Development of a High-Current Gun and Increase of the Electron Charge in a Single-Bunch Beam of the Electron Linac at ISIR, Osaka University

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Abstract

A new electron gun using a YU-156 cathode-grid assembly was developed for the L-band linac at The Institute of Scientific and Industrial Research, Osaka University. The configulation of the electrodes were optimized by using a simulation code and the bench test of the gun was performed. The maximum peak current of an electron beam from the gun was 30.1 A for a pulse width of 5 ns in FWHM at an anode voltage of 100 kV. The characteristics of the electron beams generated from the linac equipped with the gun were much improved. The maximum charge of electrons in a single-bunch beam was 73 nC, which is higher than that obtained in the previous accelerator system.

1. Introduction

The 38 MeV L-band (1300 MHz) electron linac in The Institute of Scientific and Industrial Research (ISIR), Osaka University was constructed in 1978 for generating the high-intensity single-bunch electron beams. After the improvement of a subharmonic-prebuncher (SHPB) system, a charge of electrons in the single-bunch beam of 67 nC was obtained in maximum [1]. In the case the peak current and a pulse width of the electron beam injected from the gun were 30 A and 5 ns in FWHM, respectively. In order to achieve such a high current a triode gun having a cathode of a large area 51 mm in diameter was used. The high-intensity electron beams have been utilized to excite matters for analyzing ultra-fast phenomena induced by the irradiation. Many other researches are also being made in various pulse modes of the beams.

Generation and application of the short electron bunches and the coherent light from the high-energy electron beams are researches in the new fields. Brightness and pulse characterisitcs of electron beams are important factors, which depend strongly upon the features of the electron gun. In the present work a new electron gun was developed in order to improve the characteristics of the electron beams of the L-band linac.

2. Development of a New Electron Gun

Previously, the electron gun of Model-12 (ARCO) has been used. For a new gun the cathode-grid assembly, YU-156 (EIMAC), was adopted, in which the configuration of electrodes should be designed.

2.1 Design of the Electron Gun

When a single-bunch beam is generated from the linac the pulsed beam at a width of 5 ns in FWHM is injected from the electron gun. The width is determined from the operational conditions of the SHPBs. The peak current of the electron beam from the gun was 30 A for generating the electron beams having the maximum charge of 67 nC. In the design this value is made to be the goal of the maximum obtainable peak current at an anode voltage of 100 kV. The main properties of the gun are listed in Table 1. The diameter of the cathode is 20 mm, which is smaller than the previous one. Hence, the higher beam quality is expected. The area of this cathode is 1.5 times that of Y-796 (EIMAC) which is generally used for electron linacs.

The configuration of the electrodes of the gun was optimized by calculation with an EGN2e simulation code. The orbits of the electrons and the equi-potential planes obtained by the calculation are shown in Fig. 1. In this design the electron beams having a peak current below 30 A are stable in the gun. The current density of electrons at the cathode is 10 A/cm^2 in maximum, which is 6.5 times

Table 1 Characteristics of the previous and the new guns

	Model-12	YU-156
Structure	Electron gun	C-G assembly
Relative price	High	Low
Maximum peak current (A)	30	30
C diameter (mm ϕ)	51	20
C-G distance (mm)	2.5	0.15
Maximum G drive voltage (V)	~2000	700
Pulse rise-up time (ns)	>1.5	<1
Out-gassing time	2~3 days	2~3 hours

C: Cathode, G: Grid

that of the previous one, and hence, relatively strong focussing is required for the configuration of the electrodes.

2.2 Test Bench for the Electron Gun and the Grid-Pulser System

The characteristics of the new electron gun was investigated with a test bench consisting of the gun, a grid-pulser system, magnetic lenses, a beam current monitor and a high-voltage power supply.

For the grid-pulser of the electron gun used in the present experiments four avalanche pulsers are connected in parallel. In each pulser three transisters are connected in cascade. This was designed to have a relatively low impedance. The shape of the output pulse of the grid pulser is nearly rectangular and has a width of 5 ns. The peak output voltage of the pulser was fixed and was estimated to be about 700 V during operation. The injection current from the gun was controlled by changing the bias voltage supplied to the cathode.

2.3 Results for the Experiments in the Bench Test

In Fig. 2 the peak current of the pulsed electron beams from the gun, measured with the beam-current monitor, is plotted versus the bias voltage and the anode voltage . At a certain anode voltage, with decreasing the bias voltage the peak current increases, and then saturates, as shown in this figure. The cause of the saturation was estimated to be the space-charge effects working in the electron beams between the grid and the anode [2]. At a point indicated with "a" in this figure the measured pulse shape of the electron beam from the gun is shown in Fig. 3. The response of the gun to the pulsed voltage from the grid pulser was improved compared with the previous one. The pulse width is about 5 ns which satisfies the condition for generating the single-bunch beam. In Fig. 4 the maximum peak current obtained is plotted versus the anode voltage. At a voltage of 100 kV the maximum current is 30.1 A. This value well agrees with that obtained in the design. The present results are also listed in Table 1. Most characteristics of the gun was much improved.

3. The Characteristics of the Beam from the Linac Equipped with a New Gun

The characteristics of the single-bunch beam generated from the linac equipped with a new gun were investigated. By using the new gun which has a cathode smaller than the previous one, beam quality and the efficienty of the beam transportation are expected to be improved.

