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ACCELERATION CHARACTERISTICS OF THE POSITRON GENERATOR INJECTOR AT KEK

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ABSTRACT

Development of the electron gun has been made ; injection voltage was raised from 115 kV to 160 kV, and a new grid pulser with a higher output voltage was made and installed. As a result, the emission current from the gun was increased from 5.4 A to 9 A. With the increase of emission current it became necessary to modify the waveguide system and the transport system to accelerate the injection current more efficiently. As for the performance of the injector, first its progress is briefly described, then it is shown that the accelerated current varies linearly with the injection current, and lastly the relation between the accelerated current and the SHB rf power is studied.

INTRODUCTION

TRISTAN MR test operation started in October, 1986, and high energy physics experiments on $e^- - e^+$ collision began in November, 1986. The positron generator has been used for the operation of TRISTAN AR and MR, and in the meantime continual efforts have been made to improve the accelerator characteristics. Conversion efficiency from an electron to a positron is so low that it is essentially important to produce electron beams with a sufficiently high current(>10 A)and a width of less than 2 ns.

The status of the injector was already reported[1] sometime before the MR test operation. In the present paper described are main components for which some modifications were made since ref 1), and then as for the acceleration characteristics are presented its progress, relation between the injection and the accelerated currents, and relation between the accelerated current and the SHB rf power.

MAIN COMPONENTS

Electron gun[2]

To obtain a high injection current with a short pulse width, it is important to use a grid pulser for the gun with good characteristics. A grid pulser[3] of the electron gun is a pulser in which avalanche transistors are used as a switching element. Transistors 2N2222A had been used for this, but were recently replaced by 2N5551. The new pulser produces an output voltage of 200 V, whereas that of the previous one was 140 V.

Injection voltage of the gun was designed to be 150 kV, however, it had been 115 kV due to the insulator limitation. A new insulator with a higher working voltage was made as shown in Fig. 1, and the injection voltage was raised to 160 kV, which enabled the injection current to increase appreciably and the acceleration of the beam much easier. With these improvements the injection current from the gun reached to 9 A with a pulse width of 4 ns.

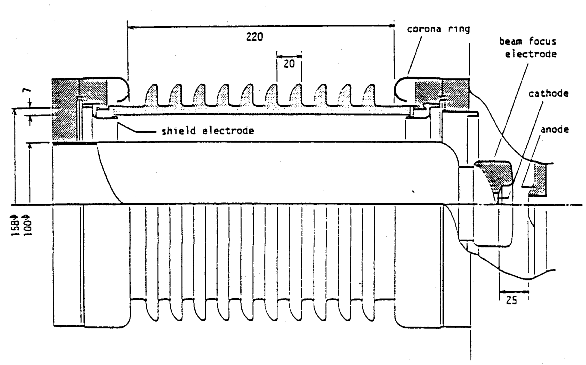
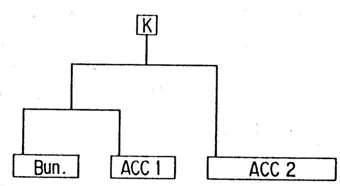


Fig. 1 Insulator of the gun

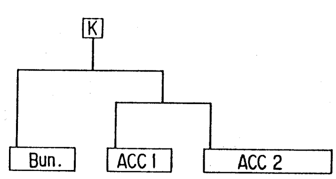
SHB

One of the problems encountered in the initial stage of the generator operation was an instability of the positron beam. One of the major reasons was a drift of the SHB rf phase, to which the positron beam is sensitive. Therefore, a phase lock system was made to the associated circuits, and the phase stability was much improved. Another alteration concerning the SHB is with the rf power, which is described later in PERFORMANCE.

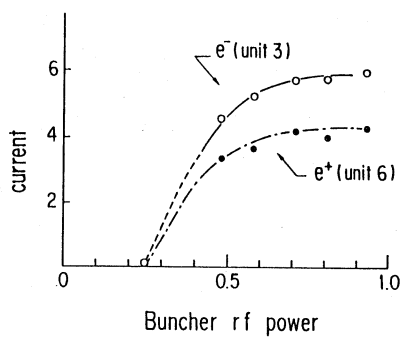
RF power to the buncher



(a) previous configuration



(b) present configuration



(c) accelerated currents vs. buncher rf power

Fig. 2 modification of rf waveguide

With the increase of the injection current, it was experienced that the capture efficiency of the beam was not satisfactory in the buncher, probably because the rf power was not sufficient. To test this problem the rf waveguide configuration was modified as shown in Figs. 2(a) and 2(b). In the previous configuration, the klystron output power was divided and fed to the buncher, the first(2 m) and the second(4 m) accelerator guides with the ratio of 1/4 : 1/4 : 1/2,respectively. In the latter, the above ratio is 1/2:1/4:1/4,i.e., a half of the total power is fed to the buncher, which is achieved at a sacrifice of decreasing rf power to the second accelerator guide.

