SHORT PULSE GRID PULSER FOR AN ELECTRON GUN OF THE KEK POSITRON GENERATOR

Y.Otake, Y.Ogawa, S.Ohsawa,
K.Nakahara and A.Asami

National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

ABSTRACT

A fast grid pulser was developed for the electron gun of the KEK positron generator linac. An output pulse of 200 V and 3 ns FWHM was obtained by using the grid pulser of can type transistors. For more speedup, a hybrid integrated circuit with avalanche transistors was newly designed. The hybrid IC was carefully designed as to reduce distributed inductance and stray capacitance in the circuit.

INTRODUCTION

The positron generator is to produce a 1.5 ns positron beam with a current of more than 10 mA to obtain a single bunched beam in TRISTAN (acceleration rf frequency is 508 MHz.). For this purpose, an emission current of more than 10 A is needed for an electron gun, because conversion efficiency from an electron to positrons is about 1/1000. The pulse width may be 3 ns, which is compressed to 1.5 ns by a sub-harmonic-buncher(SHB).

To produce such electron beams, a grid pulser with an output voltage of 200 V, 3 ns was needed, and we selected a grid pulser in which an avalanche phenomena of a transistor is used.

For high speed operation, the grid pulser was set closely to the electron gun. A mount of the grid pulser is shown in Fig. 1[1], and its circuit diagram is in Fig. 2[2]. A typical output waveform and an electron beam waveform are shown in Fig. 3.

Development of the grid pulser has been made in the following steps.

* An emission current of an electron gun depends on a voltage between a grid and a cathode, therefore, first of all development of the grid pulser with a high voltage output was most important.

* For an electron gun, the grid-cathode impedance depends on an emission current. Thus an output impedance of the grid pulser is to be matched to the grid-cathode impedance.

* In fabricating the grid pulser with can type transistors, distributed inductances and stray capacitances effect must be decreased as much as possible for high speed operation. A grid pulser with a hybrid IC was made.

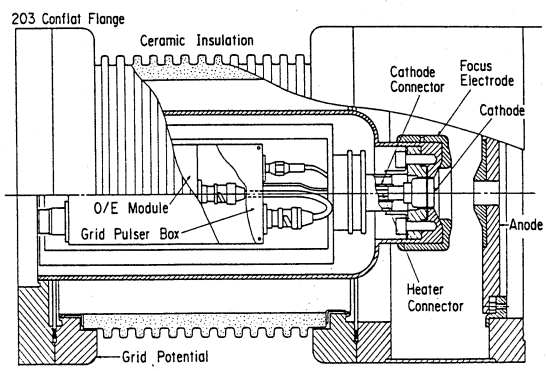


Fig. 1 Electron gun assembly.

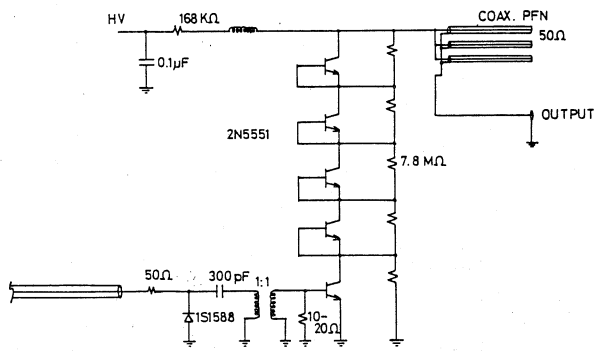
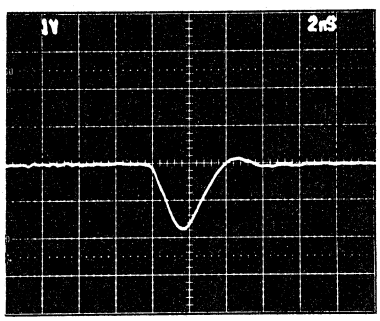
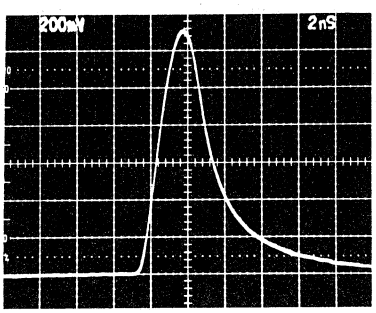


Fig. 2 Grid pulser.



V: x100

Typical output waveform of the short pulse grid pulser.



8.6 A

Fig. 3 Short pulse beam waveform.

