INJECTOR OF THE POSITRON GENERATOR

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Abstract: Main components of the Positron Generator injector are briefly described, which include an electron gun, an SHB, a prebuncher and a buncher, an rf waveguide, a transport and a vacuum system, etc. The vacuum system around the gun was carefully made to obtain a high emission current. The SHB was introduced to inrease the peak current and operates at 119 MHz, the 24th subharmonic frequency. Performance of the injector has been tested yielding the results that about 60 % of the injected current from the gun is successfully accelerated without the SHB. An injection current obtained is typically 7 A for 5 nsec pulse. For 3 nsec (FWHM) beam the accelerated electron and the positron beams are increased by a factor of 1.5 with the SHB.

Introduction

Positron beams required in TRISTAN for $e^+ - e^-$ collision experiments are produced by bombarding a tantalum target with electrons in the Positron Generator. The conversion efficiency from an electron to a positron, however, is very low (an order of one thousandth at 200 MeV) and, therefore, it is important to obtain an electron current as high as possible for getting a sufficiently high positron beam. In addition, the beam emittance and the bunch width should be suitably small not to deteriorate positron beams, which already have a larger emittance and easily produce a large bunch spread. The beam pulse width should be less than 2 nsec at the base in order to be accelerated as a single bunched beam in TRISTAN.

To meet these requirements, the injector of Positron Generator was designed and constructed. The design of a prebuncher, buncher and a beam transport system is described in ref. (1), and the development of a high current electron gun is reported in ref. (2).

The construction of injector was almost completed in April 1985, and later in October a modification was made to install a subharmonic buncher (SHB). The SHB was adopted to increase the peak current by suppressing the beam width, and is now under test operation.

In the next section main components of the injector are briefly described, and the results of the test operation are given in the last section.

Main components

The layout of the injector is shown in Fig. 1. A relatively large distance between the gun and the SHB is needed to set a low conductance vacuum duct for differential pumping and to install the electron gun in an adjacent room to the accelerator tunnel separated by 1 m thick concrete wall. The space from the acceleration gap of the SHB to the prebuncher is a drift distance of 2.6 m long.

Electron gun

This uses the same type of grid-cathode assembly with a diameter of 10 mm as used in the PF linac[3]. In order to draw much higher currents modifications were made to its electrode and vacuum system[2]. The maximum current obtained is 9.5 A for a pulse of 10 nsec, and it decreases to 7 A for a 5 nsec pulse due to a decrease of grid pulse amplitude. The injection voltage is 100KV, and the perveance of the gun is approximately 0.26 $\mu A/V^{3/2}$.

