HIGH CURRENT 1ns PULSE ELECTRON GUN

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Abstract

The electron gun of the injector linac for SPring-8 (Super Photon Ring 8GeV, Japanese large synchrotron radiation facility) has achieved the generation of 1ns bunch of up to 14 Amps. This bunch is very clear and does not have reflective pulse trains which are the problem contained with conventional method of short pulse generation using a clip line. This paper describes a new method of short pulse generation which uses the high voltage rapid rise time pulser of Kentech and a long transmission line of low impedance. The performance and characteristics which are obtained by experiments are shown.

Introduction

The injector linac of SPring-8 is now under construction to accelerate electron/positron up to 1GeV by S-band of 60pps. This linac will be used not only for the injector but for other experimental purpose on its standalone operation. The electron gun of this linac 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 of the storage ring is 508MHz).

For the purpose to make high current short pulse beam, we think that the application of photo-cathode and RF-gun is desirable. But our linac must be 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 thermo-ionic electron gun type, and made a new method of short pulse generation using a low impedance long transmission line of axial rigid tubes.

Pulse Forming System

Schematic view of our pulse forming method is shown in fig.1, and dimensions are shown in fig.2. Z1,Z2 and Z3 are pulse transmission lines made of axial rigid tubes. The impedance between 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 10ns. The pulse leads to the transmission line through the impedance

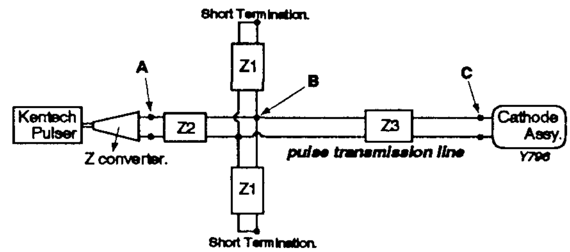

Fig. 1 Schematic view of pulse forming system for grid pulse.

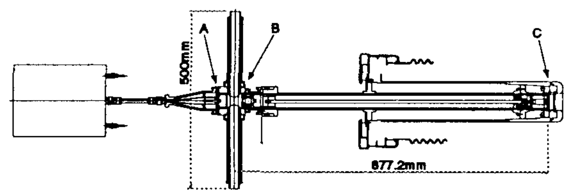

Fig. 2 Cross sectional view of pulse forming system.

converter which consists of microchip-array resisters. This impedance converter also works as the absorber of reflected pulse from the cathode assembly. At the point B, 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. The last quarter reflects to the pulser, and is absorbed by the impedance converter. It takes 1ns for the pulse running by the double way from point B to the short termination. The tail of the pulse running to the cathode cut out after 1ns by the reflection from two Z1s. And 1ns width pulse has been delivered between the cathode and the grid at last.

We have several kinds of Z1s with different length, and succeeded in making 500ps beam too by shorter length Z1. Heater power feeder is set inside of inner tube of Z3. Contact at the point C is rigid axi-symmetric, and an air blower is set to prevent from oxidization of contact surfaces.

Cathode Impedance Measurement

We presumed that the cathode impedance is 12Ω. Knowing the cathode impedance is very important for making impedance matching at the point C. Off-line measurement of the cathode impedance is not equivalent to actual impedance when the cathode is driven. Then we measured the impedance of driving cathode by the configuration of fig.3.

We've got a new wall current monitor(WCM) which can

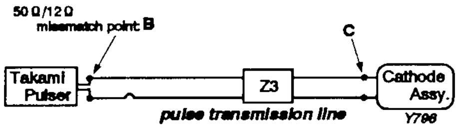

Fig. 3 Schematic view of cathode impedance measurement system.

measure pulse width of less than 1ns[1]. Using this WCM, we try to measure the train of actual beam pulse. This WCM is set 420mm away from the anode of the gun.

When the impedance of cathode is not matched with 12Ω, reflection pulse goes back from the point C to the point B. So the point B is a mismatch point as an aim, the reflection pulse runs Z3 again. As the result, the second beam pulse appears. Our transmission line of Z3 is long enough(877.2mm), and we can separate the first beam pulse and the second pulse. For the ratio of the two beam pulse, reflection coefficient at the point C 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. Takami pulser can generate a pulse of 1ns width by avalanche transister, and its rise time is the same of Kentech pulser, and output voltage is 440v to 880v lower than that of Kentech pulser.

Result

We operate the injector section using both the configuration of fig.3 and fig.1, and compare the beam shapes measured by the WCM. Appearance of the second beam pulse in fig.4 depends on varying the parameters around the gun, and it was found that the heater power is most effective with the cathode impedance.

Fig.4 and fig.5 are shown as typical beam shapes when the impedance is mismatched at the point C(This is obtained when the cathode impedance is not 12Ω). In fig.4, the interval of the first beam pulse and the second beam pulse corresponds to the time of double way of the pulse transmission line. In the configuration of our pulse forming system, there is no second beam even though the impedance is mismatched. When the pulse forming system is used, reflection pulse from the point C runs back to the point B and meets the lower impedance(4Ω) than that of the transmission line(12Ω), and the reversed pulse running to the cathode again does not make the second beam pulse any more. This is the advantage of our pulse forming system, and low impedance of these transmission lines contribute to decrease of transmission loss.

