

DEVELOPMENT OF BEAM DIAGNOSTICS FOR SPRING-8 LINAC

K. Yanagida, S. Suzuki, Y. Itoh, H. Yoshikawa,
 A. Mizuno, T. Hori, and H. Yokomizo
 JAERI-RIKEN SPRING-8 Project Team
 Tokai-mura, Naka-gun, Ibaraki-ken, Japan 319-11

Abstract

The preinjector of the SPRING-8 linac is constructed in Tokai Establishment. Several monitors are installed in the preinjector. They are designed to measure a low current beam such as a positron beam as well as a high current beam. A wall current monitor has achieved a fast rise time of ≤ 300 ps.

Introduction

In the electron linac, principal beam characteristics such as beam current, emittance and energy deviation are determined by the beam dynamics from the gun to the point where the beam energy is several MeV. The preinjector was constructed to examine the beam characteristics as a part of SPRING-8 linac. A beam test started from August 1992. In the preinjector several monitors are installed not only to measure the beam characteristics but also to examine the performance of monitors using the electron beam. This article presents the design and the performance of these monitors.

Design of SPRING-8 Linac

The injector system of SPRING-8 (Super Photon ring 8 GeV) [1] is composed of a 1GeV linac and a 8GeV booster synchrotron. The positron beam is available in this system as well as the electron beam. In order to produce a positron beam, an electron/positron converter is installed in the midst of the linac. Therefore the linac consist of a 250MeV high current linac (HL), a converter and a 900MeV main linac (ML).

The beam characteristics such as an energy, an emittance, an average peak current and a microbunch length are measured at three points; at the preinjector, around the converter and at the end of ML. Table 1 shows the beam parameters for designing monitors. The positron beam must be measured after the positron converter. For R&D monitors were designed so as to detect a low current beam, even though they are used in the high current preinjector.

The preinjector includes an electron gun, two prebunchers, one buncher, focussing magnets and beam

monitors (see Fig. 1) [2]. In order to measure the performance of gun the current monitors are installed at the exit of gun. The current monitors are also installed at the exit of buncher to measure transmission rate through the prebunchers and the buncher. The beam characteristics are measured at the location after the buncher where the beam is bunched and accelerated up to 9MeV. A transverse emittance is measured by the slit1 and the wire grid monitor. An energy spectrum is measured by the spectrometer that consists of the quadrupole magnets, the slit2, the bending magnet, the slit3, and the Faraday cup. To measure a microbunch length, the Cherenkov radiators are installed. The Cherenkov radiator1 is installed for the precise measurement. Profile monitors are installed at four locations for the beam transport.

TABLE 1

Parameters for Beam Diagnostics				
Pulse Width and	1	ns,	10	A
Average Peak Current	1	ns	10	mA
	10~40	ns,	10	A
	10~40	ns	10	mA
	1	ns,	300	mA
	≥ 1	μ s,	100	mA
Microbunch Length	≥ 5	ps		
Beam Energy	9	MeV		for Preinjector
	250	MeV		before Converter
	120	MeV		after Converter
	1	GeV		for ML
Transverse Emittance	~ 10	π mm \cdot mrad		for Preinjector
	1	π mm \cdot mrad		for Others

Design of Monitors

This section describes the designs of each monitor, such as design parameters, a structure, an electronic circuit and so on.

Long Pulse Current Monitor (LCM)

The LCM is a monitor to measure the average peak current and the pulse width of the long pulse beam ($\sim 1\mu$ s). The required parameters are as follows; output of $\geq 1V/A$, maximum peak current of $\geq 1A$, rise time of ≤ 20 ns and droop of $\leq 1\%/ \mu$ s. The model 2100 (Pearson) satisfies the parameters.

