

REMOTE CONTROL OF AN EMISSION CURRENT OF A HIGH-CURRENT, SHORT-PULSE ELECTRON GUN

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ABSTRACT

A remote control of an emission current in pulse height and pulse width for the high-intensity, short-pulse electron gun is made possible by two-pulse superposition scheme. As a preliminary result, the pulse height of the emission current from 8 to 4 A and the pulse width from 2 to 4 ns become variable with ease.

INTRODUCTION

It is desirable that one should have a remote control system of the emission current of the electron gun when measuring the characteristic parameters of the linear accelerator. In the electron gun^{1),2)} with a grid, one can control the emission current in principle by changing the pulse height and the pulse width of the cathode-grid voltage. Such systems are easily constructed for the long-pulse electron gun(pulse width of micro seconds), but those for the high-intensity, short-pulse electron gun(for example, 10 A, 1.5 ns) are in general relatively difficult to design because of their high-speed characteristics of time response. Two-pulse superposition scheme(Fig. 1)is introduced into the electron gun system in order to control a pulse height and a pulse width where an inverse long pulse of variable pulse height and an inverse short pulse of variable time-delay are added to the original short pulse of fixed pulse height and pulse width respectively.

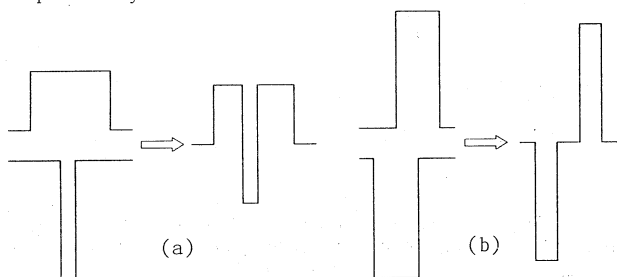


Fig. 1 Two-pulse superposition scheme.
(a) long + short pulse(pulse height).
(b) short + short pulse(pulse width).

TWO-PULSE SUPERPOSITION SCHEME

SUPERPOSITION OF LONG AND SHORT PULSES
(CONTROL OF THE PULSE HEIGHT)

A bias long pulse(1 microsecond pulse width) is applied to the cathode-grid gap and by changing its pulse height, the emission current is controlled. Fig. 1a shows a block diagram of the superposition system of the long and short pulses. The electric circuit is easily adjusted because of the different characteristics of time response of two pulses.

SUPERPOSITION OF SHORT AND SHORT PULSES
(CONTROL OF THE PULSE WIDTH)

Two grid pulsers^{3),4)} for a positive short pulse and an original negative one are connected in the output.(Fig. 2) The trigger signal for the positive pulse is delayed as compared with that for the negative one and by varying the time delay, the pulse width is controlled. In this case, the same characteristics of time response make difficult the simple superposition(Fig. 1b) of the pulses. The simplified equivalent circuit of this system is given in Fig. 3, when the pulse width is not longer than a few nanoseconds.

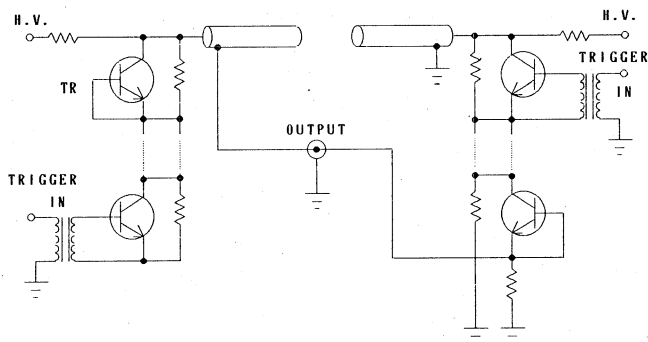


Fig. 2 Electric circuit of two grid pulsers connected in the output.

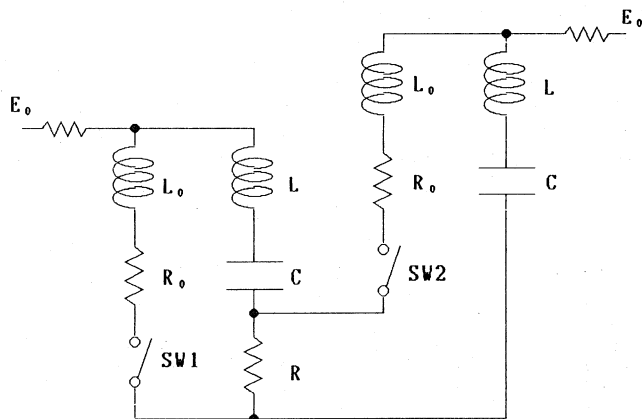


Fig. 3 Simplified equivalent circuit for two grid pulsers connected in the output.