A beam test was performed with this configuration and resulted that when the accelerated currents are plotted as a function of the buncher rf power, the curves showed saturation, as in Fig 2(c), i.e., the available rf power of the buncher is now sufficient. However, it is to be noted that the positron yield decreased because of the energy decrease of the electron beam.

Beam transport system

Another problem met with the increase of the electron beam current is a necessity to strengthen the beam focusing. It is caused by the fact that the beam emittance seems to be much larger than originally assumed at high currents.[4] This is especially true with coils located in the place where the beam current becomes high. Power supplies and cooling of a couple of them around the prebuncher and the beginning of the buncher were reinforced. A few words may be added to the beam transport in electron accelerating sections (unit 2 and 3) ; two sets of Q-triplet magnets were added to this part[5], which made the tuning of the beam transport much easier.

PERFORMANCE[6]

Progress of the acceleration characteristics

As described in ref.1, the acceleration characteristics at that time were that the beam current injected from the gun was 5.4 A with a width of 4 nsec and 3.5A current was accelerated. With the raise of the injection voltage from 115kV up to 150kV, the accelerated current was appreciably increased to 5 A, whereas the injection current was increased only a little to 6 A. Then the new grid pulser of the gun was installed, which, together with a further raise of the injection voltage to 160 kV, enabled to draw an emission current of 9A. The accelerated current reached to 7.5 A. These are shown in Fig. 3.

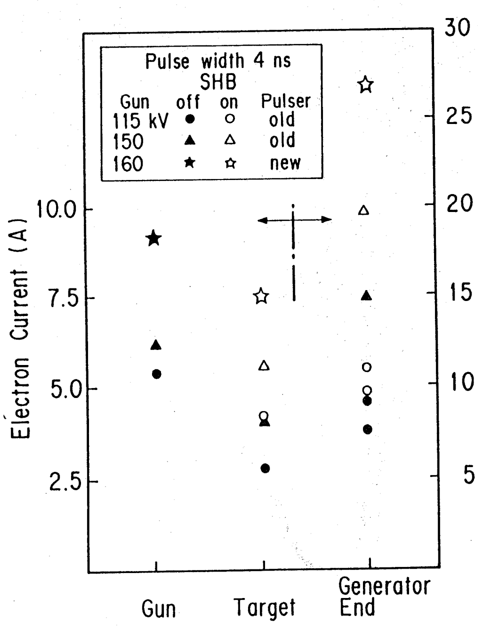


Fig. 3 Beam current along the positron generator

Progress resulted from the rf waveguide modification and the transport improvement is mentioned in the following sections.

Relation between the injection current and the accelerated current

It has been sometimes experienced as described before that although the injection current was increased, the accelerated current or the positron current could not be increased so much as expected. This is probably due to such a reason that the beam emittance became large by a space charge effect. To check this problem it is necessary to use an electron gun with which the emission current can be varied. Since this type of gun became available recently[2] the relation was studied between the accelerated currents and the injection current.

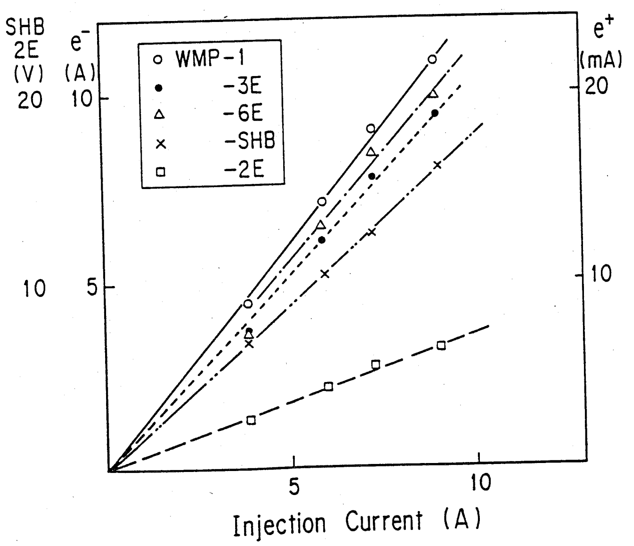
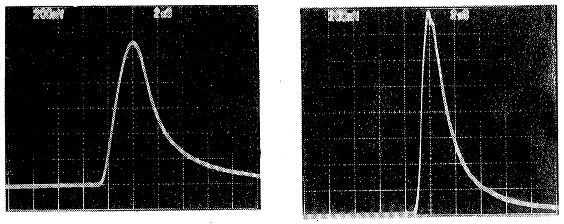


