PROGRESS OF POSITRON GENERATOR AT KEK

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Abstract : After the 1986 linac conference, various modifications and improvements were made with the positron generator used for TRISTAN. They are with the electron gun, beam transport, control, and injector rf systems. As a result a considerable improvement in the acceleration characteristics has been achieved. The accelerated electron current increased from 3.5 A to 10~12 A at the positron producing target, the positron current increased from ~10 mA to 30~34 mA at the end of the generator, and from 4.5 mA to 15~17 mA at the end of 2.5 GeV linac. Meanwhile a study has bean made to obtain positron beams suitable for acceleration and injection into the Photon Factory storage ring for synchrotron radiation research. A few tens of nanosecond beam is most adequate at present, and a higher injection rate by a factor of three to four was obtained with 40 ns beam than with 2 ns beam.

Introduction

The positron generator was constructed from 1982 to 1985 for the e^+-e^- collision experiments in TRISTAN, and its construction and initial operation were reported in the previous linac conference in 1986.[1] A general description of the generator and some improvements made afterwards were given in ref. 2. In this report modifications and improvements are described, which have been made since the 1986 Conference to improve the accelerator characteristics. Modified systems are with the electron gun, the beam transport, the control, and the rf.

Recently injection of the positron beams into the PF storage ring was performed, and synchrotron radiation from the positron beam was test used for synchrotron radiation research, aiming at obtaining more stable lights than from the electron beam. In this connection the positron beam suitable for this use was studied, the result of which is also presented.

Modifications and Results

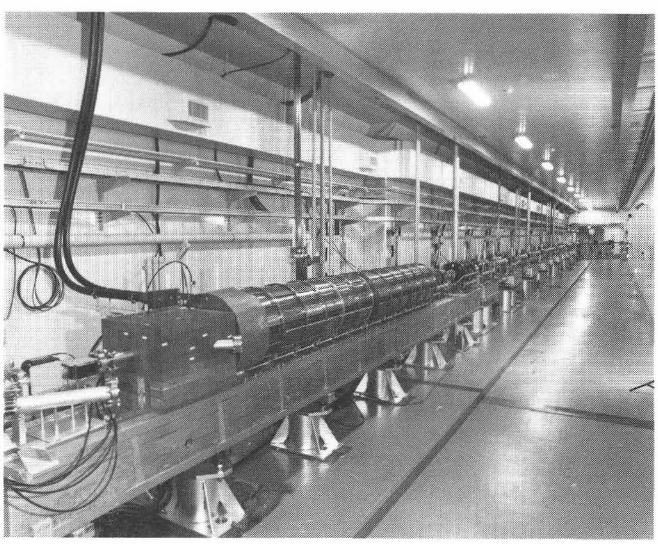

Fig. 1 Positron producing target and positron accelerator of the generator.

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The generator consists of two rf linacs. The first linac accelerates electrons up to an energy of 200 MeV with a pulse width of less than 2 ns. This accelerator consists of the injection unit and two other acceleration units (unit 1~3). The injection unit has a gun, an SHB, a prebuncher, a buncher, and two accelerator guides. Each of the other two units has two 4 m long accelerator guides. A positron producing target, a water-cooled tantalum, is installed just upstream of the second linac, which consists of three acceleration units (unit 4~6) similar to the others. Positrons are accelerated up to an energy of 250 MeV at the end of the generator, and injected into the 2.5 GeV linac through a 30°deflection beam transport. Figure 1 is an over-all view of the target and the positron accelerator of the generator.

Electron Gun and Beam Transport Systems

Development of the electron gun and reinforcement of the beam transport systems were partly reported in ref. 2, and are to be reported more in detail in refs. 3 and 4 , so these are very briefly described here.

The electron gun was initially operated at 115 kV , but after sometime the injection voltage was raised up to 160 kV. This was made possible with the use of a new insulator. A grid pulser was also developed to produce a larger output.

With an increase of the injection current, it was found that the beam focussing was not sufficiently strong ; therefore, focus coils were reinforced around the prebuncher and the buncher, and a quadrupole triplet was added to each of units 2 and 3. The arrangement of the target and its associated pulsed coil was modified ; the coil is set in the atmosphere in the present configuration, whereas it was in vacuum in the previous one. This was chosen from a safety consideration, although the conversion efficiency from electrons to positrons decreased by ~0.05%.

