ELECTRON GUN FOR THE POSITRON GENERATOR

S. Fukuda, Y. Ogawa, Y. Saito, Y. Otake, S. Ohsawa, S. Anami,
T. Shidara, N. Kaneko, A. Asami and J. Tanaka
National Laboratory for High Energy Physics (KEK)
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305 Japan

ABSTRACT

A triode electron gun has been installed on the Positron Generator at KEK, and brought into test operation. It involves a grid-cathode assembly currently used in a planner triode. The cathode has a diameter of 10 mm and is coated with Ba-Sr-Ca oxide. Because of the short grid-cathode distance (0.18 mm), the relatively low grid pulse voltage makes possible to draw a high current. The assembly has a small vacuum flange which allows its easy replacement.

Emission current from the oxide cathode is sensitive to residual gases, therefore the vacuum system is carefully made and the pressure is kept in the range of 10^{-9} Torr even when the accelerator is on. The grid pulser is a line type pulser using multi-stage avalanche transistors as a switch. The pulse width of 10 nsec has been used for the test to investigate the gun characteristics.

The performance of the gun has been tested with this pulser and the emission current of 9.7 A was achieved at an injection voltage of 110 kV. The characteristics of the gun are described together with the beam trace.

INTRODUCTION

The Positron Generator is designed for the position injection into the TRISTAN ring at KEK. Because of a very low conversion efficiency from an elecron to a positron, an electron beam current should be very high, and moreover its width should be less than 2 nsec. To satisfy these requirements the injector of the Positron Generator has been constructed,[1] and a high current electron gun has been developed.

A peak current of 10 A was aimed and for this purpose a high current thermionic gun has been tested and brought into operation. The beam width of 2 nsec will be achieved with a suitably short pulse and using a subharmonic buncher.

ELECTRON GUN

The electron gun for the Positron Generator is a gridded oxide coated gun currently used in a planner triode and basically the same one as used in the PF linac.[2] This makes use of a cathode-grid structure; a part of 2C39 planner triode, and is supplied from TOSHIBA Co. Ltd. as a Ba-Sr-Ca carbonate coated cathode.[3] The cathode has a 10 mm diameter and a grid-cathode distance is 0.18 mm. Because of its short distance the relatively low grid pulse voltage makes it possible to draw a high current. Rating of the filament voltage and current are 6.3 V and 1.3 A respectively. Maximum rating of the peak cathode current is 20 A. This has merits of its compact size and very low cost . Its structure is shown in Fig. 1. The gun structure has small vacuum flange, which allows its easy replacement. The gun is mounted on an assembly stem. Inside of the stem, there are a grid pulser and an optical-electric trigger-signal converter module. Figure 2 shows the cross section of a whole electron gun assembly. The gun electrode geometry was determined using the electron trajectory program of W.B. Herrmannsfeldt.[4] Its geometry is chosen so that the gun has a slightly higher perveance to get an enough emission current. The distance between the cathode and the anode aperture is 24 ± 0.5 mm and the anode hole diameter is 13 mm. The calculations predict a perveance of 0.26 $\mu A/V^{3/2}$ and an emittance of 1.65 × $10^{-3}\pi$ m₀c-cm. Also the predicted maximum field gradient is 88 kV/cm on the anode aperture at 110 kV cathode voltage. Figure 3 shows the calculated beam trajectory.

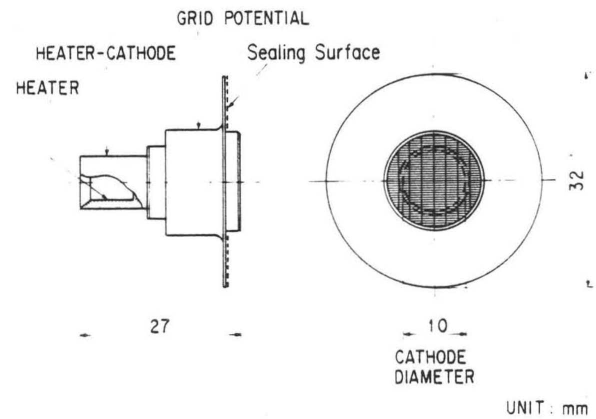

Fig. 1 A cathode-grid structure of the oxide gun E3078.

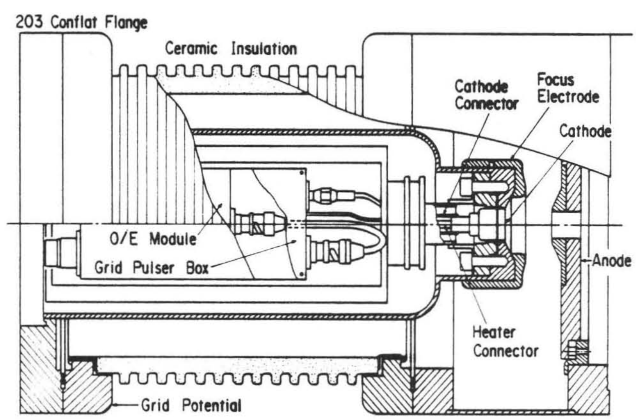

Fig. 2 Cutaway view of the electron gun assembly.

