PROGRESS OF ELECTRON GUN SYSTEMS FOR THE e-/e+ LINAC AT KEK

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Abstract: Several improvements have been made in the electron gun systems of the 2.5 GeV PF linac and the Positron Generator. In the electron gun system of the PF linac, the vacuum system and the focusing system have been modified, and the anode current was increased. In the case of a short pulse beam with a width of 2 ns, the anode current has been more than 200 mA for about a year with a constant pulse voltage output of a grid pulser. Injection time of the electron beam into the Accumulation Ring of TRISTAN has been normally less than 10 s. Meanwhile in the electron gun system of the Positron Generator, improvements have been made mainly in the following two points; (1) a raise of injection voltage of the gun from 115 kV to 150 kV, which was made possible by using a newly designed insulator, and (2) an increase of pulse voltage output of a grid pulser by use of new transistors with a high slew rate. As a result of these improvements, a maximum anode peak current of 12 A with a pulse width of 4 ns can be obtained, which satisfies the design parameters of the gun system.

Introduction

In the electron linacs at KEK, two electron guns are now in operation. One is the gun for a 2 ns / 0.7 μs electron beam which is injected into the colliding ring of TRISTAN / the Photon Factory storage ring.[1] The other is the gun for a high intensity electron beam in the Positron Generator. In the gun of the PF linac, there was a problem that anode current was affected by residual gases in the gun chamber and changed with pressure. This situation has been improved by modifying the vacuum system. The focusing system and beam monitors were also modified. Meanwhile in the gun of the Positron Generator, some improvements have been made to increase the anode current and to obtain a beam suitable for easy operation. Positrons had been used only in the colliding ring of TRISTAN, but recently it has started to use positrons also in the PF ring.[3] It has been confirmed that a positron beam with a width of tens ns is suitable for the PF ring to decrease the injection time. Therefore, it is necessary to prepare two kinds of positron beams of which pulse widths are 2 ns and tens ns. A beam width selection system has been developed to remotely switch over the beams.[4]

Electron Gun System for the 2.5 GeV PF Linac

Overall modifications have been made in the electron gun system in 1987: the vacuum system, the focusing system, and beam monitors. Improvement of the vacuum system, however, was main in these modifications. As a result, the anode current became considerably stable over a long range of time especially in the long pulse mode operation, and in the short pulse mode operation anode current noticeably increased.

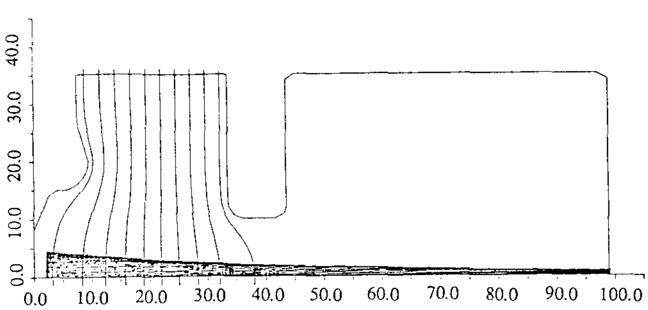

Fig. 1. Computer plot of the gun optics at 100 kV showing equipotential surface and beam focusing pattern. Shaded area denotes the electron beam. The emission current assumed to be 573 mA.

Electron Gun

In our electron guns, a grid-cathode assembly of a planar triode is used. The cathode is an oxide-coated type.[1,2] In addition to merits of its compact size and very low cost, it has an advantage that the relatively low grid pulse voltage makes possible to draw a high current because of a short grid-cathode distance (0.18 mm). This feature is important especially in obtaining a beam as short as 2 ns from the gun, meanwhile it has a disadvantage that the emission current is sensitive to residual gases in the vacuum .

Figure 1 shows the electron trajectory calculated by the program of W. B. Hermannsfeldt.[5] In the calculation,the current is limited in the range of an actual value of a short pulse beam, that is 573 mA. The calculations predict a perviance of 0.12 $\mu A/V^{3/2}$ and an emittance of $1.1 \times 10^{-3}\ \pi\ (m_0c\cdot cm)$. When the gun is operated in the space charge limited region, the maximum anode current is expected to be 3.8 A at the injection voltage of 100 kV.

