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DEVELOPMENT OF AN ELECTRON GUN FOR THE KEK POSITRON GENERATOR

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Abstract In the KEK Positron Generator, a semi-long pulsed beam (~40ns) has turned out to be suitable for effective positron injection into the PF storage ring. However, to use the semi-long pulsed beam, there was a problem concerning the cathode lifetime of the gun. Thus, a new gun has been developed with a dispenser cathode, Y-796(EIMAC); the characteristics of this gun have been investigated. This new gun has been used since October 1988 and has continued to produce constant current of about 12 A without having to exchange its cathode. Thus, the cathode lifetime has been remarkably improved.

INTRODUCTION

Positrons had so far been utilized only in the e^+-e^- colliding experiments of TRISTAN, which began in November 1986. Since 1988, however, it had started to use positrons also in the Photon Factory storage ring. It had been confirmed that a positron beam with a width of ~40 ns was suitable for the PF ring to reduce the injection time.[1,2,3] However, to use this semi-long pulsed beam, there was a problem regarding the cathode lifetime of the old gun, the cathode of which was an oxide-coated type.[4] Therefore, a new gun with a dispenser cathode, Y-796(EIMAC), has been developed to achieve a long lifetime of the cathode and to obtain a larger anode current.

DESIGN OF THE ELECTRODE SHAPE OF THE GUN

It is expected that a new gun with a cathode of Y-796 will produce a large anode current,[5] since the cathode is of large dimension (~ϕ 16.0 mm). On the contrary, it is necessary to take account of the focussing of an emitted beam with large dimensions. Defocussing of the beam in the gun is mainly caused by the effects of beam space charge and the anode aperture of the gun. A cathode with a flat surface, like Y-796, does not have a focussing effect in itself, which may counteract the above-mentioned defocussing effects. Therefore, it is necessary to design the gun's electrode shape so as to produce a

focussing effect on the emitted beam. Figure 1 shows the gun optics calculated by the electron-trajectory program of W.B.Hermannsfeldt.[6] In the calculation the current was assumed to be 12 A, which is the actual value of a short-pulsed beam (2 ns). The calculations predict a perviance of 0.19 μ A/V$^{3/2}$ and an emittance of 1.4x10^{-2} π (m$_0$c cm). In the space-charge limited region the maximum anode current is predicted to be 32 A at an injection voltage of 160 kV. However, under real operation the anode current may be limited by the emission capability of the cathode.

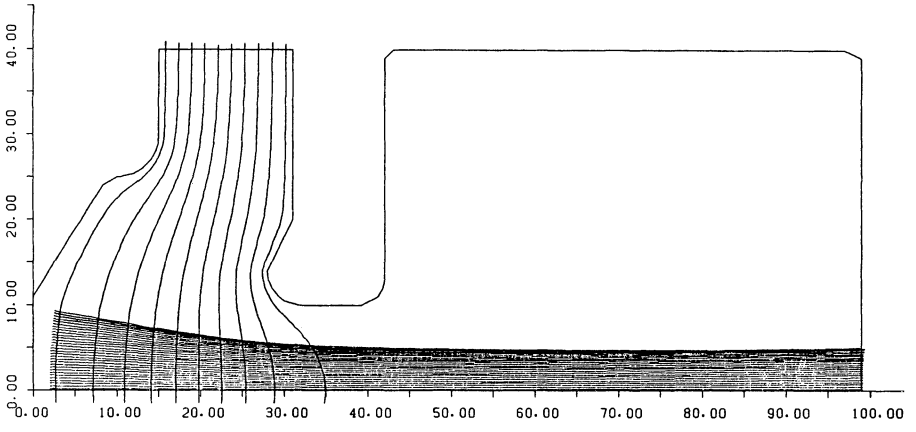

FIGURE 1 Computer plot of the gun optics at 160 kV showing equipotential surfaces and the beam-focusing pattern. The shaded area denotes the electron beam. The emission current is assumed to be 12 A.