3.1 Accelerator System and Operational Conditions

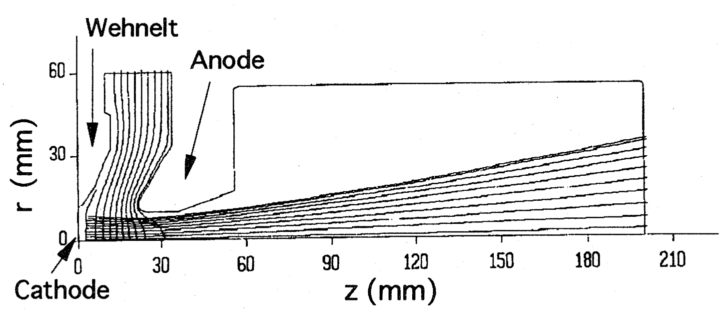

Fig. 1 Optimized configuration of the electrodes of the new electron gun and the calculated results for the electron orbits and equipotential planes at an anode voltage of 100 kV for a peak current of the beam of 30 A.

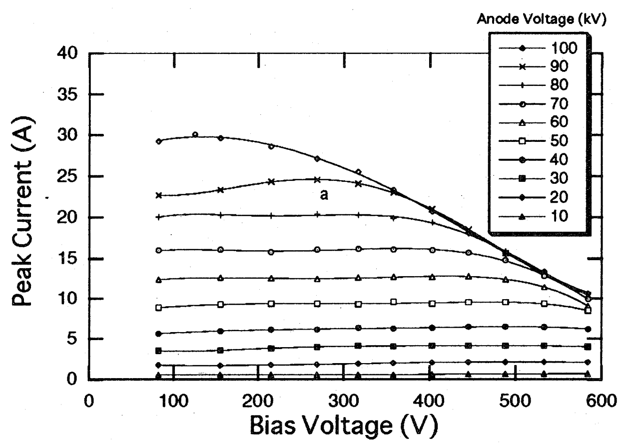

Fig. 2 Dependence of the peak current of an electron beam from the gun on the grid bias voltage and the anode voltage: pulse drive voltage for the grid is estimated to be 700 V.

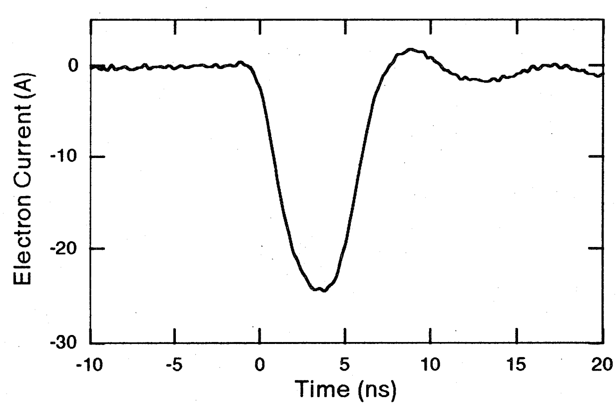

Fig. 3 Pulse shape of the electron beam from the gun at an anode voltage of 90 kV for the point indicated by "a" in Fig. 2.

The accelerator system of the ISIR linac is schematically shown in Fig. 5. The linac is equipped with an electron gun, three SHPBs (two at the twelfth

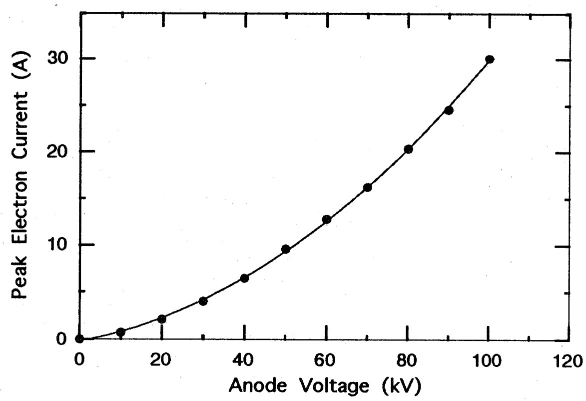

Fig. 4 Dependence of the maximum peak current of the electron beam from the gun on the anode voltage.

subharmonic of the fundamental and one at the sixth), fundamental bunchers and an accelerating waveguide 3 m long. The maximum beam energy is 38 MeV for no beam-loading. The details are described in Ref. 3.

3.2 Measurements of the Beam Characteristics

Pulsed electron beams were injected from the gun at a pulse width of 5 ns in FWHM, a peak current of 24 A and an energy of 104 keV. The peak powers of microwave supplied to the three SHPBs were 4, 12, 13 kW, respectively. The energy for acceleration was 27 MeV.

The charge of electrons in a single-bunch beam was measured with an aluminum block placed at an output window for the electron beam of the linac. The maximum charge of electrons measured is 73 nC/bunch. This value is higher than that for previous one. In the previous case the peak current of the electron beam injected from the gun was 30 A. The difference between the beam currents for injection from the guns is attributed to the improvement of the efficiency of the transportation of the beam in the present case, according to the higher quality of the electron beam. The energy spread of the electron beam is about 2% in FWHM. The charge of the single-bunch beam is expected to be increased for higher injection current from the gun. The other characteristics of the electron beams are being measured.

4. Conclusion

For the purpose of improving the characteristics of the electron beam generated with the L-band linac at ISIR, a new electron gun using a YU-156 cathode-grid assembly was developed. In the bench test of the gun the electron beam having a pulse width of 5 ns in FWHM and the maximum peak current of 30.1 A was obtained at an anode voltage of 100 kV. The single-bunch beam was generated from the L-band linac equipped with the new gun at an energy of 27 MeV. The maximum charge of

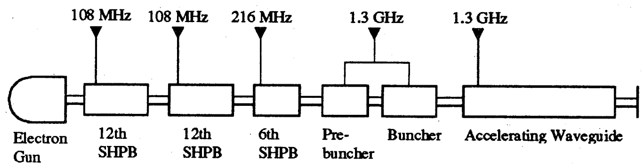

Fig. 5 Schematic diagram of the ISIR linac.

electrons in a bunch was 73 nC, which is higher than that of the previous value.

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