GENERATION OF MULTI-BUNCH BEAM WITH THERMIONIC GUN FOR THE JAPAN LINEAR COLLIDER

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Abstract

We report on the development of a thermionic gun that is capable of producing multi-bunch beam to be used at the KEK Accelerator Test Facility for the Japan Linear Collider project. Two types of grid pulse generators have been developed. One is an avalanche pulse generator. A Y-646E cathode was successfully operated to generate double-bunch beam with a pulse width shorter than 700 ps, bunch spacing 1.4 ns, and a peak current 4.3 A. The other grid pulse generator is a fast ECL circuit with an RF power amplifier. Generation of 20-pulse trains with 2.1ns time spacing has been demonstrated.

Introduction

The Accelerator Test Facility (ATF) has been built at KEK as a development bench of the Japan Linear Collider (JLC) project. To achieve the design high luminosity of the JLC, it is required to generate multi-bunch beams without any satellite beams. Presently the ATF consists of a thermionic gun, three sub-harmonic bunchers, S-band bunchers, followed by a high-gradient accelerating structure. Various experiments are planned for the gun to generate and accelerate multi-bunched beams. In the early stage of the experiment, the thermionic gun used a dispenser cathode with an area of 2 cm^2 (EIMAC Y-796), operating up to 240 kV. It had been successfully generating a single-bunch, high-current beam with a short pulse width. The beam was accelerated with a high-gradient structure over 80 MV/m[1]. Recently the cathode Y-796 was replaced with Y-646E which has an area of 1 cm^2 in order to reduce the beam emittance and to improve the gun response to fast driver pulses.

As a first step we have fabricated a grid pulse generator which can produce double pulses with 300V peak, 500 ps width and 1.4 ns time spacing. It consists of two fast avalanche pulse generators and an RF power combiner. With this pulse generator the amplitude of each pulse and the pulse time spacing can be easily controlled. We have generated the double-bunch beam with this pulse generator[2]. However with this type of grid pulse generator it is difficult to produce more than several bunches in bunch train. Consequently we have decided to develop another type of grid pulse generator that consists of a fast ECL circuit and an RF power amplifier. This circuit should be able to produce more than 20 bunches/shot. In this paper we describe the experimental results of beam emission using the Y-646E cathode with the double pulse generator, and experimental results of the low level test of the multi-pulse generator.

Experiment with double-pulse generator

The design of the gun using Y-646E cathode was performed using the program ETP to obtain a high current and low emittance with low surface electric field [3]. Figure 1 shows the particle trajectory. With the anode voltage 240 kV

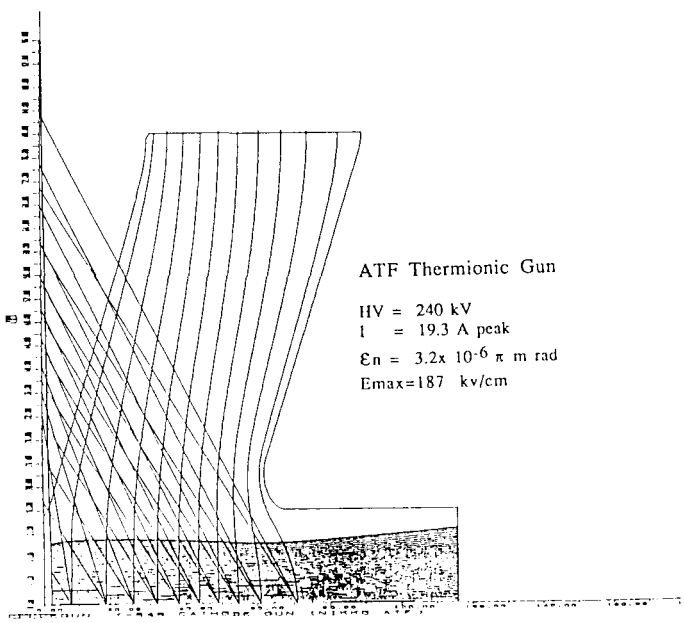

Fig.1 Beam trajectory

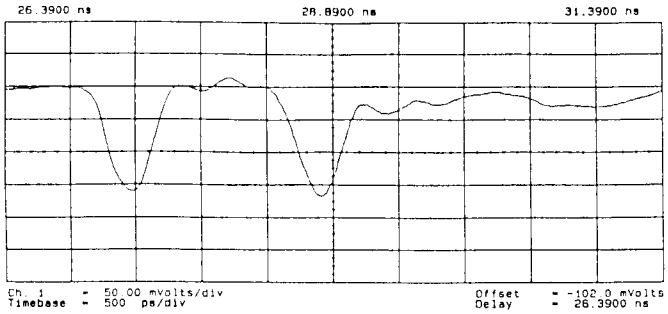

Fig.2 Output of the double-pulse generator
(100V/div, 500ps/div)

the peak current at the space charge limit is expected to be 19.3 A, the beam emittance(ε_n) $3.2\times10^{-6}\pi$ m-rad and the maximum surface electric field 187 kV/cm.

The grid pulse generator used in this experiment was similar to the one described in reference [2]. The observed output pulse shape is shown in Figure 2.