Owing to these modifications mentioned above, the acceleration characteristics of the generator were considerably improved: The injection current from the gun was increased to 8~9 A from the previous value of 7 A, and the accelerated electron current reached 10~12 A at the target. Correspondingly the positron beam was also increased to 20~24 mA at the end of the generator, and became 10~12 mA at the end of the 2.5 GeV linac. An example of the beam current measured along the accelerators is shown in Fig.2, where the abscissa shows the position of measurement, and the ordinate is an electron (on the left) or a positron current (on the right). It is to be noted that the accelerated beam current is higher than the injection beam because of the use of the SHB.

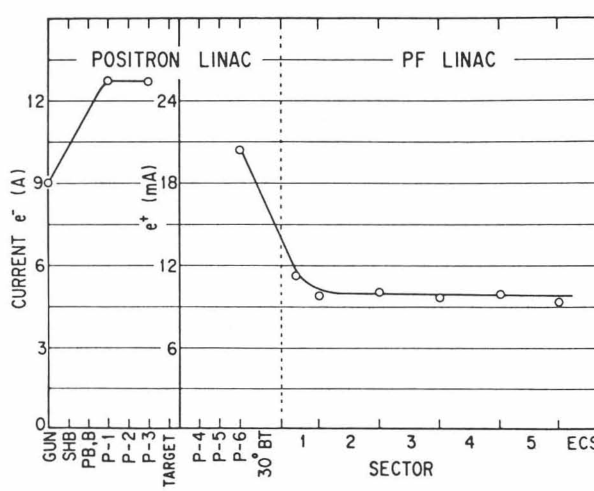


Fig. 2 Beam current along the accelerators , Nov., 1987.

Control System

One of the problems encountered in the positron generator operation was an instability of the positron beam. One of the major reasons was fluctuation of the rf, especially a drift of the rf phases, since the beam was most sensitive to rf phase variation.

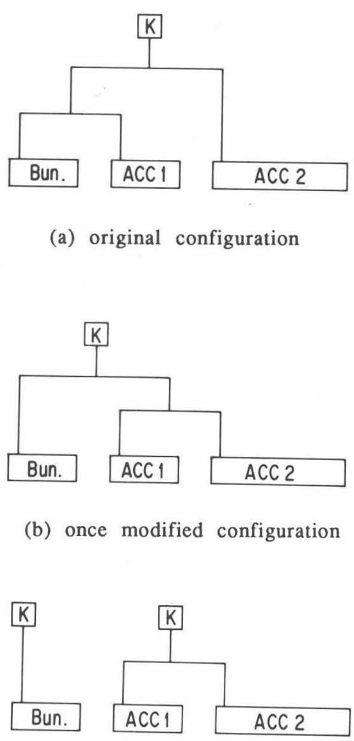
Therefore, a phase control system was developed[5] to overcome this difficulty. The most sensitive phase drift is that of SHB, and a phase-locked-loop was made and applied to it, as well as to the main booster. In addition, an automatic phase control system was introduced with the beam induction method to control the phase drift not only for the generator but also for the 2.5 GeV linac. Phasing of a klystron can be done within a minute with an accuracy of less than $\pm 3°$.

Another fluctuation of the rf is associated with the rectified waveform of a high power klystron output. A system was devised to monitor always this waveform and to detect its change, if any, for all klystrons. More specifically, the quantities of the waveform to be monitored are timing of a modulator switching, the amplitude, the width, and the area, and these are compared with the stored data for each klystron.

With these systems the operation of the accelerator became much more stable and easier.

Reinforcement of an Rf Power to the Injection Unit

With the increase of the injection current, another problem encountered was that the rf power fed to the buncher was not sufficient for the waveguide configuration shown in Fig.3(a) ; therefore, it was modified to that shown in Fig.3(b). Then the positron yield vs. rf power curve showed saturation, suggesting that the rf power became sufficient. However, the electron positron conversion efficiency decreased by ~0.05% ; this was probably because the rf power fed to the second accelerator guide was reduced to a half of the previous value.



(a) original configuration

(b) once modified configuration

(c) present configuration

Fig. 3 Modification of injector rf system

Table 1 Comparison of e-/e+ current

	Before modification	After modification
Gun	8.6A	8.2A
Target(e-)	10.0A	10.4A
Generator End (e+)	21.0mA	31.2mA
e+/e-	0.21%	0.30%

It was decided, therefore, to reinforce the rf power to the injection unit, and the unit was divided into two, to each of which the rf power was supplied by individual klystron as shown in Fig.3(c). With this configuration the energy increase of electrons was estimated to be about 24 MeV.