OUTPUT VOLTAGE OF THE GRID PULSER

An operating point of the grid pulser proceeds from the 1st break down to the 2nd break down point as in Fig. 4[3]. The grid pulser is a line type pulser and a charging voltage of a PFN (coaxial cables, pulse-forming-network) is determined by an avalanche starting voltage of transistors. An output voltage of the grid pulse is given by

$$V_{ava} = n \times V_{avat}, \quad Q_{cox} = C_{cox} \times V_{ava}$$

$$dQ_{cox}/dt = -Ip, \quad Vp = Ip \times Z_L.$$

n : Number of transistors connected serially.
V_{avat}: An avalanche start voltage of a transistor.
C_{cox}: Capacitance of coaxial cables.
Q_{cox}: Total charge of coaxial cables.

Vp, Ip : Output voltage and current.
Z_L : load impedance.

Therefore, it is advantageous to use higher avalanche voltage transistors. For the grid pulser of the positron generator, 2N5551 transistors (Vceo = 160 v) are used which have higher Vceo than 2N2222A transistors used in the PF linac grid pulser.

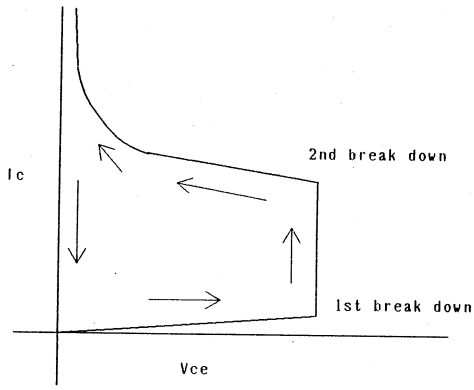


Fig. 4 General feature of the Vce-Ic characteristic of a transistor.

RELATION BETWEEN A GRID PULSER OUTPUT IMPEDANCE AND A GRID-CATHODE IMPEDANCE

A grid-cathode impedance of our electron gun (Oxide cathode) depends on an emission current. Its value is about 50 ohm at 1 A and about 12 ohm at about 10 A. A grid pulser impedance must be matched to the grid-cathode impedance. If the grid pulser output impedance is not matched to the grid-cathode impedance, the output pulse of the grid pulser can not be effectively transmitted to the electron gun.

The emission characteristic of the gun is shown in Fig. 5[4]; which may be expected if an adequate vacuum condition is fulfilled (10^{-9} torr). Number of parallel cables of PFN (coaxial cables) is varied from one to four. Thus the grid-cathode impedance may be about 12 ohm corresponding to about 10 A emission current. As a result, an emission current increased to 9.5 A from 6.5 A, and the output impedance was 50 ohm.

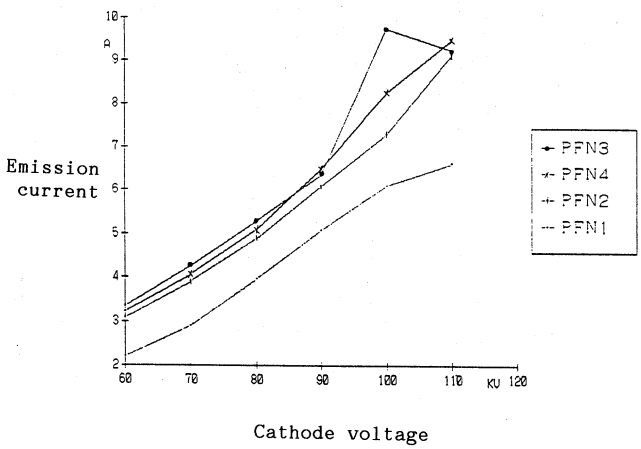


Fig. 5 Emission characteristics of the gun with PFN varied.

SPEEDUP OF THE GRID PULSER

An ideal output of the grid pulser should be a rectangular waveform, however, the actual waveform is considerably distorted. This is probably due to distributed inductances and stray capacitances of the circuit. In order to test this problem analysis of the circuit was made with an equivalent circuit in Fig. 6 in which the distributed inductance was varied. If the distributed inductance is decreased, the grid pulser works much faster as in Fig. 7[5]. Similar effect is expected if stray capacitance is decreased.

One way to decrease distributed inductance is to make the grid pulser with parallel circuits for which distributed inductances become L/n (n: number of parallel circuits). However, the circuit would become complex and, in addition, stray capacitances would increase. Another way to decrease distributed inductances and stray capacitances is to make the circuit in a small size. Therefore, we made a grid pulser in which a hybrid IC was utilized. It is shown in Fig. 8. For comparison, a grid pulser of can type transistors was also made. The result is shown in Fig. 9[6].

