STATUS OF THE KEK 2.5 GeV ELECTRON LINAC

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ABSTRACT

The operational behaviour and status of the KEK 2.5 GeV electron linac are described. Scheduled operation of the linac for the Photon Factory was opened in June 1982 and injection into the TRISTAN accumulation ring was started in November 1983. Operation of the linac for both of the rings has been continued without any serious trouble. Energy, energy spread, profile and position of the accelerated beam are stable. Fault rate of the high power klystrons is decreasing according as improvement of the klystron.

INTRODUCTION

After the initial operation, with the advance of fine tuning of the machine, the beam quality has been remarkably improved. Constant improvement in the control system have made routine operation of the linac more easy and simple.

Although the beam energy of the linac can be changed continuously without deterioration of the beam quality, the energy has been fixed at 2.5 GeV since October 1982 because of the requirement of the synchrotron radiation research.

Total operation times of the linac in FY 1982 and FY 1983 were 1,600 hrs and 2,100 hrs respectively.

The PF ring is normally operated in a multi-bunch mode. It means pulse width of the injection beam is enough in a range of microsecond.

On the other hand, in the TRISTAN accumulation ring, single-bunch mode operation is usual. It requires an injection beam which has a very short pulse width (< 2 ns) and is synchronized with the ring rf.

The synchronized short pulse beam is also used for single-bunch mode operation of the PF ring. Although the routine operation of the PF ring is the multi-bunch mode, the stored beams filling up all of the rf backets (312) cause an instability due to the effect of ion-trapping. To reduce the instability, a partial-fill mode (fill up 2/3 backets) operation is often efficient. For such an operation, the synchronized injection is also important.

Because of the linac is an injector for the two storage rings, high stability is required for the beam. To accelerate stable beam, high level of stabilization for the rf sources and the beam transport system is required. In addition, high threshold for the beam break up is desirable for such a long linac.

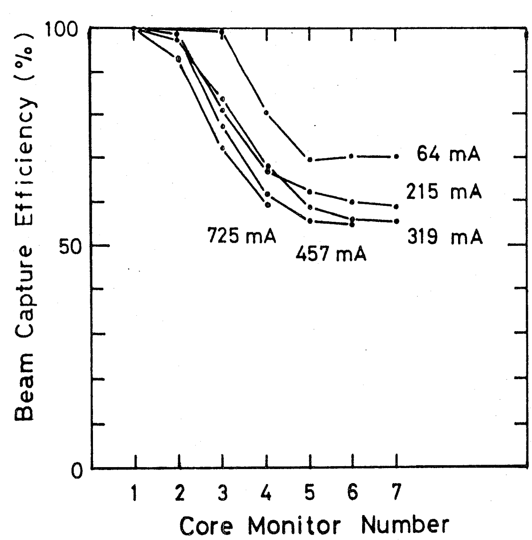

Fig. 1 Beam capture efficiency of the 35 MeV injection system.

OPERATIONAL PERFORMANCE

Stability of the beam energy in a long linac depends on the stability of the rf power and rf phase. During one week operation period, the rf phase adjustment is unnecessary unless the high power klystron voltage is changed. For trimming of the beam energy, rf phase of the last acceleration unit is changed with respect to the beam bunches.

A number of beam monitors; current transformers, fluorescent screens and ionization chambers distributed along the beam line facilitate the beam handling of the linac.

Figure 1 shows beam capture of the 35 MeV injection system. In a range up to hundreds mA of the beam current, the capture efficiency is 60 to 70 percent. Beam bunch width was measured at the 500 MeV beam analyzer. Although the bunch width depends on the beam current and the rf phase adjustment, the minimum bunch width was 2 to 3 degrees up to 150 mA (Fig. 2).