Short Pulse Current Monitor (SCM)

The SCM is a monitor to measure the average peak current and the pulse width of the short pulse beam (1~40ns). The required parameter are as follows; output of $\geq 1V/A$,

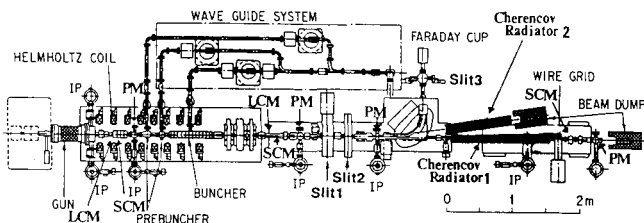


Fig. 1 Arrangement of the preinjector.

maximum peak current of $\geq 10A$, rise time of $\leq 300ps$ (if possible 100ps), droop of $\leq 10\%/100ns$. Two types of SCM were manufactured in order to obtain fast rise time.

One is a wall current monitor (see Fig. 2). It is composed of a ring-type ceramic resistor (ASW, Tokai) with a resistance of 1.8Ω connected across the ceramic insertion, a signal pick up and a loading core (FT-1M, Hitachi).

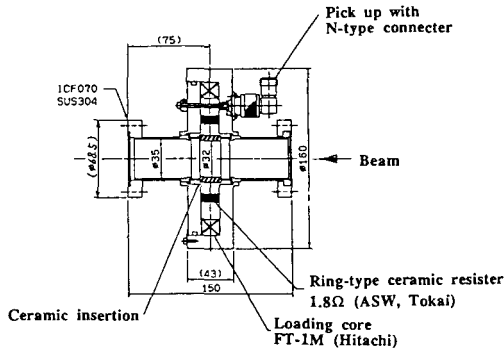


Fig. 2 Cross section of the wall current monitor.

Another is an amorphous CT (Current Transformer) (see Fig. 3). It is composed of an amorphous core (FT-1L, Hitachi) with 13 turns windings, and a signal pick up. The windings and the pick up are connected directly.

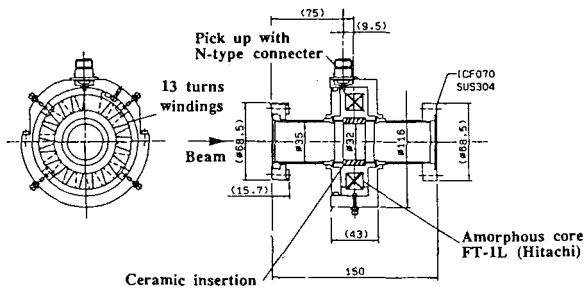


Fig. 3 Cross section of the amorphous CT.

Transverse Emittance Monitor

Two different methods [3] are introduced in SPring-8 linac for the transverse emittance measurement.

One is a method using a slit and a wire grid monitor. The phase space is scanned directly. The width and thickness of the slit are 0.3mm and 30mm respectively. The wire grid monitor has a single wire with a diameter of 0.3mm for the charge detection. And it also has two wires to extract secondary emission.

Another is a method using the three profile monitors (wire grid monitors). This method will be used in the higher energy region. Three profiles measured in the different points provides the twiss parameters and the emittance.

A charge sensitive amplifier is prepared for the signal processing. An expected charge is $1pC \sim 0.1\mu C/pulse$. A sensitivity is required as $1V/pC$ in the smallest range. At present the model 142A and 113 (Ortec) is used as the amplifier. Another charge sensitive amplifier (see Fig. 4) is developed. If it presents a good performance the multi-wire

type monitor (~ 10 wires) and the integrated type amplifier will be used.

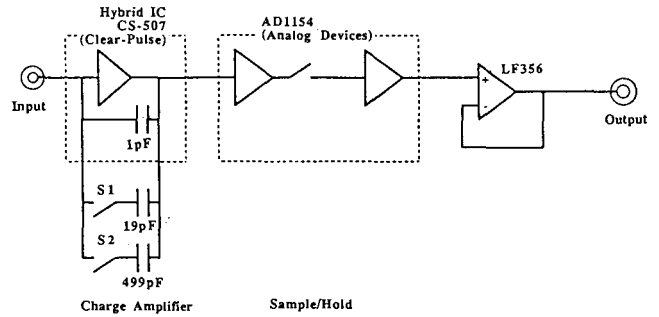


Fig. 4 Block diagram of the charge sensitive amplifier with the hybrid IC.

