High Current 1ns Pulsed Electron Gun

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1. Introduction

The injector linac of SPring-8 is now under construction to accelerate electron/positron up to 1GeV by S-band by 60pps. This linac will be used not only for the injector but also for other experimental purpose on its standalone operation. The electron gun has three modes of pulse length: single mode(1ns), short mode(10-40ns) and long mode(1-2μs). The long mode is inevitable for the commissioning of the machine. And the single mode is required up to 14Amps of electron to generate the positron beam for the single bunch operation of the storage ring(the RF frequency of the storage ring is 508MHz).

For the purpose to make high current short-pulsed beam, we think that the application of photo-cathode and RF-gun is desirable. But our linac must be in commercial use, and robust operation ability is very important. Conventional short pulse generation takes the way to make the distance between the pulse generation circuit and the cathode assembly as short as possible to prevent from voltage down and rise time stretch. We chose a thermo-ionic electron gun, and made a new method to generate short pulses using a low impedance long transmission line of axial rigid tubes.

2. Pulse Forming System

View of our pulse forming method and dimensions are shown in Fig.1.

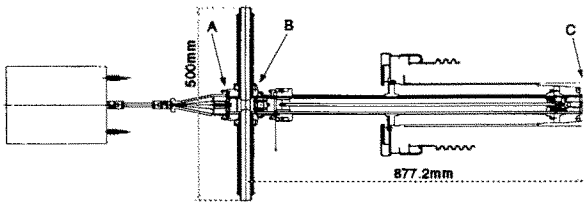

Fig.1 Cross sectional view of pulse forming system

Pulse transmission lines are made of axial rigid tubes. The impedance between an inner tube and outer tube of each transmission lines is 12Ω correspond to the cathode impedance we expected (Our cathode assembly is Eimac-Y796). The output of specially ordered Kentech Pulser is 2.4kV to 4kV, 50ps rise time and exponential decay of several tens of nano-seconds. The pulse leads to the transmission line through the impedance converter which consists of microchip-array resisters. This impedance converter also works as the absorber of the reflected pulse from the cathode assembly. At the point of two stab, the pulse is divided into 4 direction. A quarter power of the pulse runs to cathode assembly, and two quarters run to the short termination of stabs. The last quarter reflects to the pulser, and is absorbed by the impedance converter. It takes 1ns for pulse running by the double way to the short termination. The tail of pulse running to the cathode is cut out after 1ns by the reflection from two stabs. And the 1ns width pulse has been delivered to the cathode and the grid at last.

We have several kinds of stabs with different length, and succeeded in making 500ps beam too by shorter length stab. A heater power feeder is set inside of an inner tube. The contact at the cathode assembly is rigid axi-symmetric, and an air blower is set to prevent from oxidization of contact surfaces.

3. Cathode Impedance Measurement

We presumed that the cathode impedance is 12Ω. Knowing the cathode impedance is very important for making impedance matching at the attached point of the transmission line and the cathode. The result of an off-line measurement of the cathode impedance is not equivalent to the actual impedance when the cathode is driven. Then we measured the impedance of driving cathode by the configuration which has an intentional mismatch point.

We have got a new wall current monitor(WCM) which can measure pulse width of less than 1ns[1]. Using this WCM, we have tried to measure the train of actual beam pulse. This WCM was set 420mm away from the anode of the gun.

When the impedance of cathode is not matched to 12Ω, the reflected pulse goes back from the cathode to the point of pulser connection. So the point is a mismatch point as an aim, the reflected pulse runs again. As the result, the second beam pulse appears. Our transmission line was long enough(877.2mm), and we could separate the first beam pulse and the second one. For the ratio of the two beam pulse, the reflection coefficient at the point of the cathode can be calculated. And the coefficient gives us the impedance of the working cathode.

Minimum output voltage of our Kentech pulser is too high(2.4kV) to connect the transmission line directly, then we used a short pulse generator made by K.Takami to connect the pulser and the transmission line without the impedance converter.

Transister, and its rise time is the same of Kentech pulser, and output voltage is 440v to 880v.

4. Result

We operated the injector section using both the configuration for the impedance measurement and for the standard operation, and compared the beam shapes measured by the WCM. Appearance of the second beam pulse showed in Fig.2 depends on the parameters around the gun, and it was found that the heater power was most effective with the cathode impedance.