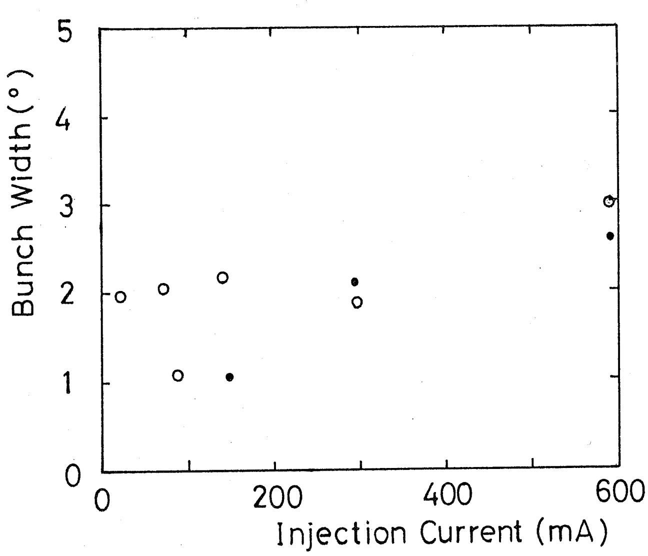

Fig. 2 Beam bunch width for various injection current.

Beam transmission over the main accelerator was remarkably improved owing to the monitor system and to experience of the linac staff. Beam spill over the main accelerator is less than few percent (Fig. 3).

Beam profiles and beam positions at the sector ends are monitored by the air actuated fluorescent screens. Two screen plates placed down stream beam transport line of the linac have 4 mm diameter holes at their centers so as to observe axial displacement and profile of the beam at "beam ON". The beam diameter is less than 5 mm and the greater part of beam current passes through the screen holes. Figure 4 shows the beam current: beam energy relations. Beam break up threshold currents for 2.5 μs and 1.5 μs pulse beams are shown in the figure.

Measured energy spread is less than 0.5% for the 2.5 GeV, 1 ∿ 2 μs beam. However, for the nanosecond beam such as 1.5 ns, the energy spread decreases to 0.1%. Accurate emittance measurement for the electron

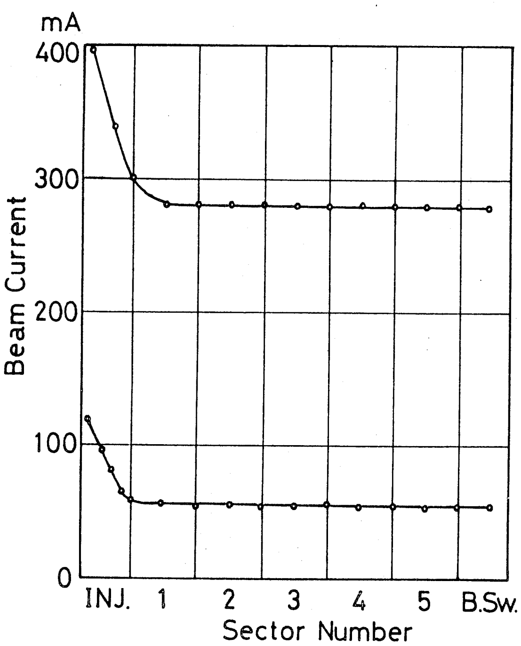

Fig. 3 Beam transmission of the linac.

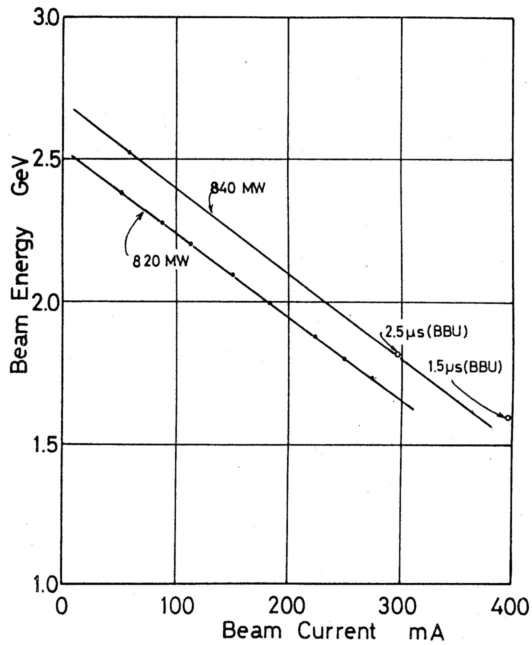

Fig. 4 Beam current-beam energy relations.

linac is rather difficult compared with the proton linac because of its thin beams. The measured emittance is less than 30 πcm•mrad (normalized).