The modification was completed recently, and a test operation was performed.[7] An example of some numerical data is shown in Table 1 for comparison where are listed the currents obtained just before and after the modification. A result of the beam current measurements along the accelerators is shown in Fig. 4, which may be compared with Fig. 2. From Table 1 and Fig. 4, it is clearly seen that a considerable improvement is achieved in obtaining high intensity positron beams, although the injection current in Fig. 4 is even a little less in Fig. 4 than in Fig. 2. This increase is more than expected from a simple energy

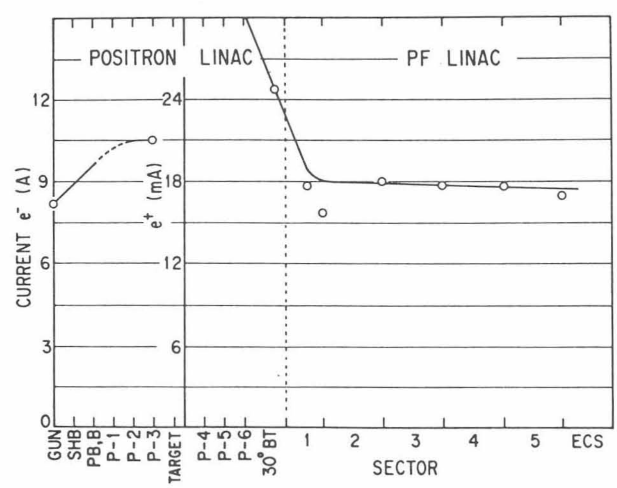
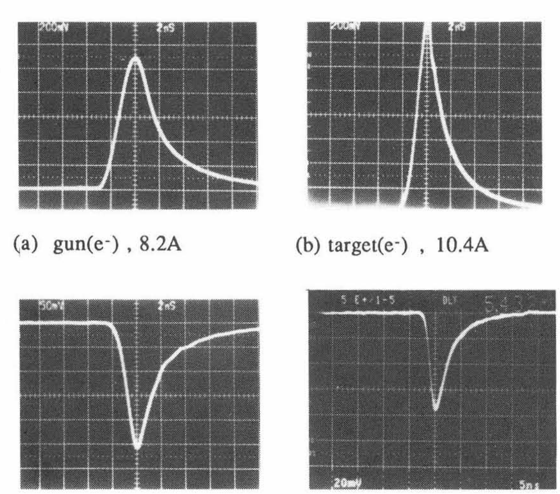


Fig. 4 Beam current along the accelerator , may , 1988



(a) gun(e-) , 8.2A

(b) target(e-) , 10.4A

(c) generator end(e+) 31.2mA

(d) 2.5GeV end(e+) 16.7mA

Fig. 5 Beam waveform

consideration, and probably due to an improvement of beam quality, such as a decrease of beam emittance. Examples of beam waveforms are shown in Figs. 5(a) to 5(d). They are measured with wall current monitors ; a long tail of a pulse is due mainly to signal transmission via a long coaxial cable.

Production and Acceleration of Positrons for PF

The positron generator has been used so far for TRISTAN, and only electron beams have been used for the Photon Factory. As for the electron beams in the storage ring for synchrotron radiation research, instability of the beam is more or less inevitable arising from ion or charged dust trapping by the beam. Therefore, to use positrons instead of electrons has been planned in the PF to overcome this difficulty completely.

Positron Beam Characteristics

In July 1988, this was tested using similar positron beams to those used for TRISTAN. One of the problems was that the time required for injecting and accumulating the beams was too long, e.g., it took ~90 minutes to accumulate 300 mA. To make it shorter it is necessary to increase the total charge, which may be achieved by using a beam with a longer pulse width. To accelerate a certain amount of charge, it is usually more advantageous to use a longer pulse as far as it is allowable for the rf pulse width, because a space charge effect as well as a wake field effect are less for a smaller peak current.

At first, therefore, a ~500 ns beam was tested ; however, it turned out that the measurement of the positron beam was difficult as the peak current was very low. Then, 20 and 40 ns beams were chosen for the test.

Result

The result of the 40 ns beams is summarized in Fig. 6. When the injection current is varied as 1.2, 2.4, 3.0, and 3.6, the positron beam current varies linearly, and about a half of the positrons is spilled in the 30° beam transport line, as in the case of 2 ns beam in Fig. 2. Examples of beam waveforms are shown in Figs.7(a) to 7(c). The electron beam at the target has a similar shape to that of the gun, whereas that of the positrons(Fig.7(b)) is appreciably different from that of the electrons. This is probably because the total electron charge is so large that the quality of the beam is different within the same pulse, such as the energy spectrum and the emittance. This may be suggested from large beam loadings observed in the rf waveforms in Fig. 7(d).

