

BEAM DEFLECTOR FOR SPRING-8 LINAC

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Abstract

The electron gun of the SPRING-8 linac contains a thermionic cathode with a control grid. After long time operation of the gun, barium atoms evaporate from the heated cathode and accumulate on the grid, resulting in increase in the emission current from the grid. This grid emission spoils the purity of the single bunched beam of the storage ring, since it cannot be regulated by a grid control voltage. Therefore a beam deflector for kicking only the grid emission was designed and constructed. The deflector is composed of a rectangular chamber with two parallel-plate electrodes in it. The electrodes were designed by using the HFSS code to realize a good frequency response over 2 GHz. Fast rising high voltage pulses are applied to both electrodes so as to pass only the grid-controlled current. Experimental results will be reported.

1 INTRODUCTION

The SPRING-8 linac accelerates 1-GeV electron beams with pulse widths of 1-ns or 40-ns. The 1-ns beam is injected to form a single bunched beam in the SPRING-8 storage ring.

The gun of the linac holds a thermionic cathode assembly Y845. A gun modulator applies -180-kV pulse of 5- μ s duration to the gun cathode. The cathode is always heated during an operation cycle of several weeks to keep the gun ready to eject a beam. After long-time operation of the electron gun, barium atoms evaporate from the heated cathode of the gun and accumulate on the grid of the cathode assembly. This phenomenon causes electron emission from the grid when a high voltage is applied to the cathode. The grid emission current depends on the cathode high voltage only, therefore it cannot be controlled by a grid control voltage. This current is the background of an electron beam injection into a booster synchrotron. The synchrotron's kicker magnet accepts not only the 1-ns beam but also the background during about 100-ns, which is determined by the kicker pulse width. As a result, the purity of the single bunch circulating in the synchrotron can be spoiled because the background electrons are injected in RF buckets around the target bunch, which have to be vacant. The RF-KO system of the synchrotron reduces the background. However, higher bunch purity has been requested.

In order to reduce grid emission, a prototype of a beam deflector was developed in 2000. A practical beam transport to the prebuncher was carefully investigated by simulating the beam orbit by PARMELA and the design of the deflector was refined so as not to spoil the linac's

beam quality. The second product was installed in the gun of the linac in December 2001.

2 BEAM DEFLECTOR

The schematic drawing of the linac injector system is given in Fig.1. The deflector system consists of a deflector chamber, two Helmholtz coils, a steering coil, an iris chamber, a beam profile monitor and two ion pumps. The deflector chamber is placed just after the gun anode.

The deflector is composed of a rectangular chamber and two parallel-plate electrodes in it. The RF simulation code HFSS designed the electrode size and its vacuum feed through so as for their characteristic impedance to be around 50 ohms over the frequency range of DC to 4 GHz. The length of the deflector electrodes has to be minimized also not to degrade the beam quality, hence its size was determined to be 100-mm long, 15-mm wide and 3-mm thick. A simulated return loss of the electrode including the feed through is -22 dB at 2 GHz, for example. The total capacitance and inductance of the electrode were measured and they were about 4 pf and 10 nH. The total length of the chamber is 253 mm. The 180-keV electron beam is horizontally deflected with angle of 110mrad when an electric field of 7 kV is applied between both the electrodes, then it is blocked by an iris plate placed 150 mm downstream.

The iris chamber equips two iris plates, and a screen to monitor a beam profile. A remote controlled pneumatic plunger inserts or draws them. Diameters of the irises are 1.3, 2, 3 and 10 mm to determine specified beam currents. The total length of the iris chamber is 90mm. The maximum magnetic flux densities of the two Helmholtz coils are 160 and 190 gauss, respectively. The maximum deflection angle of the steering coils is about 10 mrad.

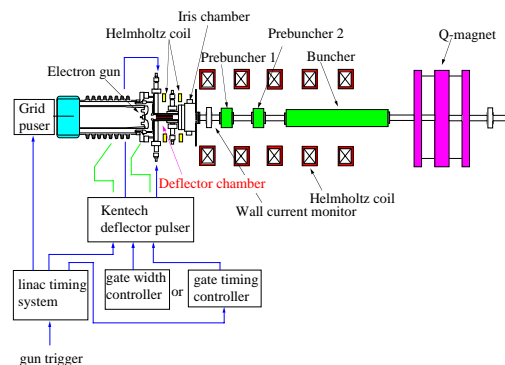


Figure 1: Schematic drawing of the SPRING-8 beam deflector system.