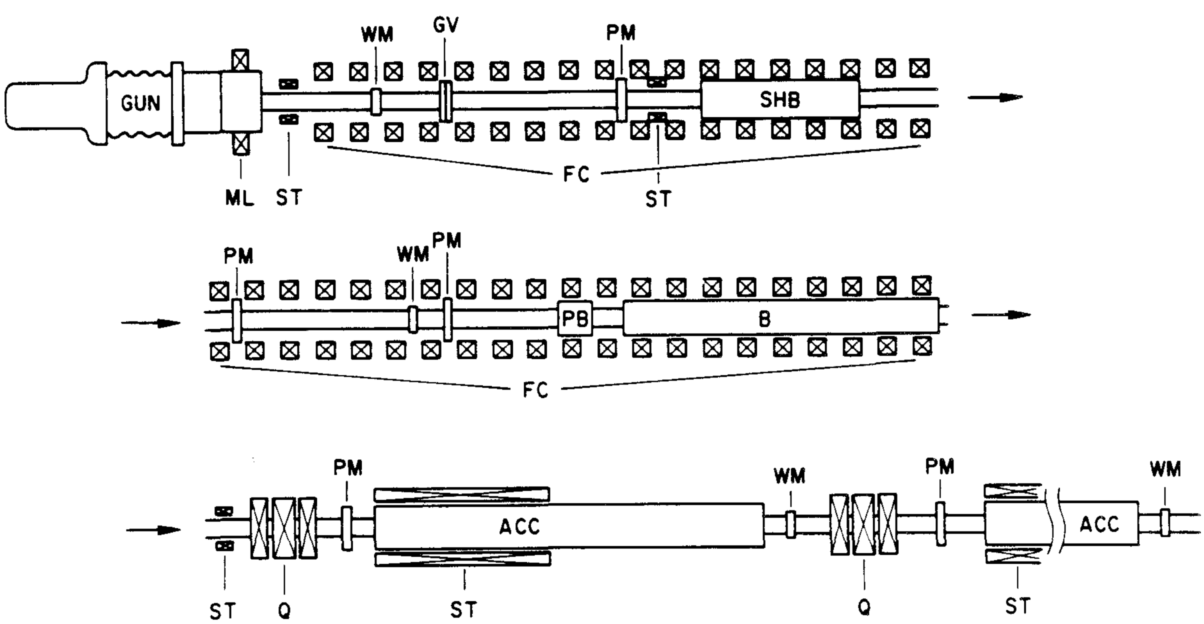

Fig. 1 Layout of the injector of the Positron Generator.
SHB: Subharmonic buncher, PB: Prebuncher, B: Buncher, ACC: Accelerator guide, ML: Magnetic lense, ST: Steering coil, FC: Focus coil, Q: Q-magnet, GV: Gate valve, WM: Wall current monitor, PM: profile monitor.

SHB

The SHB operates at a frequency of 119 MHz, corresponds to the 24-th subharmonic of 2856 MHz, acceleration rf frequency of the Generator. The cavity is a quarter-wave resonant cavity of coaxial type, and its structure is shown in Fig. 2. The main parameters of SHB are summarized in Table 1. Calculations are made with a code similar to ref. (4), which shows that with the SHB the increase of peak current is expected by a factor of two or so. However, if the initial beam pulse has a long tail,some of them would remain in the final beam and produce backgrounds,even though they would be reduced appreciably.

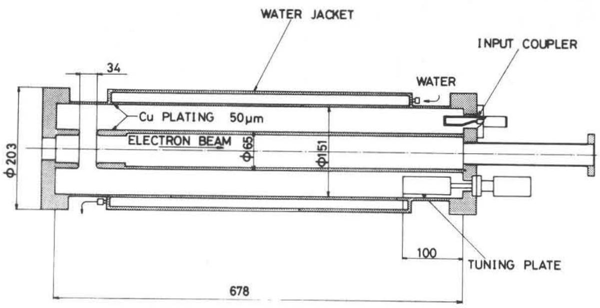

Fig. 2 SHB cavity.

Table 1. SHB main parameters

Resonance frequency	119 MHz
Tunning range	710 KC
Cavity dia.	151 mm
Drift tube dia.	65 mm
Cavity length	678 mm
Gap length	34 mm
R_o/Q_o	270 Ω
Q_o	3500

The rf amplifier for the SHB cavity consists of an 80 W and a 500 W driver amplifier and a final stage amplifier, in which a conventional power tube (RCA 7651) is used. Its maximum output power is 5 kW pulse. The power supplies for the electrodes of this tube are very well-regulated, which makes it possible to stabilize the rf output amplitude and phase without rf feed-back circuits.

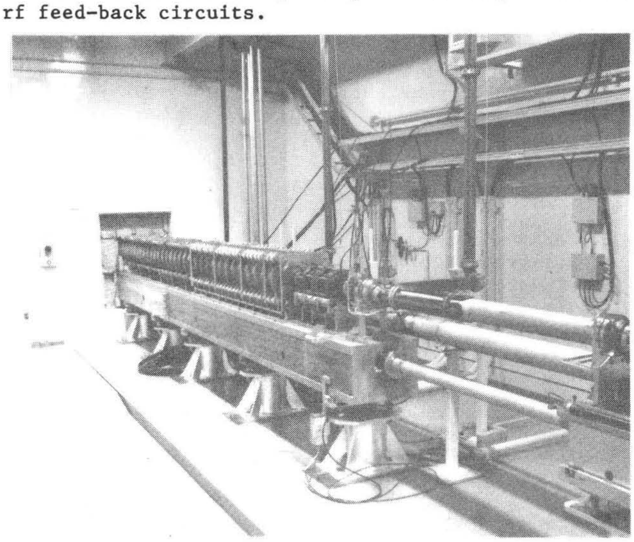

Fig. 3 Photograph of the injector from the end of the first accelerator guide.

Prebuncher, buncher and accelerator guides

These are all 2/3π mode and of the travelling wave type. The prebuncher consists of 7 cavities with a β-value (phase velocity/light velocity) of 0.7, and prebunches electrons with a little acceleration. The buncher consists of 9 cavity buncher section and 35 cavity regular section. In the buncher section the β-values gradually varies from 0.78 to 1.00, and electrons are rapidly accelerated by a high electric field. Attention has been paid to enable to accelerate high currents and to produce narrowly bunched beams.