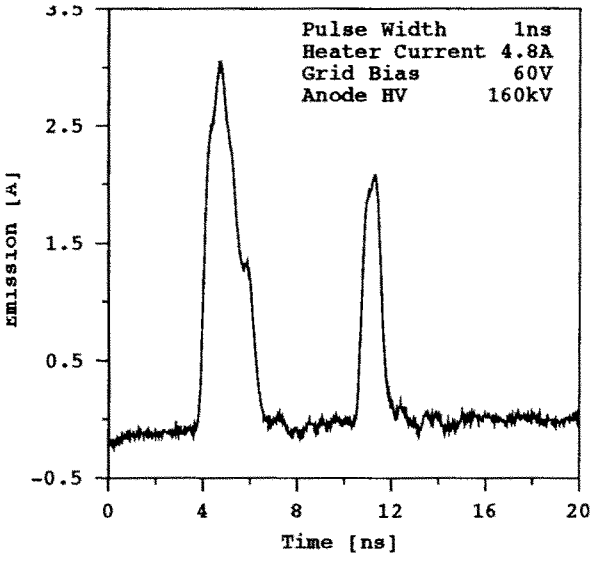

Fig.2 Beam current at 4.8A of heater and the configuration of the cathode impedance measurement

Fig.2 and 3 show typical beam shapes when the impedance was mismatched at the cathode connection (This is obtained when the cathode impedance is not 12Ω). In Fig.2, the interval of the first beam pulse and the second one corresponds to the time of double way of the pulse transmission line. In the configuration of our pulse forming system, there was no second beam even though the impedance was mismatched. When the pulse forming system was used, a reflected pulse from the cathode what back to the stabs and met the lower impedance(4Ω) than that of the transmission line(12Ω), and the reversed pulse running to the cathode again did not make the second beam pulse any more. This was the advantage of our pulse forming system, and low impedance of these transmission lines contributed to decrease of transmission loss.

We tried varying the bias and the pulser voltage,

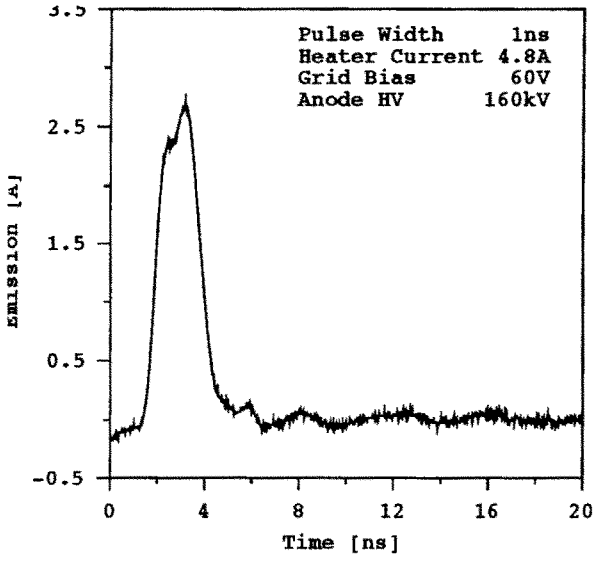

Fig.3 Beam current at 4.8A of heater and the configuration of pulse forming system

but a drastic change of cathode impedance was not found. When the heater current was higher than 5.3Amps, the second beam pulse disappeared, and the cathode impedance could not be calculated. The temperature of the cathode surface was measured by optical thermo-meter. When the heater current was 5.8A the temperature is 1000℃, and when the heater current was 4.8A the temperature is 800℃. At the condition for standard use, the cathode impedance should be lower than 10Ω.

5. Conclusion

The cathode impedance in the situation of the injector working was measured by a pulse reflection method, and the heater power dependency of it was found. Taking the impedance matching between the cathode assembly and the pulse transmission line is important for making a fine single pulse beam, and the characteristics of our pulse forming system for grid pulse was made clear. We suppose that several hundred picoseconds is fairly close to the minimum limit of pulse width by thermo-ionic emission cathode. For applications to FEL and others, the combination of a photo-emission cathode and a mode-lock laser is suitable to make a beam of pico-second order of extra high current. But thermo-ionic cathode will be used in future because of its reliability and maintenancability.

Reference

[1] K.Yanagida, Wall Current Monitor for SPring-8 Linac, JAERI-M 94-078.