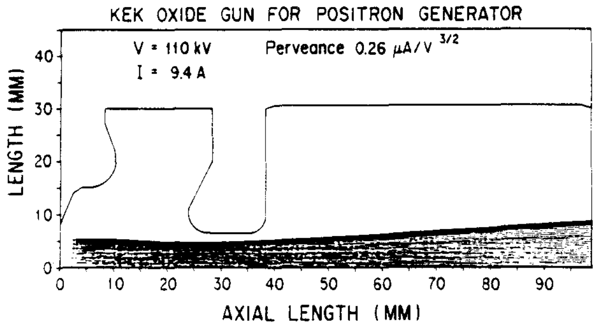

Fig. 3 Beam trajectory from the cathode to the center of magnetic lens.

VACUUM SYSTEM

The oxide coated cathode has an advantage that a high current is produced at the relatively low temperature (about 800°C), while it has a disadvantage that an emission current is sensitive to residual gases. Therefore a vacuum system was carefully designed. Figure 4 shows the block diagram of the vacuum system. In order to isolate the gun chamber from the accelerator guide (where typical pressure is 10^{-7} Torr), a beam duct has a small diameter (35 mm) to give a low conductance and is differentially pumped with 4 ion pumps of which pumping speed is 10 ℓ/s, respectively. A turbo molecular pump is used as a roughing pump and a cryo pump is used in the conversion process from carbonate to oxide. The cryo pump is also used as an auxiliary pump. The gun assembly parts are carefully processed in vacuum. For example an anode aperture and a focus electrode are made of low carbon material (SUS316L), polished within the surface roughness of a few μm and baked out in a vacuum induction furnace. Baking of a whole system is performed more than 48 hours to reduce a water vapor after installing the gun stem to the chamber. After these processes, the conversion is completed within 40 minutes, and easily activated. The emission test is run under the pressure in the range of 10^{-9} to 10^{-10} Torr. The pressure is kept in the same range on a beam extraction while the gate valve between the gun chamber and the accelerator guide is opened.

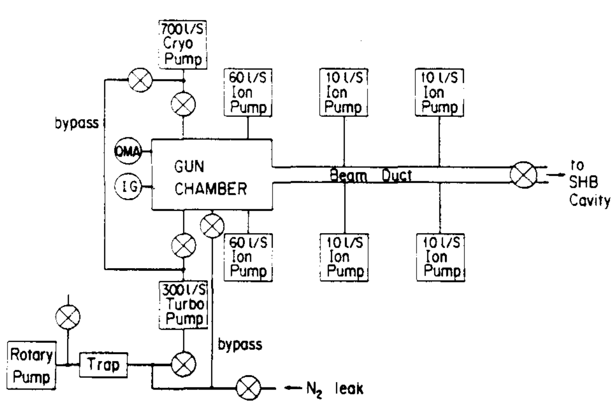

Fig. 4 Block diagram of vacuum system. QMA: Quadrupole Mass Analizer, IG: Ion Gauge.

PULSER SYSTEM

The cathode pulse is fed from a line-type gun modulator and a pulse transformer with its step-up ratio of 1:12 through a high voltage deck. Available maximum voltage is 150 kV. The heater power supply and associated control modules are on this deck. The trigger signal which drives the grid pulser is sent through an optical fiber and converted to the electrical signal in the gun assembly. The grid pulser is a line type pulser using avalanche transistors as a switch. Figure 5 shows the diagram of this pulser. A pulse width is determined varying the length of 50 ohm coaxial cables. For the purpose of a high current drive, this pulser consists of multi-stage avalanche transistors. Two transistors are triggered simulataneously in order to make a stable avalanche operation. The output impedance is determined by the number of parallel coaxial cables.

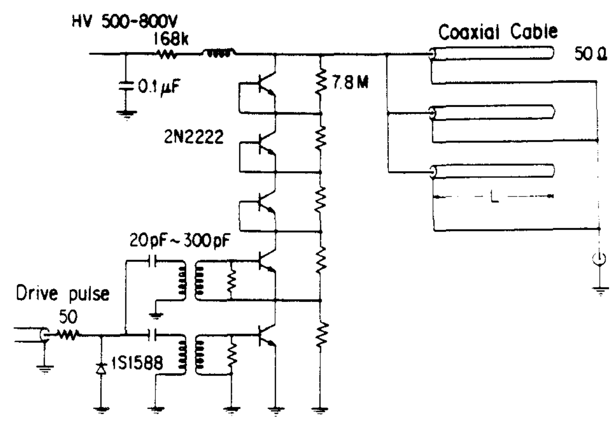

Fig. 5 Simplified circuit of the short pulse grid pulser. L is about 24 cm at the 10 ns pulse width.