The beam emission of the Y-646E cathode driven by this grid pulse generator was measured(response time ~200 ps), located immediately downstream of the gun. The wall current monitor has four output ports which are used for the correction of the position dependence[4]. A typical data of the emitted beam is shown in Fig.3 in the case that anode voltage 170 kV, heater voltage 6.0V, net drive voltage 260 V and vacuum pressure 2×10^{-8} Torr. The peak current of two bunches were measured to be 4.3 A (1×10^{10} electrons/bunch). In Fig.3, ringing signals which follows bunch signals can be observed. It is caused by characteristics of the wall current monitor. The current density of Y-646E cathode is two times higher than that of the Y-796 cathode. The pulse response of this cathode is improved compared with the Y-796 cathode, because of the small stray capacitance. These stray capacitance were measured to be 13 pF for Y-646E and 27 pF for Y-796. The peak current of the emitted beam is still below the space charge limit. We can expect higher current by increasing the amplitude of the grid pulse generator.

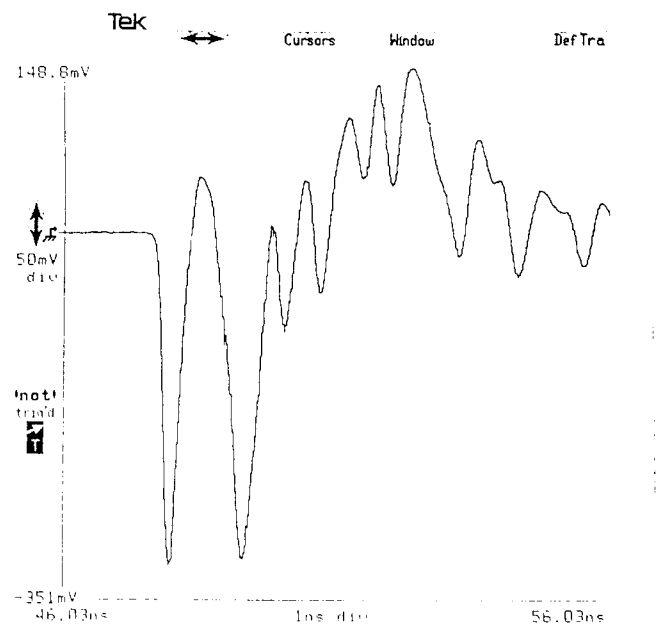

Fig 3 Wave shape of double bunches beam,
Anode voltage: 170 kV, Heater voltage: 6.0 V, Net drive voltage: 260 V, Vacuum 2×10^{-8} Torr

Multi-pulse generator

As mentioned earlier, a new multi-pulse generator is under development. It consists of a fast ECL circuit and an RF power amplifier to generate more 20 pulses per train. Figure 4 shows its schematic diagram, and Figure 5 gives details of the ECL circuit. The ECL circuit clock is a 476 MHz RF signal synchronized to the RF of the accelerating structure. The required number of pulses are formed by counting and gating the RF signals in the circuit. The SONY CXB-seris circuits were used. The maximum operational frequencies of their flip-flop and preset counter circuits are 3.2 GHz and 1.1 GHz, respectively. The output pulse of our circuit is shown in Figure 6(a). This pulse train is then amplified by the RF power amplifier. The RF amplifier is required to have an output power of ~ 10 kW and the gain 60 dB to achieve sufficiently large pulses to drive the gun. Ordinary the band width of RF power amplifier is not enough to amplify this pulse train with no distortion. Output pulse train of the 1 W test RF amplifier is shown in Figure 6(b). The band width of this amplifier is between 5 MHz and 1 GHz, and is not wide enough so the signal distortion is taking place. In order to get the flat-topped pulse train, a wave form shaper to create a compensation signal needs to be introduced. The design work of the wave form shaper and the RF power amplifier is under way.

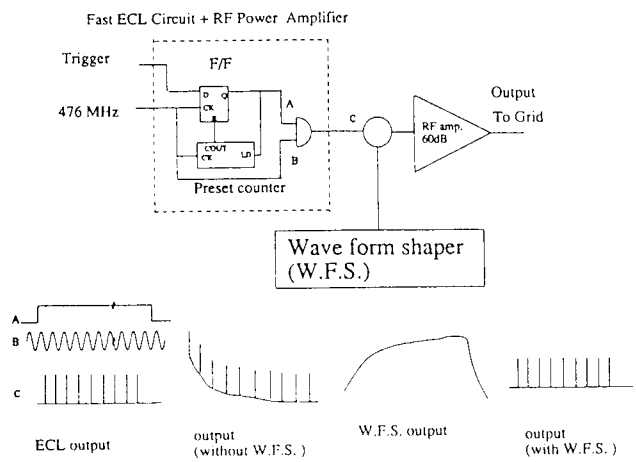

Fig 4 Schematic drawing of multi-pulse generator.