EMISSION TEST AT THE TEST BENCH

The characteristics of the newly designed gun were investigated at a test bench before actually being installed into the Positron Generator. At the test bench the anode current was measured with a Faraday cup. Here, it must be mentioned that the anode hole of the gun installed into the test bench was a little larger than the present one used in the Positron Generator (by 2 mm in diameter). Therefore, it may be erroneous to make a comparison with this measured test-bench value and that with a wall current monitor in the Positron Generator (mentioned later).

According to the measurements, when the anode currents are plotted as a function of the heater current or the injection voltage, the curves show saturation, as in Figs. 2 and 3, respectively. Those characteristics can be explained as follows. In Fig. 2, when the heater current is below 5.5 A, the emission current depends primarily on the temperature

of the cathode. Thus, the emission current is linearly increased, as shown in Fig.2. When the heater current is increased by more than 5.5 A, the emission current comes to be limited by the effect of the space charge of the emitted beam. In the case of Fig.3, the saturation is due to the emission limit of the cathode at its temperature. Thus, the emission current is not so much increased as is the increased anode voltage.

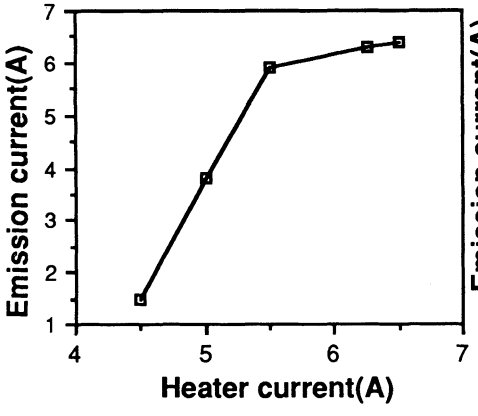

FIGURE 2

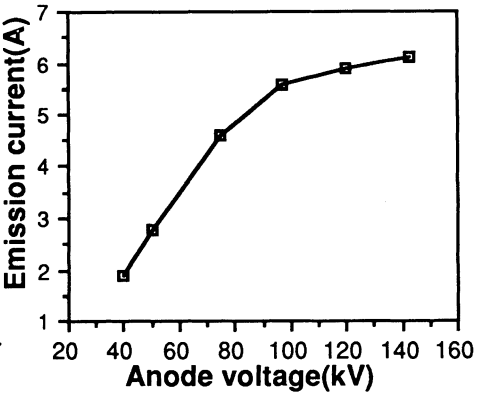

FIGURE 3

FIGURE 2 Emission characteristic of the new gun as a function of the heater current. The short-pulsed beam (2 ns) was operated at an anode voltage of 143 kV.

FIGURE 3 Emission characteristic of the new gun as a function of the anode voltage. The short-pulsed beam (2 ns) was operated at a heater current of 6 A.

BEAM TEST AT THE POSITRON GENERATOR

After the bench test, the newly designed gun was installed in the Positron Generator. At first, there was strong anxiety that the final e^+/e^- ratio of the Positron Generator might decrease, since the beam emittances might become much larger than the former value as a result of this exchange for a cathode with larger dimensions. The transport characteristics of the semi-long pulsed beam are shown in Fig.4; the accelerated currents were measured with a wall-current monitor at several locations along the accelerator. P-3 and P-6 are the last units of the electron- and positron-accelerating sections of the Positron Generator, respectively. As shown in Fig.4 , the ratio e^+/e^- (P-6 / P-3) is about 0.3% in both guns. Thus, there was no deterioration of the final ratio e^+/e^- due to the exchange.

Figure 5 shows the change in the anode current of the 2-ns beam during the first month, during which the operation with the new gun was started. After the first operation of the 40-ns beam, the anode current of the 2-ns beam was suddenly increased by 60%, as shown in Fig.5. It can be seen that the cathode was more activated by heavy loaded operation, like the emission of the 40-ns beam, and the cathode changed to one which tended to emit more electrons. Finally, a 2-ns beam current of about 12 A could be obtained in the Positron Generator,which was larger than the former one.