Vacuum system

Major modification has been made in the vacuum system in order to decrease residual gas pressure in the gun chamber. Figures 2(a) and 2(b) show the layout of the new gun system for the 2.5 GeV

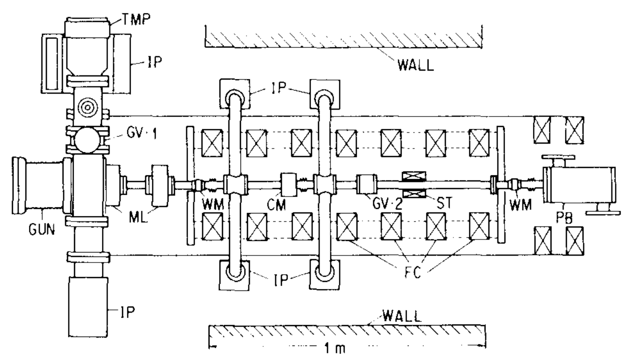

Fig. 2a. Top viewed layout of the new electron gun system for the 2.5 GeV linac. GV: Gate valve, IP:Ion pump, TMP: Turbo molecular pump, ML: Magnetic lens, WM: Wall current monitor, CM: Core monitor, ST: Steering coil, FC: Focusing coil, PB: Prebuncher, B-A G: B-A gauge, CCG: Cold cathode gauge

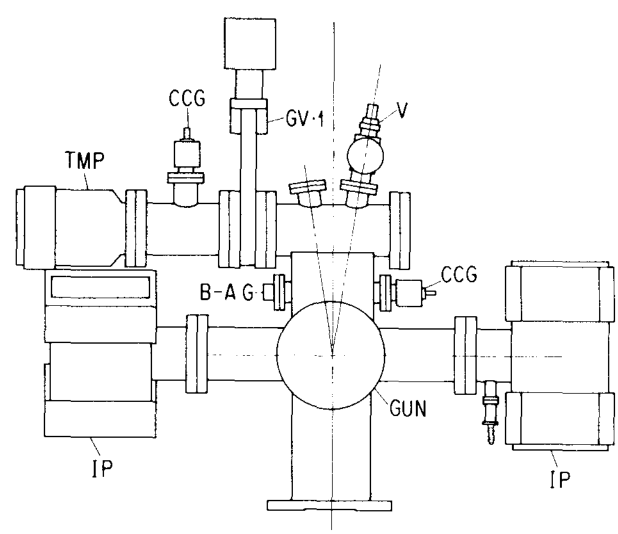

Fig. 2b. Layout of the new vacuum system for the 2.5 GeV linac.

linac. The same differential-pumping method was adopted as in the positron generator, and the gun chamber was isolated from the prebuncher.[2] The gun and the prebuncher are connected with 30 mm diameter small pipes to give low conductance. The pipes are differentially pumped with 4 ion pumps of which pump speed is 10 l/s each. The gun chamber is pumped by 2 ion pumps (60 l/s) and a turbo-molecular pump (300 l/s) as a roughing pump.

After baking out the vacuum system in the temperature range between 120 to 150 °C, the pressure in the gun chamber is kept as low as in the range of 10^{-7} Pa.

Control and Monitoring System of Vacuum

The control and monitoring system of vacuum was also improved. It controls on/off switches of vacuum valves, vacuum gauges and a rotary pump locally or remotely. It makes possible to keep the cathode safe by closing a vacuum valve (GV1) when accidents happen such as a failure or an emergency in the turbo-molecular pump, etc. The circuit has also a logic as the following: if an electric power supply stops, all auto-valves are closed, and even if a power supply recovers, all valves remain in the states before recovery of a power supply.

Focusing System and Beam Monitors

Although the improvement of the vacuum system is the main purpose of this modification, it was necessary to replace magnetic coils, focusing lenses and beam monitors with new ones, since the beam pipe connecting the gun and prebuncher should be smaller and longer than before in order to realize differential pumping.

The focusing system consists of 2 magnetic lenses and 7 focusing coils. A two-magnetic-lens system is adopted to be able to adjust both of size and divergence of the beam at the entrance of the first focusing coil. An end plate of the focusing coil's support is made of iron so as to decrease the leakage magnetic field and to shield the cathode from magnetic fields. There are three beam monitors between the gun and the prebuncher. Two of them are located between the gun and the first gate valve (GV2), that enables one to measure anode current even when the valve is closed: One is a wall current monitor for measuring a short pulse beam and the second is a core monitor for a long pulse beam. The third one is also a wall current monitor and is located at the entrance of the prebuncher .