Operating conditions of both grid pulsers were adjusted so that the same output pulse voltages were obtained, and transistors in seven stages were used in both cases. The hybrid IC grid pulser operates 1.4 times faster than the can type grid pulser.

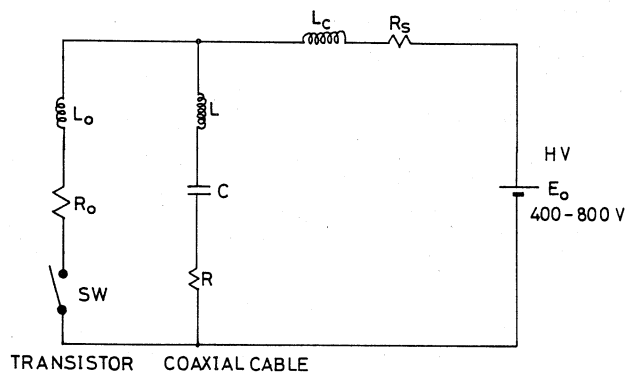


Fig. 6 Equivalent circuit of the short pulse grid pulser.

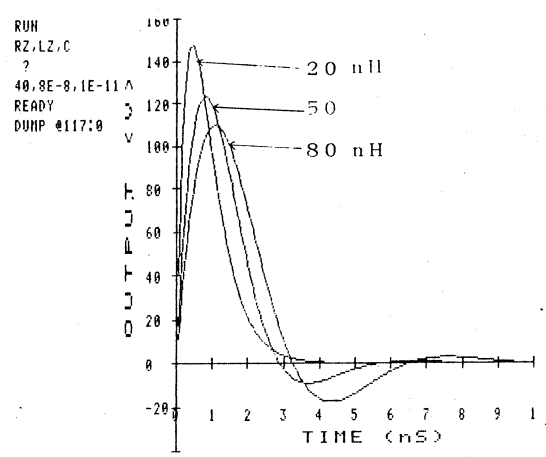


Fig. 7 Output waveform simulation with L_0 varied.

CONCLUSION

The grid pulser for an electron gun has been developed for a higher emission current. For this purpose, transistors with a higher avalanche voltage are preferable, and a 4-stages grid pulser of can type transistors (2N5551) has been made. For making a grid pulser faster than the present one, distributed inductances and stray capacitances should be reduced thoroughly.

The newly designed hybrid IC with avalanche transistors (2N2222A) showed an explicit progress in providing a fast pulse with a high voltage.

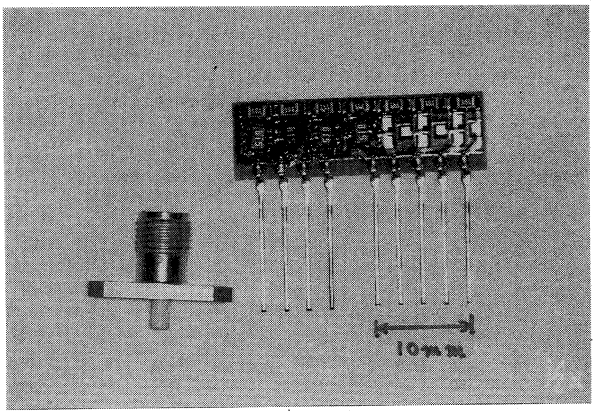
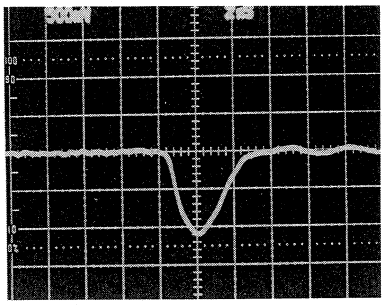
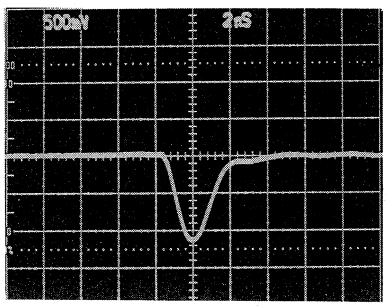


Fig. 8 Hybrid IC grid pulser.



V: x 100

Output waveform of can type transistor grid pulser.



V: x 100

Fig. 9 Output waveform of hybrid IC grid pulser.

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