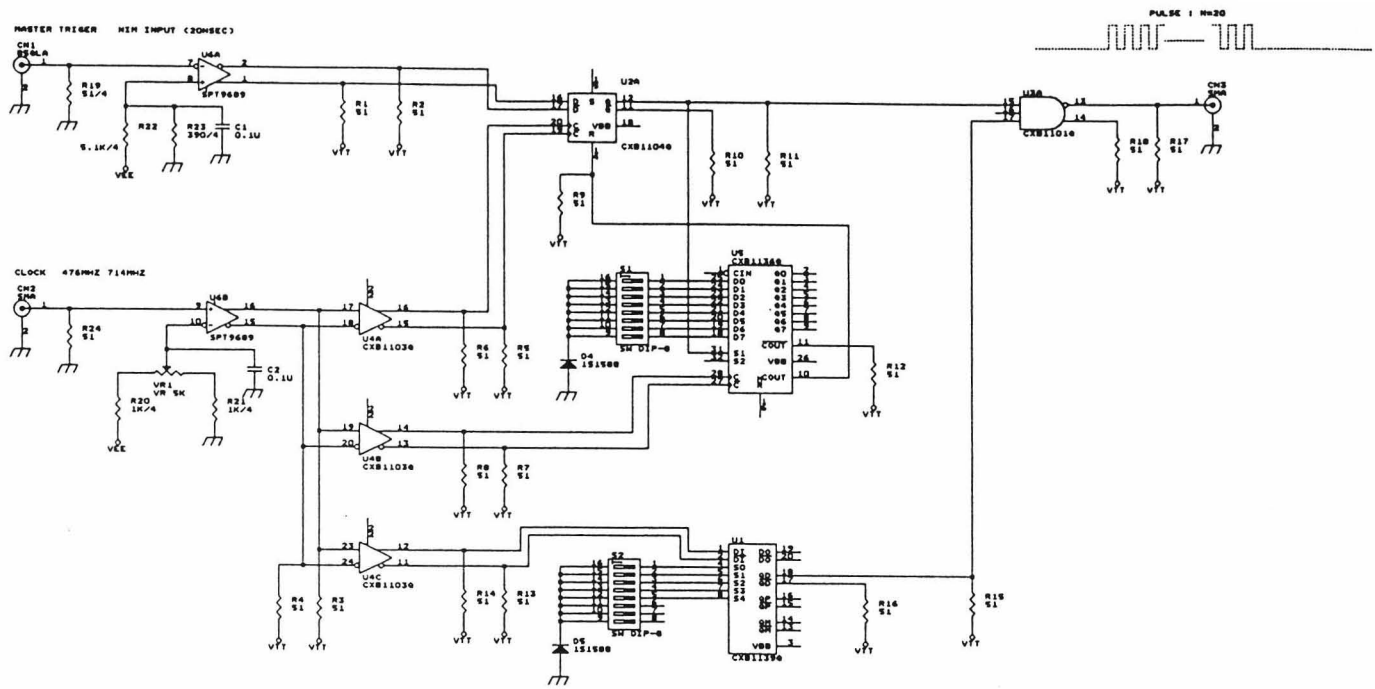

Fig.5 Circuit diagram of the fast ECL of multi--pulse generator

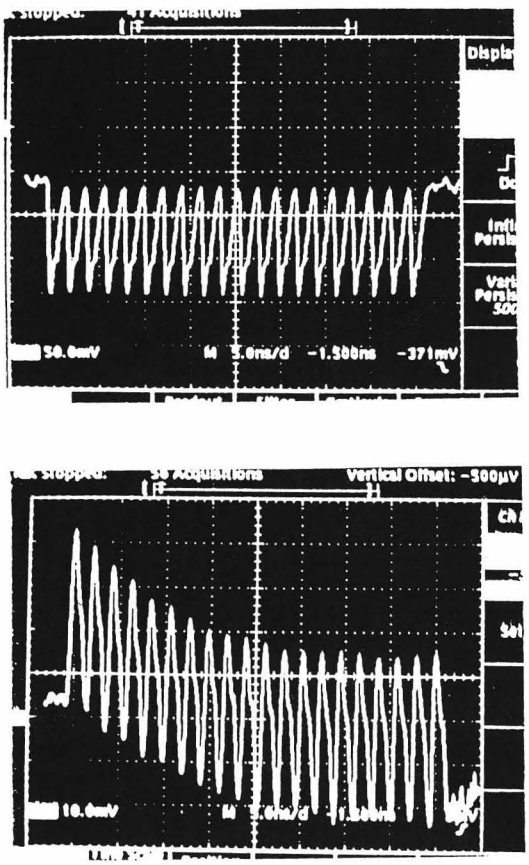

Fig.6 (a)Output of the fast ECL circuit (upper),
(V: 50 mV/div, H: 5 ns/div)
(b)Output of the test RF amplifier(lower)
(V: 1.5 V/div, H: 5 ns/div)
power 1W
Band width 5M~1GHz

Summary

We have improved the beam characteristics of the double-bunch beam by replacing the Y-796 cathode with Y-646E cathode driven by a double-pulse generator.

In order to satisfy the JLC parameter requirements, we are developing a multi-pulse generator using a fast ECL circuit and an RF power amplifier. The fast ECL circuit could make a pulse train consists of 20 pulses and the wave form shaper and RF power amplifier are developing.

Acknowledgements

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