With using this beam, positron injection into the PF ring was tried. The beam had an energy spread of $\pm0.25\%$, and an emittance of $4\sim8\times10^{-6}$ m·rad, which are similar to those of the 2 ns beam. The injection rate of 0.2~0.25 mA/s was obtained, which was larger than 0.05~0.07 mA/s for a 2 ns beam by a factor of three to four.

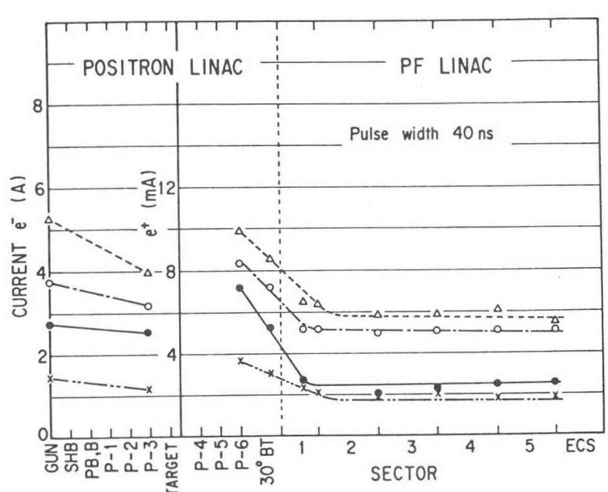
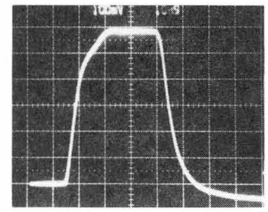
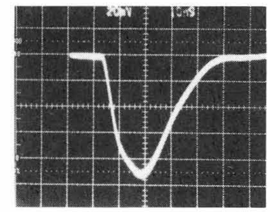
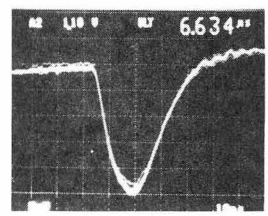
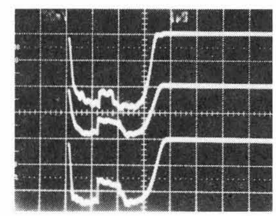


Fig. 6 Beam currents along the accelerator for 40ns pulse

(a) target(e-) , 2.4A (b) generator end(e+) , 7.0mA





(c) 2.5GeV end (e+), 2.4mA (d) electron beam loading of rf power

Fig. 7 Beam waveform and loading

Present status

One of the most important problems left at present is to provide more detailed data of the beams for the positron generator. For this purpose a system is in preparation to analyze and to monitor the accelerated beams at more points and more easily[8] Another system is also in preparation to enable the use of a long pulse positron beam for the PF in daily operation.

References

1. I. Sato et al., " Acceleration Characteristics of Positron Generator Linac, " **Proc. of 1986 Linac Conf** , SLAC , 1986 , pp. 502-504 .
A Asami et al., " Injector of the Positron Generator, " ibid , pp. 496-498 .
S. Fukuda et al., " Electron Gun for the Positron Generator, " ibid , pp. 487-489 .

2. A. Asami et al., " Present Status of Positron Generator at KEK, " **Proc. of Japan-China Joint Symp. on Accelerators for Nucl. Sci. and Their Applications** , RIKEN , JAPAN (1987) pp. 160-162 .

3. S. Ohsawa et al., " Progress of Electron Gun Systems for the e^-/e^+ Linac at KEK, " presented at this conference.

4. A. Enomoto et al., " Focussing system for the KEK Positron Generator, " to be published in NIM .

5. H. Hanaki et al., " Phase control at the KEK electron linac, " **Proc., of 12th Linac Meeting in Japan** , Tokyo Univ. and JAERI , JAPAN (1987) , pp. 177-179 .(in Japanese)

6. K. Furukawa and H. Hanaki , " Monitoring system for klystron RF outputs, " ibid , pp. 193-194 .(in Japanese)

7. T. Urano et al., " Improvement of Positron yield by an Increase of Electron Energy at the KEK Positron generator, " **Proc . of 13th Linac Meeting in Japan** ,ETL Tsukuba , JAPAN (1988) . pp. 144-146 . (in Japanese)

8. T. Shidara et al., Private communication