Following the buncher there intalled two accelerator guides, the first guide is 2 m long, the second guide 4 m long. These accelerator guides are of the same type as used in the following acceleration units[5]. The injector seen from the end of the first accelerator guide is shown in Fig. 3.

Beam transport system, beam monitors, and vacuum system

The beam transport system reported in ref(1) was modified to allow the SHB installation, and total of 22 solenoid coils was fabricated and installed, each has an inner and outer diameter of 200 and 400 mm, respectively, with a thickness of 75 mm. The maximum magnetic field obtainable with these coils is about 600 gauss.

To measure the beam current two kinds of wall current monitor is used, one without any electric shield, the other with an aluminium shield case. Beam profile monitors utilize a chromium activated alumina ceramics (Desmarquest AF995R) as a screen. These monitors are placed along the injector as shown in Fig. 1.

The vacuum system of injector is similar to those in the following acceleration units, but evacuating pumps are reinforced that two 500 l/s ion pumps are provided for its vacuum manifold and two 60 l/s ion pumps for its rf wave guide. In particular, it is important to attain a clean ultrahigh vacuum around the gun and a special vacuum system is adopted in this part.[2]

RF waveguide

A high power klystron with an output power of 30 MW is provided in the injector, and a quarter of the output is fed each to the buncher and to the first accelerator guide, and the remaining half of the power to the second accelerator guide.

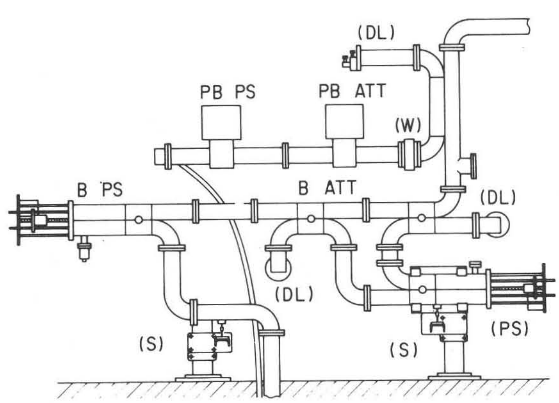

Fig. 4 RF wave guide for the buncher (B) and prebuncher (PB).
PS: Phase shifter, ATT: Attenuator, DL: Dummay load, W: Window, S: Support, A simbol blackets denotes a component of PS or ATT.

One of the characterestics of our linac rf system is that neither high power attenuator nor phase shifter is used except in the injector. A high power attenuator and a phase shifter are both essential in the injector. They are designed and manufactured to be operated in vacuum, whereas most of those currently used are operated in pressurized SF6 gas. The advantage of those operational in vacuum is to eliminate vacuum windows and extra vacuum system and makes the operation much easier. An attenuator and a phase shifter for the prebuncher are used in atomosphere because rf power concerned is sufficiently low. The waveguide system for the buncher and prebuncher is shown in Fig. 4.

Performance

As described in Introduction, the beam pulse width should be sufficiently less than 2 nsec at the base, however, the test operation was carried out with a beam pulse of a 10 nsec half width. This is because it enables to obtain a higher electron current, and to produce a more intense positron beam, thus making the test much easier.

Recently the pulse width was reduced to 5 nsec at FWHM. The beam current from the gun observed with the first beam monitor is shown in Fig. 5, where the peak is about 7 A and the width is a little longer than 5 nsec at FWHM. The rather long undershoot observed at the tail would mainly be due to the response of the

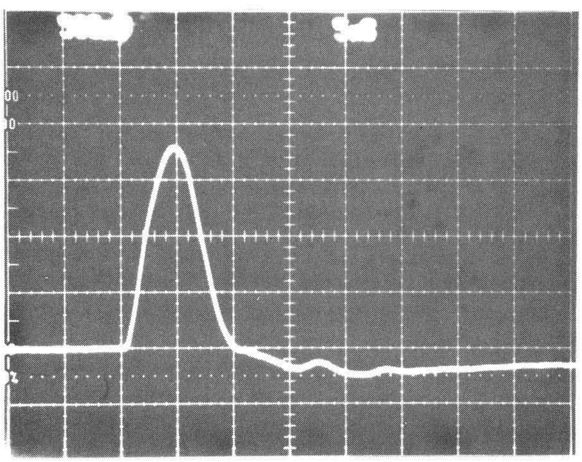

Fig. 5 Injected beam from the gun. The peak current is about 7A.