Time Variation of Emission Characteristics in a Long Term

After the modifications mentioned above, the anode current became more stable and did not decrease rapidly over a long term, compared with the state before. Consequently available beam current increased considerably. Figure 3 shows time variation of the emission characteristics of the gun for the 2.5 GeV linac. Data were measured during a year from September in 1987 to August in 1988. In the long pulse (~ 0.7 μs) mode operation, the anode current required was usually in the range of 30 ~ 50 mA, and was controlled by the grid pulse voltage. Since the maximum current obtainable was high enough

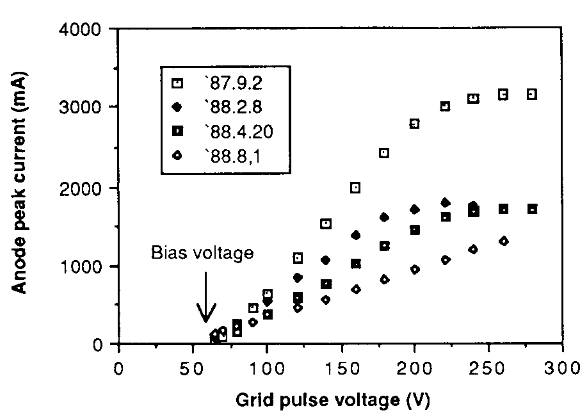

Fig. 3. Time variation of the emission characteristics of the oxide gun for the 2.5 GeV linac. Data were measured in the long pulse (~0.7 μs) mode operation. The anode current was usually 30 ~ 50 mA.

compared with the current needed, the influence of the time variation of the emission characteristics were negligibly small. And there were no problems in practical use during the period although maximum current decreased gradually from about 3 A to 1 A. In the short pulse mode operation, however, anode current was affected by deterioration of the cathode and actually decreased gradually during the same period as illustrated in Fig. 4. In this case, the output voltage of the grid pulser was not controlled and constant (~ 110 V). Anyhow the anode current has been more than 200 mA for the period, and the injection time of the beam into the Accumulation Ring of TRISTAN has been normally less than 10 seconds even when the anode current was the lowest one. This indicates that the practical life time of the oxide cathode is at least a year in high vacuum.

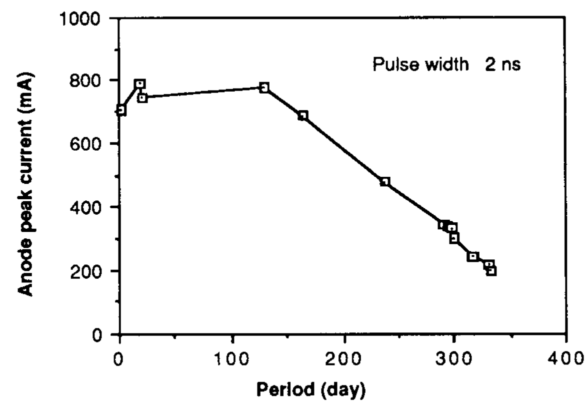

Fig. 4. Time variation in the anode peak current of the 2-ns beam. The grid pulse voltage was not controlled and constant. (~ 110 V.)

Electron Gun System for the e+ Linac

New Ceramic Insulator

The injection voltage of the positron generator gun was designed to be 150 kV, however, it had been 115 kV owing to the short ceramic insulator. The insulator was enclosed for a while by an SF_6-gas-filled capsule in order to supply a cathode-anode voltage of 150 kV to the gun. The maintenance of the SF_6 gas, however , was troublesome so that the ceramic insulator was replaced by a new large one illustrated in Fig 5, which worked at higher voltage. The injection voltage was raised to 150 kV, that enabled the injection current to increase appreciably and made it much easier to transport the beam.

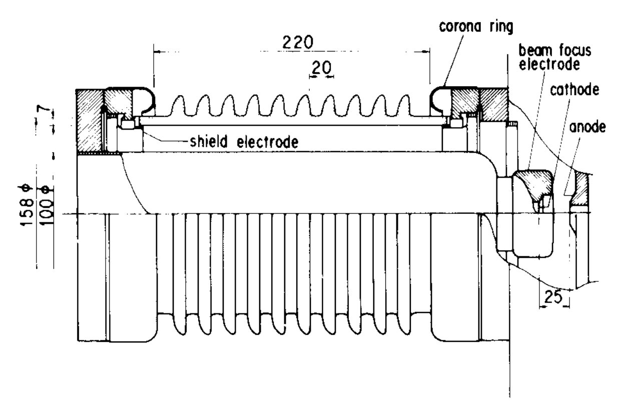

Fig. 5. New ceramic insulator of the gun for the Positron Generator. Size is shown in unit of mm.

Development of a Grid Pulser Utilizing a Hybrid IC

A grid pulser for a high-intensity and short pulse electron gun has been under development for several years. A grid pulser utilizing a hybrid IC made of transistors 2N2222A or 2N5551 was manufactured and a good characteristic was obtained.[6] Figure 6 shows a hybrid IC with 2N2222A's for the pulser which is one fourth of the can-type transistor circuit in size and has small stray capacitance and inductance, which is important especially for a high speed short pulse grid pulser. The output voltage waveform of the pulser with a hybrid IC with 2N5551's is given in Fig. 7, and the resulting electron beam current is 12 A at 150 kV as shown in Fig.8.