Microbunch Length Monitor

In order to measure the microbunch length with the smallest error the observation of Cherenkov radiation by the streak camera is preferable. Synchrotron radiation is also available but the measurement error becomes large. When the beam is bended, a geometrical bunch lengthening occurs. The bunch lengthening (Δz) is a product of beam size (Δx) and bending angle (θ);

$$\Delta z = \Delta x \cdot \theta \quad (1)$$

For example Δz is 0.7mm (2.3ps) where $\Delta x = 5mm$ and $\theta = 0.14rad$. Therefore the Cherenkov radiator1 is prepared on the straight line of the beam duct as shown in Fig. 1. In the case of the machine study, the air is filled in the radiator1 and the Cherenkov light is measured through the beam axis. However, it is unable to use the radiator1 in the normal operation because the vacuum vent is required in the beam duct, so that the Cherenkov radiator2 is prepared on the line with the bending angle of 0.14rad to the beam axis.

The Cherenkov light is transported out of the accelerator room and focused on the slit of streak camera. The focusing elements are composed of mirrors because chromatic effect is small in the case of mirrors compared with the lenses. The chromatic effect causes time error of 1ps when the light (wavelength; 250~750nm) is transported for 12m. The focusing element is a type of the Newtonian telescope (see Fig. 5). Its diameter is 150mm. The focal lengths from the elliptical mirror are 1m and 11m. In order to reduce the shadow of submirror the elliptical mirror has 75mm off set from the symmetric axis.

The streak camera is C3735-01 (Hamamatsu). Its time resolution is 0.6ps originally. It has a sufficient sensitivity to the Cherenkov radiation of the positron beam.

Total error in this measurement becomes 1.6ps (minimum) and $\sim 4ps$ (beam bended).

Energy Monitor

The absolute beam energy and the energy spread is measured by the spectrometer in the preinjector. The slit2 and slit3 is located on the double waists of the beam. The

slit3 determines the energy spread and the Faraday cup measures the beam current passed through the slit3.

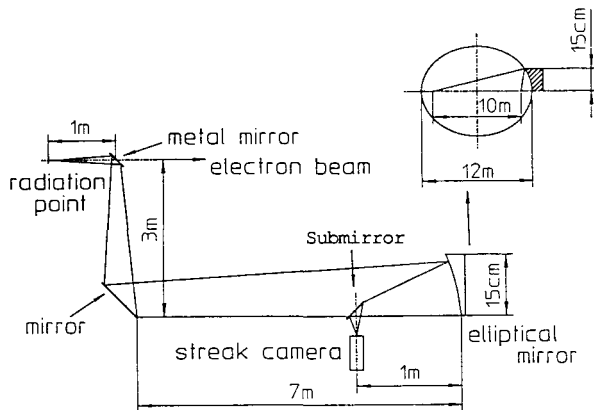


Fig. 5 Arrangement of microbunch length monitor.

Profile Monitor(PM)

This monitor is prepared for the beam transport. The PM has a scintillator screen, AF995R 1mm thickness (Desmarquest), and the profile is observed by the TV camera. The screen center is aligned to the beam axis within 0.3mm accuracy.

Present Status

The fabrication of the beam monitors for the preinjector are completed. The individual beam diagnostics show the good performance. The examination of beam monitors using the electron beam is under way. This section describes the off beam test of SCM (see Fig. 6). A pulse current transmits through the conductor instead of the electron beam. The waveform of output and transmission are measured by the sampling oscilloscope.