Our electron gun must work in several kind of different modes. The pulse length and the emission current will be

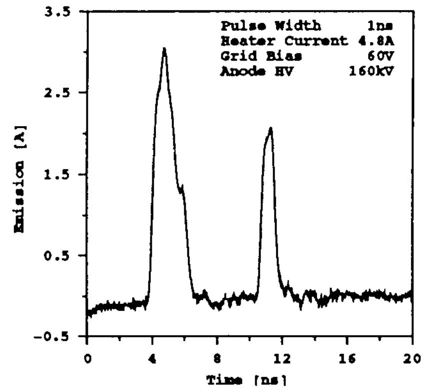

Fig. 4 Beam Current at 4.8A of Heater and the configuration of cathode impedance measurement.

changed to adapt to user requests. Operators can select parameters of the gun without care of making extra beam trains.

The higher power to the heater, the smaller the ratio of the two beam. Fig.6 and fig.7 are shown as typical beam shapes when the heater current is 5.8A, and second beam pulse disappears. We consider this situation is the impedance matching between the pulse transmission line and the cathode.

We tried varying the bias and the pulser voltage, but drastic change of cathode impedance more than one of the heater power was not found. Fig.8 is the impedance of cathode calculated from experimental data.

The higher heater current, the second beam pulse disappears, and the cathode impedance could not be calculated. The temperature of the cathode surface was measured by optical thermo-meter. When the heater current is 5.8A the temperature is 1000 ℃ , and when the heater current is 4.8A the temperature is 800 ℃.

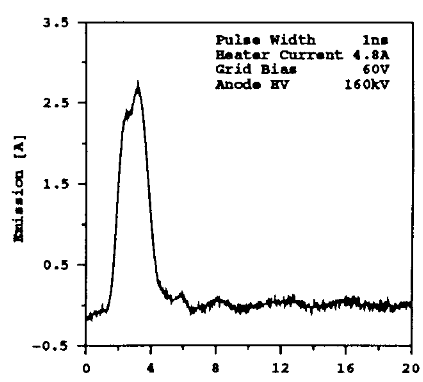

Fig. 5 Beam Current at 4.8A of Heater and the configuration of pulse forming system.

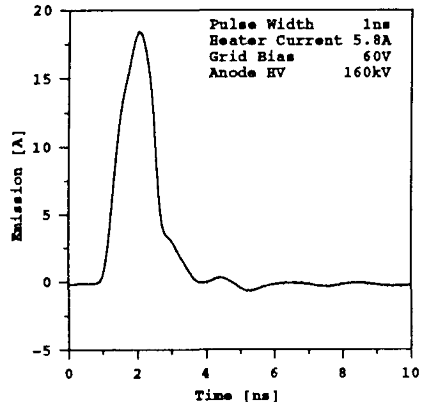

Fig. 6 Beam Current when the heater current is 5.8A, in the configuration of cathode impedance measurement.

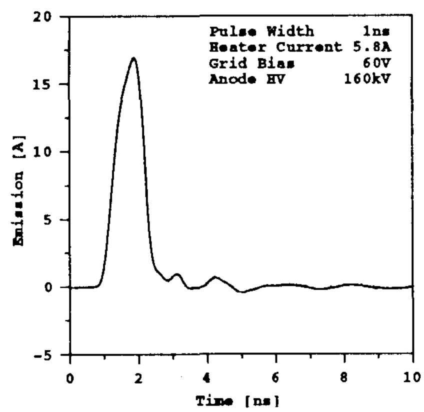

Fig. 7 Beam Current when the heater current is 5.8A, in the configuration of pulse forming system.

Discussion

Conventional configuration of a grid pulser was used to be connected like fig.3 but with a short transmission line. To keep a fast rise time and to avoid pulse voltage down, they try to set the pulser as near as possible the cathode assembly. But near the cathode, spacial limitation is very severe and cooling efficiency is not good. Our pulse forming system is an alternative approach for grid pulser configuration and is enable to release the size of limit of grid pulser circuit.

When you use a shorter transmission line, the interval between the first beam pulse and the second beam pulse will be shorter, and the two beam pulse will be merged. In that case, beam trains should not be only two because the voltage decay of the child pulse is not small. As a consequence, the beam length seems to be stretched. To prevent from this fault, not only the heater power but also other parameters must be fixed and an impedance matched transmission line has to be used. Or the pulser of which output impedance is

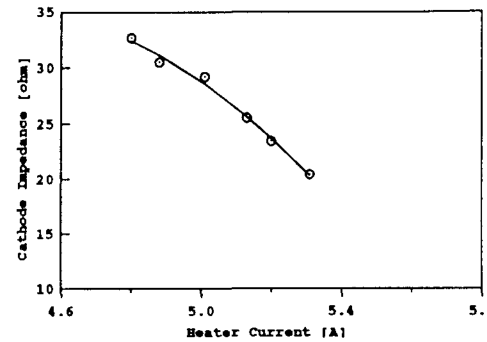

Fig. 8 Cathode Impedance depended on Heater Power.

the same of the cathode impedance must be made and connected the cathode assembly directly. But the impedance of the cathode assembly is gradually changed in the operation extended a long period of time. And parameters should be modified to keep the same emission, even though the heater power(of course usually fixed) may be modified in case. That is not to say a trivial problem for the injector linac of the third generation synchrotron radiation facility.

The weak point of our pulse forming configuration is the low efficiency of pulser power transmission. The reason is that the impedance converter works as a large load of pulse power. But in the other hand, the impedance converter works as a power absorber with reflected pulses. We don't care the low efficiency because Kentech pulser is driven by standard 100V AC power supply, and the power is smaller than that of a klystron gun heater. Anyway 5.8A of heater current would be too high for the long term operation, we will prepare transmission lines of different impedance for impedance matching at the lower heater power.

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 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.

References

[1] K.Yanagida, Wall Current Monitor for SPring-8 Linac, JAERI-M 94-078.(sorry, in Japanese)