Let the switch 1 close at t=0 and the switch 2 close at t=t₁. The output voltage of the two pulsers connected is written as:

$$\text{for } 0 < t < t_1$$

$$V = -2RE_0/R' \gamma \exp(-R't/2L') \sin(R'\gamma t/2L') \quad (R' < 4L'/C)$$

$$\text{for } t > t_1$$

$$V = A R \exp(-R''(t-t_1)/2L') \sin(R''\gamma(t-t_1)/2L' - \alpha) \quad (R'' < 4L'/C)$$

$$A = 2E_0/R' \gamma \exp(-R't_1/2L') [\sin^2(R'\gamma t_1/2L') + (R'/\gamma R'')^2 (\sin(R'\gamma t_1/2L') - R'\gamma/R(\cos(R'\gamma t_1/2L') - \exp(R't_1/2L')))^2]^{1/2}$$

$$\alpha = \tan^{-1} [\gamma R''/R \sin(R'\gamma t_1/2L') / (\sin(R'\gamma t_1/2L') - R'\gamma/R(\cos(R'\gamma t_1/2L') - \exp(R't_1/2L')))]$$

$$R' = R_0 + R, \quad R'' = R_0 + 2R, \quad L' = L_0 + L$$

$$\gamma = (4L'/CR'^2 - 1)^{1/2}, \quad \gamma' = (4L'/CR''^2 - 1)^{1/2}$$

where R_0 , L_0 are an internal resistance and an inductance of the switches and wires respectively, L, C simplified inductance and capacitance of the charging coaxial cables, R a load resistance (an impedance of the cathode-grid gap is assumed to have only a real part with no frequency dependence), and E_0 a charging voltage. An example of the calculated waveform of the output voltage is shown in Fig. 4. Two pulses are not superposed but the first negative one is forced to vanish at t_1 by the generation of the second positive pulse whose existence will not affect the emission current. The rise and falling time of the negative pulse cut at t_1 are determined only by either the rise or falling time of the pulses which suggests the possibility of making a short pulse with both small rise and falling times if a short pulse with only a small rise (or falling) time is available.

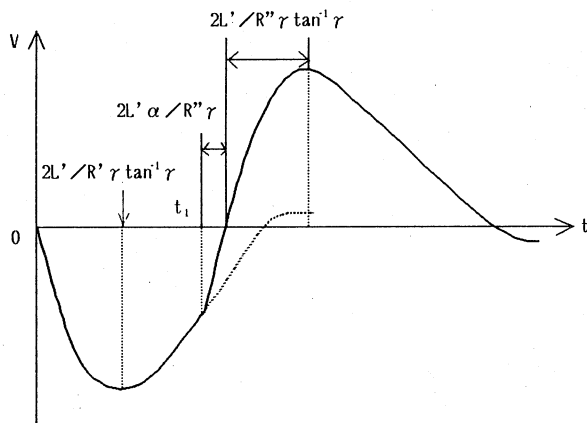


Fig. 4 An example of calculated output waveform of two grid pulsers connected in the output.

EXPERIMENTAL RESULTS

The superposition circuit for long and short pulses is shown in Fig. 5 and the emission current of the electron gun is varied from 4 to 8 A by changing the output voltage of the long pulse. (Fig. 6)

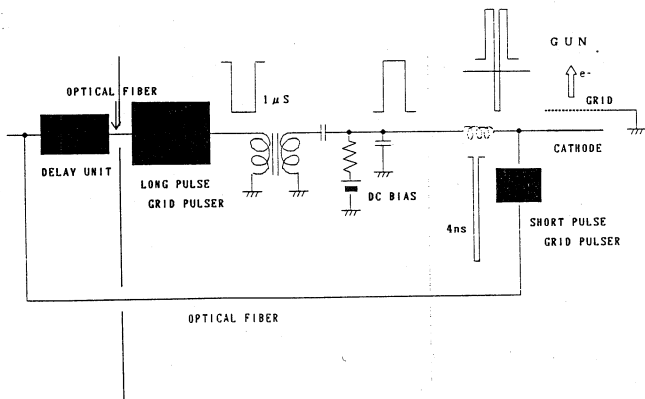


Fig. 5 Superposition circuit for long and short pulses.