CHARACTERISTICS OF THE ELECTRON GUN

Figure 6 shows the emission characteristics as a

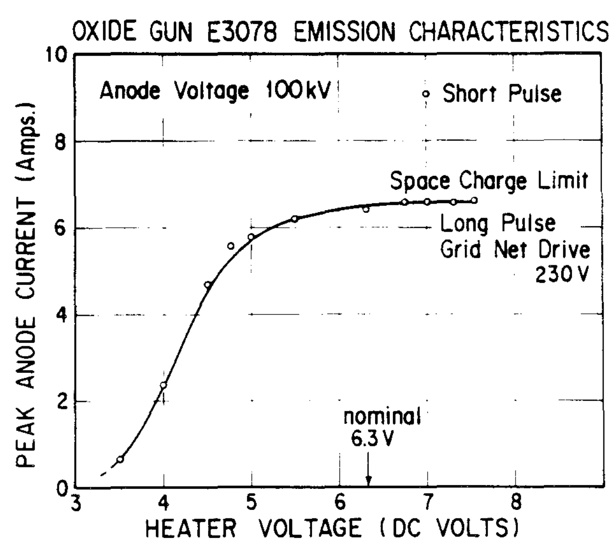

Fig. 6 Emission characteristics of the oxide gun E3078 as a function of heater voltage.

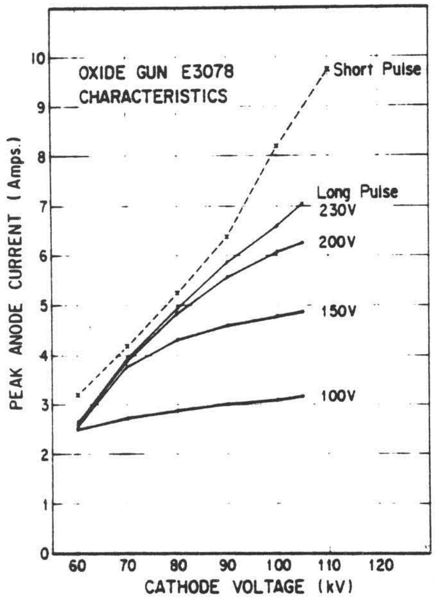

Fig. 7 Emission characteristics of the oxide gun E3078 as a function of cathode voltage. Valtage written in the graph shows the grid net drive voltage for the long pulse. Net drive voltage for the short pulse is about 250 V. Heater voltage of these tests is 7.0 V.

function of a filament voltage and Fig. 7 shows the gun triode characteristics. These measurements are done in both a short pulse mode of 10 nsec and a long pulse mode of 1 μsec. This gun works in the space charge limited regin at nearly 6.3 V filament voltage of rating specification (and measured temperature at this voltage was 810 °C_B). The cathode voltage is currently limited to 105–110 kV because the insulation ceramic is the same one as Photon Factory Linac (which is used in 100 kV operation). The peak current of 7 A with a long pulse (the cathode voltage of 105 kV and the net grid pulse of 230 V) and 9.7 A with a short pulse (the cathode voltage of 110 kV) were achieved. On the short pulse mode, a measured average perveance was 0.263 $\mu A/V^{3/2}$ and a cathode drive active impedance was about 17 ohm. The grid interception was estimated to be about 25 % from the measurement on a long pulse operation. The pressure was kept less than 3×10^{-9} Torr when the test was performed. Recently the other modes of 3 nsec and 5 nsec (FWHM) were also tested. Emission current decreases to 7 A for a 5 nsec pulse due to a decrease of a grid pulse amplitude. Figure 8 shows the waveform of the short pulse beam which has been used on the positron acceleration. The short pulse beam was measured by a wall current monitor with an ambiguity of several %. The precise characteristics of the injector section on the positron acceleration will be presented elsewhere.[1] So far this gun has a good performance, especially the current density of 12 A/cm^2 is achieved. In near future, a higher cathode voltage operation of 150 kV will be planned and then peak current of about 15 A is expected. We also planned a data accumulation about the life of this gun under a high current extraction.

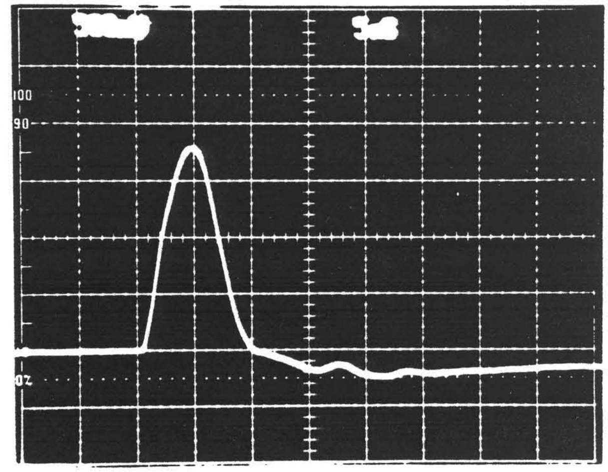

Fig. 8 Waveform of the electron beam from the gun. This pulse width is 5 nsec and the peak current is about 7 A.

REFERENCE

1. A. Asami et al., "Injector of the Positron Generator", presented at this Conference.
2. J. Tanaka et al., "Construction Progress of the Photon Factory 2.5 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.
3. Toshiba Electron Tube Component and Device Technical Data on E3078 Oxide Electron Gun.
4. W.B. Herrmannsfeldt, "Electron Trajectory Program", SLAC Report 226, November 1979.