Fig. 4 Relation between injection current and accelerated current (WMP=WCM)

When the injection current was varied, tuning was made with the transport elements and some of the rf phases. A result is shown in Fig.4, where accelerated currents are plotted as a function of the injection current. The accelerated currents are measured with wall current monitors(WCM) at several locations along the generator. WCM-gun,-SHB are located downstream of the gun and the SHB, and WCM-1,2E,3E and 6E are installed in the accelerator units 1,2,3. and 6, respectively, where E denotes the end of that unit. The unit 3 and 6 are the last unit of the electron and the positron accelerating sections, respectively. The current of WCM-3E is 9.4 A, much increased from the previous value 7.5 A. As is clearly seen, all currents at various locations vary linearly with the injection current in the present stage. This owes to the improvements described before.



(a) WCM-Gun (b) WCM-3E
Fig. 5 Example of beam waveform at SHB rf 4 kW

Relation between the SHB rf power and the accelerated current

The rf power of SHB has been 2kW, which was determined from an operation experience with the wall current monitors. However, when a beam signal is very fast, it is difficult to reproduce its waveform exactly for such a monitor as a wall current detection type. Recently a streak camera became available for measuring the beam bunches, so that the relation between the SHB rf power and the accelerated beam is investigated. As an example of the beam waveforms, WCM-gun, and WCM-3E data are shown in Figs. 5(a), and 5(b), respectively, at 4 kW SHB power. The peak current of the gun is 8.4 A, and 10.8 A is accelerated.

At some SHB rf powers between 2 to 5.5kW, tuning of the transport elements is made, and then the beam current and its bunches are measured with the wall current monitors and the streak camera, respectively. The camera is set at the end of the generator, downstream of WCM-6E . Some results are shown in Figs.6(1a) to 6(4d), which are data with the rf power of 3, 4, 5 and 5.5 kW, respectively, and figures(a) are positron beam waveforms with WCM-6E, and figures(b) are positron beam bunches with the streak camera.

At the present stage, it is erroneous to compare the output amplitudes of the streak camera for different rf powers,because there is some fluctuation, however, the shapes of bunches may be compared. With the increase of the SHB rf power, the pulse width clearly decreases. When the bunches are compared with the WCM waveforms, it is seen that the time interval from the first to the last bunch corresponds to that from the starting time to the peak. This sugests that the peak of WCM is not the peak of the pulse but is related to the total charge of the beam pulse. The tail of WCM waveform arises from the monitor characteristics and not from the beam. From these experiment and considerations, the SHB rf power has been changed from 2 kW to 5 kW in the scheduled operation.

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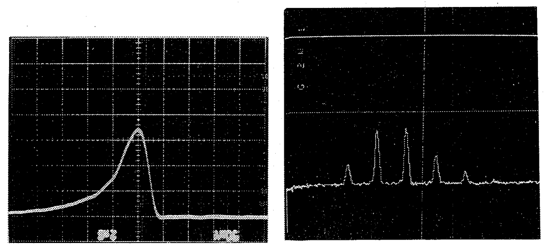
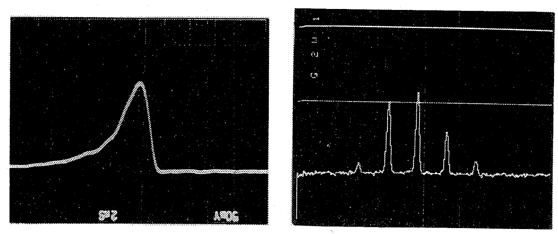
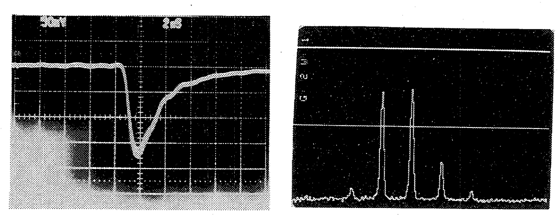


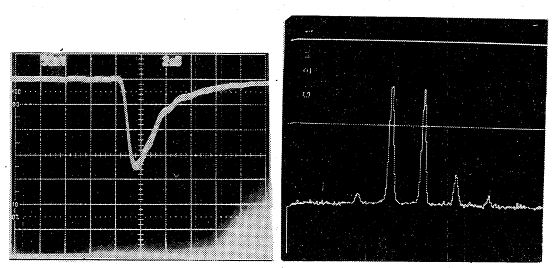
(a) (b)
(1)SHB = 3 kW



(a) (b)
(2)SHB = 4 kW



(a) (b)
(3)SHB = 5 kW



(a) (b)
(4)SHB = 5.5 kW

Fig. 6 Positron beam waveform (a) and beam bunchs (b) with SHB rf power as a parameter