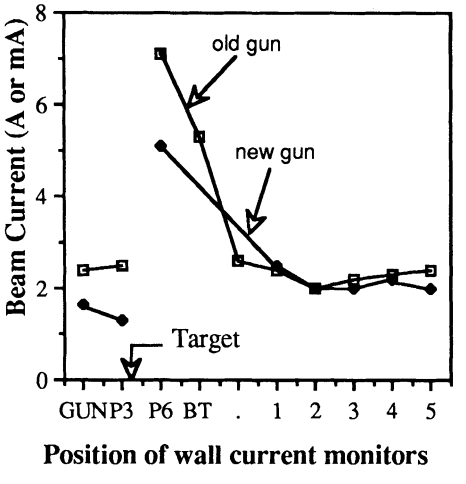

FIGURE 4

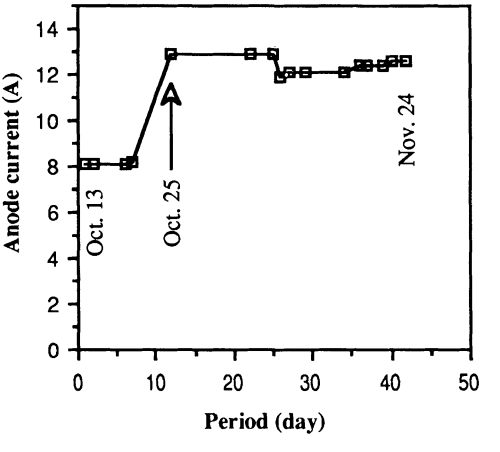

FIGURE 5

FIGURE 4 Beam current of the semi-long pulsed beam (~40 ns) along the Positron Generator and the 2.5-GeV linac.

FIGURE 5 Change of anode peak current with time during the first operation of the new gun. The short-pulsed beam (2 ns) was operated.

CATHODE LIFETIME OF THE GUN

This newly designed gun was installed in the Positron Generator in October 1988; since then, without exchanging its cathode, the gun has been used to produce the 40-ns beam for the PF-ring and the 2-ns beam for the TRISTAN Accumulation Ring. The change in the anode current of the 2-ns beam is shown in Fig. 6, where the data of the former gun are also plotted for a comparison. The case of a semi-long pulsed beam is shown in Fig.7. The anode current increased discretely sometimes during the past year. This was due to an increase in the output voltage of the grid pulser. As compared with the curve of the former oxide cathode, it turns out that the cathode lifetime has been improved.

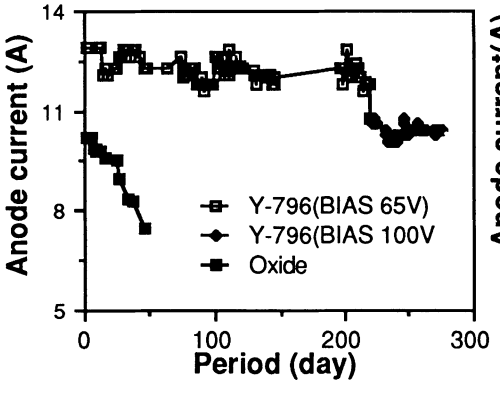

FIGURE 6

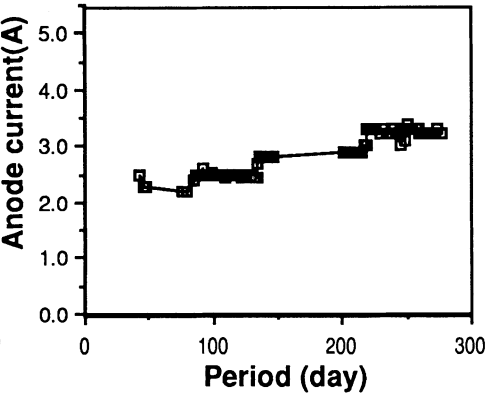

FIGURE 7

FIGURE 6 Changes in the anode peak current of the 2-ns beam of the dispenser cathode and the oxide cathode with time over about 300 days.

FIGURE 7 Change in the anode peak current of the 40-ns beam of the dispenser cathode with time over 300 days.

SUMMARY

A new gun with a dispenser cathode ,Y-796(EIMAC), has been developed, which has a remarkably long cathode lifetime. This gun was installed and has been operated during the past year without having to exchange its cathode. During this period, there was no serious trouble with the gun.

ACKNOWLEDGMENT

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