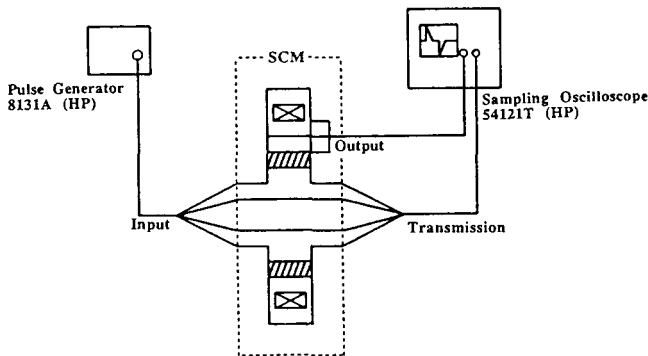


Fig. 6 Arrangement of the off beam test.

Fig. 7 shows the waveform from the wall current monitor; upper one is transmission and lower one is output. Both waveforms shows fast rise time of ~300ps which is thought to be the limit of pulse generator. The measurement of frequency spectrum indicates the upper cut off frequency of ~2GHz. Thus the rise time is expected as 170~300ps.

Fig. 8 shows the waveform from output of the

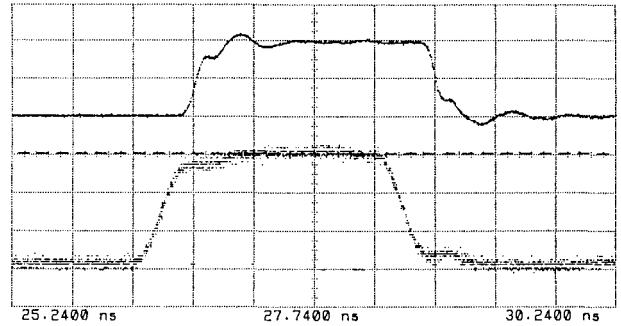


Fig. 7 Waveform from the wall current monitor. (500ps/div)
Upper: transmission (500mV/div)
Lower: output (10mV/div)

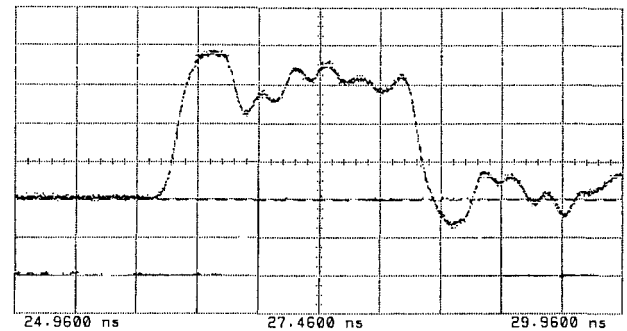


Fig. 8 Waveform from the output of the amorphous CT. (500ps/div, 20mV/div)

amorphous CT. The deformation due to ringing is very large compare with wall current monitor's. Table 2. is the specification of SCM obtained from the test.

TABLE 2

Specification of SCM

Parameter	Wall Current Monitor	Amorphous CT
Rise Time	≤300 ps	~300 ps
Drop	25 %/μs	0.7 %/μs
Output	1.4 V/A	3.8 V/A

A linear response for the large current (~10A) is not confirmed yet. In order to calibrate SCM a coaxial Faraday cup is prepared. The calibration will be done using the electron beam. The coaxial Faraday cup will measures the absolute pulse width and the absolute average peak current.

Conclusion

The monitors of the preinjector are well manufactured as the design. Especially, the fast time response is obtained in the wall current monitor without deformation of waveform.

References

- [1] H. Kamitsubo, "8 GeV synchrotron radiation facility project in Japan: JAERI-RIKEN SPring-8 Project", Nucl. Instr. and Meth., **A303**,421(1991)
- [2] H. Yoshikawa, et al., "Design of High Current Injector for SPring-8", Proc. of LINAC'92
- [3] H. Koziol, "Beam Diagnostics", CERN 89-05,63(1989)