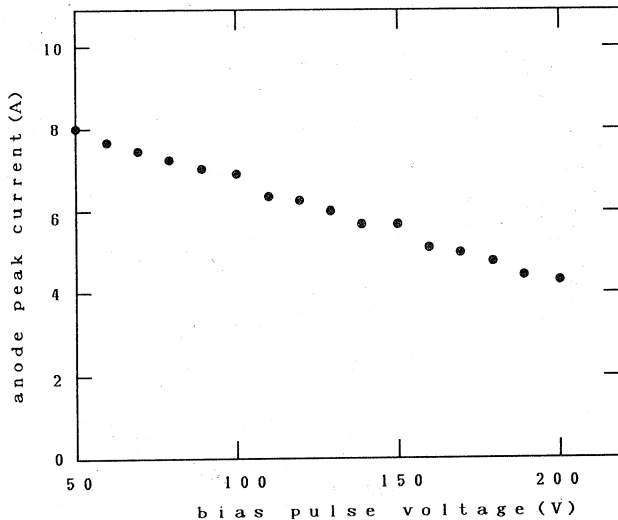


Fig. 6 Control of emission current of electron gun.

As for the variable pulse width, two grid pulsers utilizing transistors of a high slew rate (2N5551) are put into one box and the outputs are connected directly. (Fig. 2) Fig. 7 shows examples of the waveform of two pulses inverted and delayed, and of the output pulse when connected to each other, which agrees qualitatively with the waveform expected by above simple calculations. The pulse width is changed from 2 ns to 4 ns by varying the time delay t_1 . (Fig. 8)

The remote control system of the emission current described here should be elaborated when introduced into the electron gun for the KEK positron generator as a reliable system.

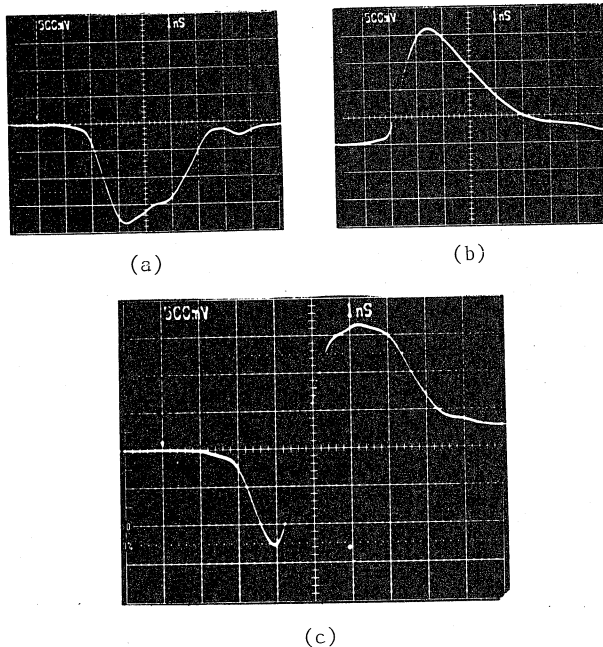


Fig. 7 Measured output waveforms of two short-pulse grid pulsers. (a) negative pulse (b) positive pulse (c) output pulse of two grid pulsers connected.

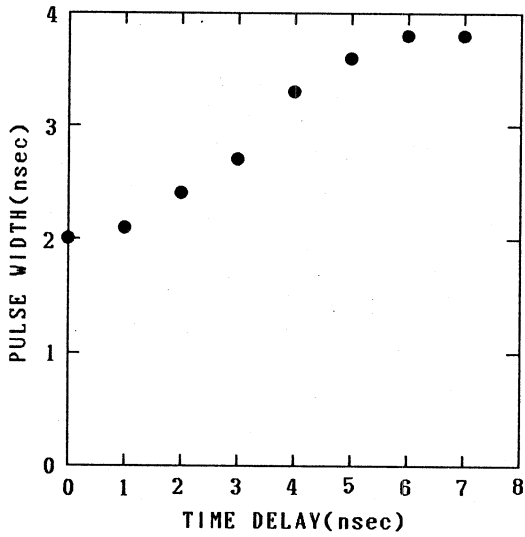


Fig. 8 Control of pulse width by time delay.

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