerator sections are under consideration. Bakeout of the accelerator sections is also considered.

The linac operating in the electron long pulse mode (100 mA, 1.3 μsec) is designed in consideration of the problem of a beam breakup. One of the design to suppress beam breakup, is to arrange six kinds of sections. The effect of this remedy expects to suppress the cumulative type of beam breakup. Another remedy is to put a quadrupole triplet every two sections in order to make the wavelength of the betatron is about 10 m.

Table 2 Characteristic of the accelerator section

Frequency	2856 MHz
Accelerator structure	traveling-wave
Accelerator mode	$2\pi/3$
RF structure	constant gradient
No. of cavity	81
Length	2.835 m

POSITRON SOURCE

The linac is required to provide positrons and electrons with high intensity and high beam quality. Utilization of positron beam will eliminate the ion trapping phenomenon in the storage ring. High intensity electron beam is requested in order to emerge high intensity positron beam, because of its low conversion ratio. It is essential to enhance the conversion ratio and transport efficiency. Therefore the positron linac and the main linac will be setting straightly. A small angle bending section is set to select positron beam from electron. It is estimated that positron beam has large emittance and momentum spread. So the beam transport line must have large acceptance, and ECS should be placed after the main linac.

Now we are planning research and developments two types of positron source at JAERI linac facility. One is the conventional type converter which is composed of a converter target, a pulsed solenoid with strong focusing field and a positron accelerator section with dc solenoid. Fig.5 shows the experimental apparatus of the conventional type positron source. The other is rf focusing type, in which positrons will be accelerated immediately after the converter target by the standing wave type accelerator section with dc solenoid.

Positrons emerging from the target have the typical energy distribution predicted by bremsstrahlung followed by pair-production mechanisms. The energy distribution is inversely proportional to the positron energy. The energy acceptance of the conventional type positron source is set to utilize the positron energy of $10\pm 5 \text{ MeV}$. The energy acceptance of the rf focusing type positron source is set to utilize lower energy of 2 MeV.

The purpose of the research and developments is to optimize the position and thickness of the target. We are

also planning to measure the conversion ratio and the beam characteristics of the accelerated positron beam.

CONCLUDING REMARKS

The general design of the injection linac and its beam parameters was described.

To achieve the reliability, flexibility, and easy operation and maintenance is the philosophy of the designing.

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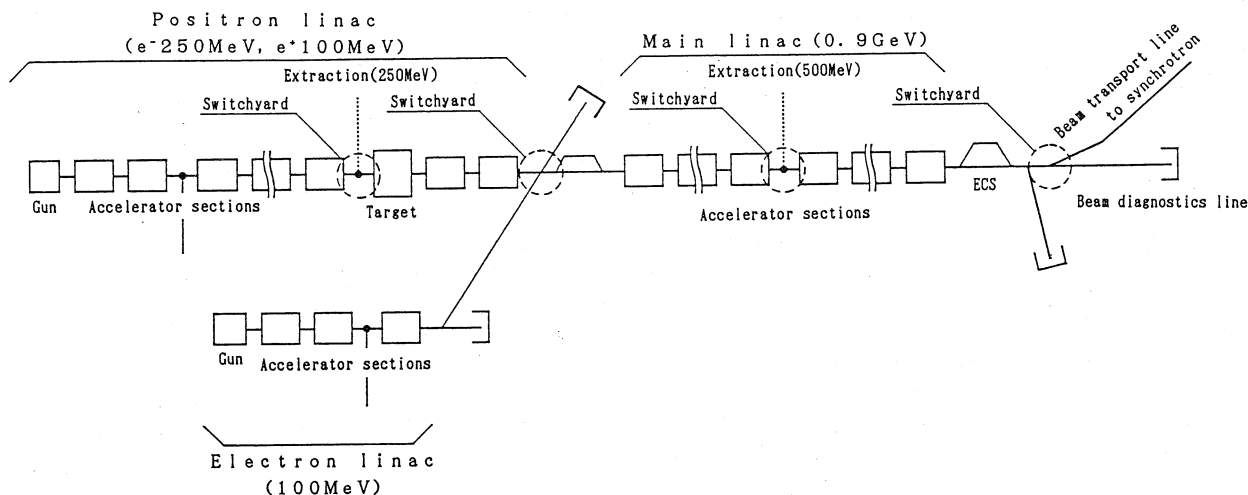


Fig.1 Illustration of the linac.

	Electrons	Positrons
Long Pulse	100 mA 1.3 μ s	10 mA 10 ns
Short Pulse	300 mA 1 ns	10 mA 1 ns

Fig.2 Macropulse waveforms provided by the linac

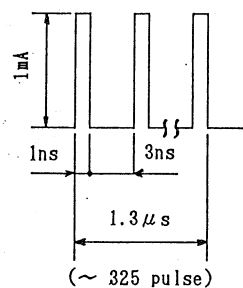


Fig.3 Burst mode positron beam

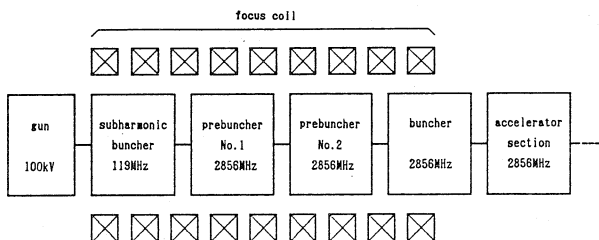


Fig.4 Electron source injector.

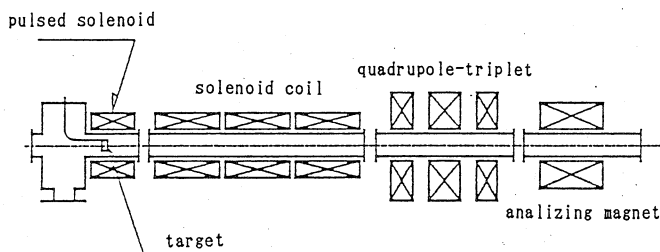


Fig.5 Experimental apparatus of the conventional type positron source.