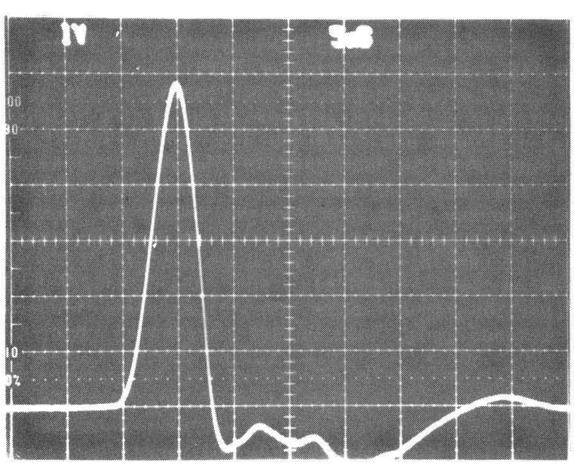

Fig. 6 Accelerated beam observed at the end of the first accelerator guide. The peak current is about 4 A.

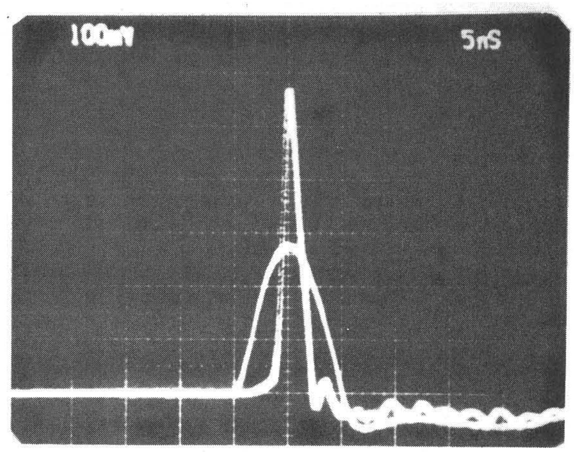

Fig. 7 Accelerated beams with and without the SHB. The beam with a lower peak is obtained without the SHB, while that with a higher peak is with the SHB.

monitor. Figure 6 shows the accelerated beam current observed with a monitor in the downstream position of the first accelerator guide. The peak current is about 4 A, which is about 60 % of the injection current. This current is accelerated to the end of the injector without any significant loss. In this case the rf power of SHB is off and the SHB has no effect on the beam.

Test operation of the SHB was carried out first with a 5 nsec beam. The phase and the power of 119 MHz rf were varied and tunning of the transport elements was also made observing the beam signals along the beam path. As a result of this test the beam current downstream after the buncher was increased by about twice. Figure 7 shows the beam waveform observed with the monitor just behind the first accelerator guide. A beam signal which has a wider width and a lower peak is obtained without the SHB, and that with a narrower width and a higher peak is obtained with the SHB on. The peak current is increased by a factor of two with the SHB. The injected beam has a width of a least 10 nsec at the base, the width of the bunched beam with the SHB is still too wide to be used in practice.

Another test was quite recently made with a narrower beam, and production and acceleration of positron beams up to 2.5 GeV was tried. The width of the beam was 3 nsec at FWHM and the peak current was 3.5 A. When the SHB was on, the accelerated electrons were increased in peak current by a factor of 1.5, and positrons accelerated to 2.5 GeV were also increased by the same ratio.

References

1. A. Asami et al., "Design of the injection system of Positron Generator", in Proc. of the 5th Symp. Accelerator Sci. and Tech, KEK, 1984, pp.71-73.
2. S. Fukuda et al., "Electron gun for the Positron Generator", presented at this conference.
3. J. Tanaka et al., "Construction progress of the Photon Factory2.5 GeV electron linac", in Proc. of 1981 Linac Conf, Santa Fe, 1982, pp.360-362. J.Tanaka, "Operation of the 2.5 GeV electron linac", in Proc. of 1984 Linac Conf., Darmstadt, 1984, pp.475-479.
4. G. Mavrogenes et al.,"Subnanosecond high-intensity beam pulse", IEEE Trans. Nuc. Sci., Ns-20(3), 919 (1973).
5. I. Sato et al., "Acceleration characteristics of positron generator linac", presented at this conference.