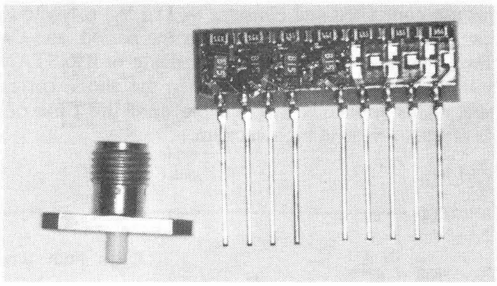

Fig. 6 Hybrid IC made of transistors 2N2222A for the short pulse grid pulser.

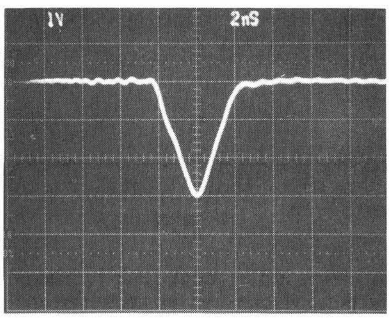

Fig. 7 Output waveform of the grid pulser with a hybrid IC (2N5551). Peak voltage of 300 V is obtained with 16.6 Ω input impedance.

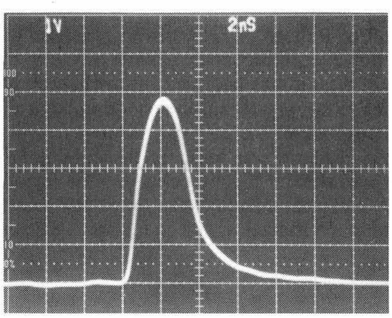

Fig. 8 Electron beam pulse obtained using the grid pulser of the hybrid IC with 2N5551 at 150 kV. Peak current is 12 A.

Control and Interlock System

A vacuum interlock system was developed utilizing a programmable sequencer. It is connected with vacuum gauges and pumps, etc. and controls gate valves and vacuum gauges for preventing deterioration of the electron gun vacuum. Another sequencer is intended to be connected with power supplies on the high voltage station of the gun. Both of the sequencers will be controlled by a microcomputer which is connected to the linac control system.

The anode current of a short pulse beam can be controlled by varying a pulsed bias voltage applied between the cathode and grid.[7]

Beam Width Selection System

Recently there was a request to inject positrons into the PF storage ring instead of electrons, and actually positrons were accumulated in the ring using the 2-ns beam and were put to practical use. The problem was the injection time, and a study has been made to obtain a suitable positron beam for the ring. As a result of the study, it was confirmed that the beam with a width of tens ns was suitable for the ring in order to decrease the injection time because much more charge could be contained in the longer beam than the shorter one.[4] On the other hand, for TRISTAN, the pulse width of the beam from the gun should be less than 4 ns, which is finally reduced to less than 2 ns by a subharmonic buncher. Therefore it is necessary to select one of the two beams remotely. A long pulse pulser was prepared in addition to the short one used so far. A beam width selection system has been made to exchange the beams by selecting one of the pulsers with a coaxial switch which is located between the electron gun and the pulsers as shown in Fig. 9. Selection signals are transferred through optical fibers which are also used to isolate the gun at high voltage from the ground potential .

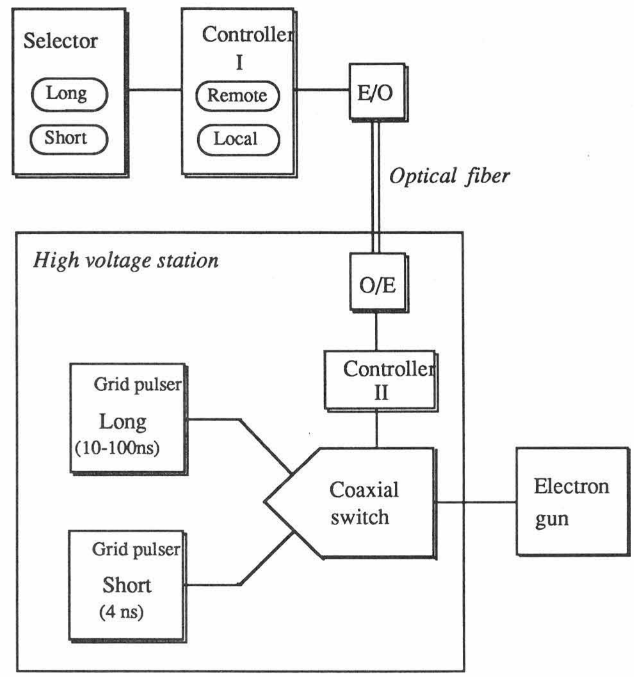

Fig. 9. Block diagram of the beam width selection system.

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