The rf coupler corrected the field and phase distributions was successful[1]. Although all of the waveguide feeders connected to the accelerator guides are placed on the left hand side of the beam line, any dominant direction of the beam deflection has not been experienced.

Figure 5 shows a typical distribution of the correction angles by the steering coils along the main accelerator. In order to make sure effect of the improvement rf phases were widely changed from -90° to +90° at the beam energies of 400 MeV and 2.0 GeV[2]. By this, electron beams were expected to experience the maximum transverse fields. The results of the experi-

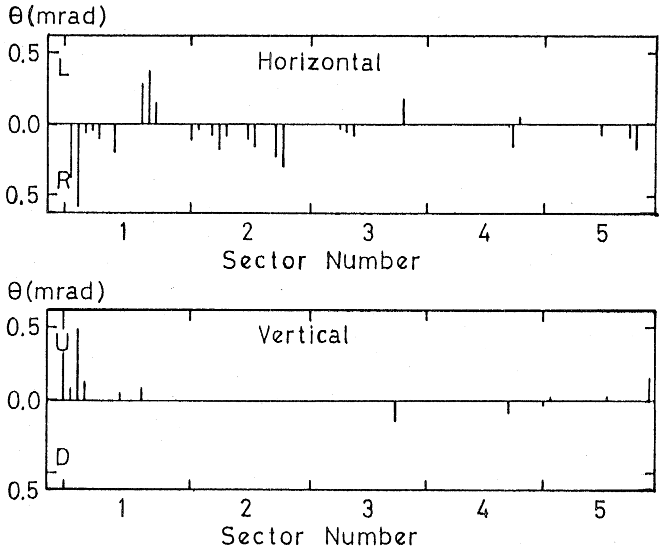

Fig. 5 Correction angles by the steering coils along the main accelerator.

ment shows that the deflections at 10 m apart from the deflecting positions were within few mm.

To provide the long (μs) and/or short (ns) pulse beams for both of the rings, easy and prompt switch over of the beam pulse width is required.

For the purpose, a new electron gun and switch over system of the beam pulse width were developed.

Figure 6 shows a cross section of the electron gun. A nanosecond grid pulser module is installed inside of the cathode assembly. On the other hand, microsecond grid pulser is placed on a gun high voltage terminal and the microsecond pulse signal is transmitted to the control grid of the gun through a coaxial cable which is connected in parallel with the output of the nanosecond grid pulser through a low pass filter. Consequently, the μ-sec and n-sec pulses are remotely exchanged by switching of the trigger pulses for both of the grid pulsers.

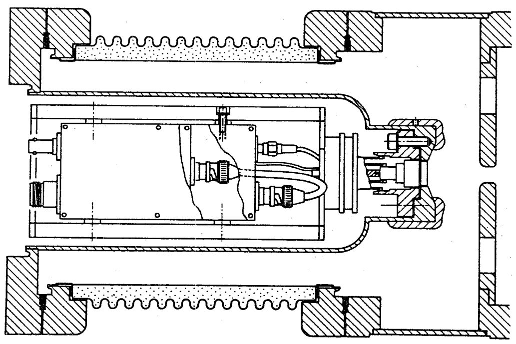

Fig. 6 Crossectional view of the electron gun with nanosecond grid pulser module.

KLYSTRON PROBLEMS

In order to accelerate a stable beam in a linac, at least high quality of the accelerating rf is required. RF system of the PF linac has been stably operated owing to the highly stabilized modulators of the main and booster klystrons.

The accelerated beam is stable, however, long term stability of the beam has been limited by occasional arcing in the high power klystrons and the beam has been interrupted for a few minutes whenever fault of the klystron took place. The rather high fault rate of

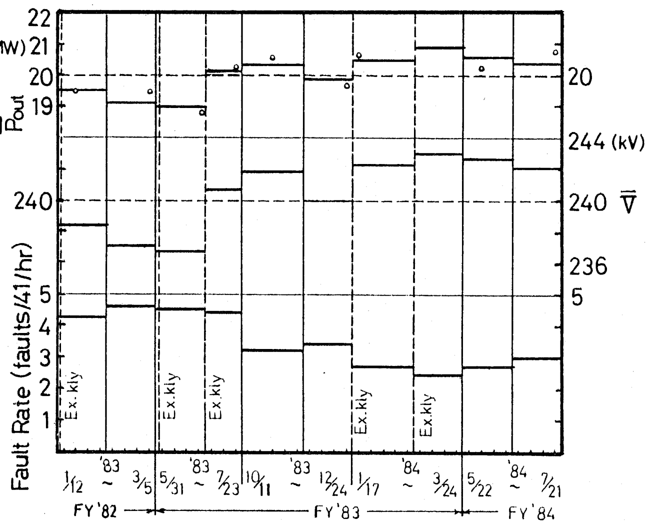

Fig. 7 Change of fault rate of the klystron.

the klystrons has been the most serious trouble of the linac. The fault due to mainly internal arcing is being cured by improvements of the cathode focussing electrode and of the klystron production process.

Figure 7 shows change of the fault rate of the klystrons year by year.

Damage of high power rf window is rather complex. In general, it is classified into three categories, these are dielectric breakdown, thermal failure and failure due to glow discharge and/or multipactor. The last one causes sometimes wormhole puncture of the ceramic window material. The pattern of the glow on ceramic surface seems due to TM_{11} mode resonance of the 2nd harmonic frequency for pill box type window.

At present, the complete cure can not be found out. However, the puncture was remarkably reduced by selection of the ceramic material and by processing of the rf windows.

POSITRON GENERATOR

Construction of a positron generator to be used for the TRISTAN has been continued since April 1982 with three year program. The general parameters of the generator are given in Table 1. It consists of a 200 MeV high current electron linac, a conversion target and a 250 MeV post accelerator. An electron beam with 1 ∿ 2 ns pulse width and current of 10 A is accelerated to 200 MeV and hits a heavy metal target of 2 ∿ 3 radiation length. Positron beam radiated from the target is momentum selected by a strong solenoid and accelerated up to an energy of 250 MeV by the post accelerator. Positron yield is proportional to the primary electron beam power and is about one part of thousand. The 250 MeV positron beam is transported to the 250 MeV point of the 2.5 GeV linac (mid point of the first sector). Tunnel and klystron gallery of the positron generator was completed at the end of March 1984. Six klystron modulators, a gun modulator about half of the accelerator guides and other components were procured and the installation and assembling were started at April 1984.

REFERENCES

1. J. Tanaka et al.: Proc. of the 1981 Linear Acc. Conf. p.360.
   A. Enomoto et al.: Proc. of the 7th Meeting on Linac, KEK-82-14 (1983) p.61 (in Japanese).
2. I. Sato et al.: Proc. of the 9th Meeting on Linac, Univ. of Kyoto, 1984, p.87 (in Japanese).

Table 1

	e^- linac	e^+ linac
Energy (MeV)	200	250
Peak current (mA)	10,000	10
Pulse width (ns)	1 ∿ 2	1 ∿ 2
Repetition rate (Hz)	< 50	< 50
Accelerator guide		
Freq. (MHz)	2856	2856
Type of mode	T.W. 2/3π	T.W. 2/3π
Gudie length (m)	1.5, 2, 4	2, 4
Number of guides	1, 1, 5	4, 4
RF		
Max. Kly. output power (MW)	30	30
Number of Klystrons	3	3
Electron gun		
Voltage (kV)	150	―
Pulse width (ns)	1 ∿ 4	