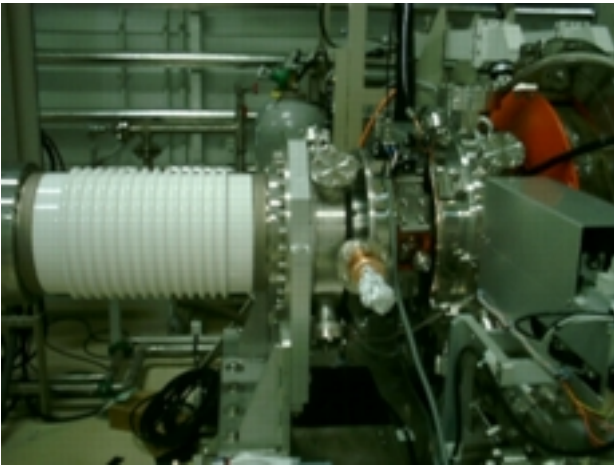
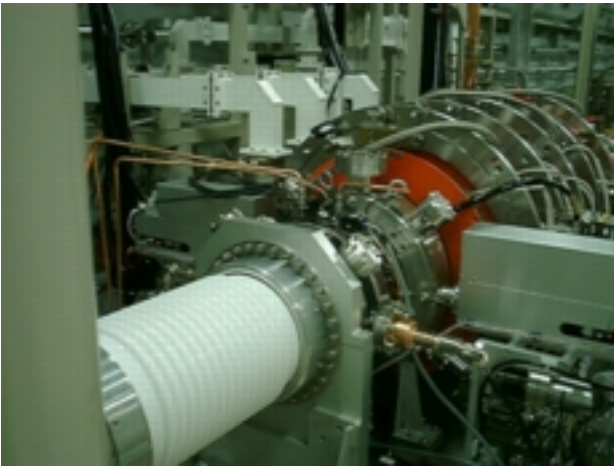


Figure 2: SPring-8 linac deflector system.

3 DEFLECTOR PULSER

A deflector pulser, produced by Kentech Co., generates two kinds of high-voltage and fast-rising pulses: Channel 2 outputs a positive pulse and channel 1 generates a pulse biased at negative kilo volts, as illustrated in Figure 3. Each high-voltage pulse is fed to each electrode of the deflector, respectively.

Performance of the pulser is as follows: The specified rise time of the pulse is 200 ps and the fall time is 6 μ s. The amplitude of both channels is adjustable in the range of 4.5 kV to 7 kV, and the bias voltage of channel 1 is variable from 0 to -7 kV. The output circuit of the pulser holds a matching resistor of 50 ohms, however, it is designed to drive only an open-end electrode with low capacitance (< 100 ps). The channel 2 output can be delayed by an internal circuit in the range of 0 to 40 ns with reference to channel 1. Two external trigger pulses can also start the pulse generation of both the channels individually, thus the delay between the channels can be remote controlled. The time jitter of each output is less than 20 ps (rms).

The timing chart of the beam deflector pulses is shown in Figure 3. When the channel 1 pulse is delayed by referring to channel 2, therefore both the electrodes are grounded during the delay time as when opening a gate.

That is, a beam can transport through the deflector chamber and the downstream iris without deflection only at this moment. Thus the deflector functions as a gate to control a beam length. The plateau of the deflecting pulse around its rising edge is not completely flat, therefore the fields may not be perfectly zero when both the electrodes are grounded. These residual fields may give the transverse momentums, which increase the beam emittance, to the 1-ns beam passing through the opened gate. Therefore the timing of both pulses is carefully adjusted referring to the beam pulse in order to minimize the beam deflection during the gate time.

4 EXPERIMENTAL RESULTS

In order to confirm the working of the deflector system, the 40-ns beam was emitted and the beam transported through the deflector was measured. The gate time was 1 ns. Figure 4 shows the beam current waveforms measured by a wall current monitor mounted between the iris chamber and the prebuncher. The upper and lower waveforms represent the original beam and the gated beam, respectively. The figure clearly indicates that the deflector gated the beam successfully to transport a 1-ns beam only.

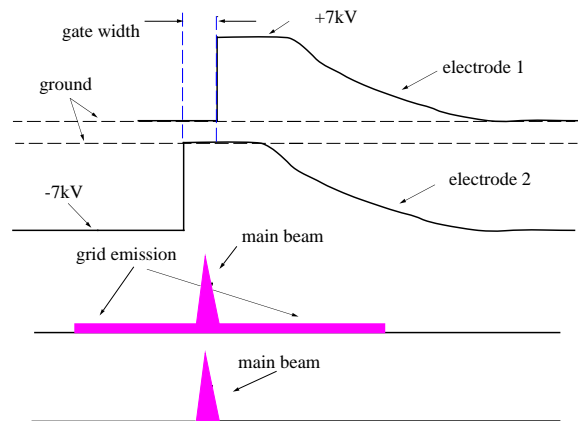


Figure 3: Timing chart of SPring-8 linac.

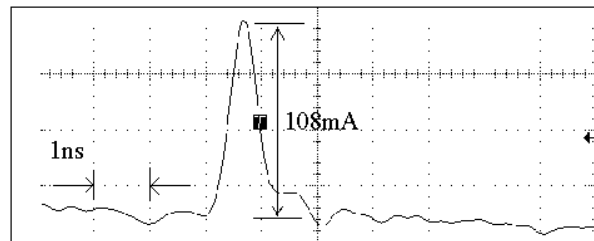
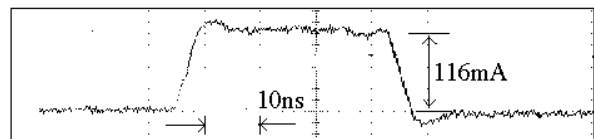


Figure 4: Beam pulse waveforms observed by beam current monitor.

Upper: original beam pulse, lower: gated beam pulse.

The beam transmission of the deflector in operation was examined with the 1-ns beam. First, the beam currents without deflection were measured for every iris size. Then operating the deflector, the current measurement was carried out again. According to the results, the beam transmission efficiencies were kept greater than 76%, as plotted in Figure 5. The efficiency for the 3-mm iris recorded the maximum of 88%. The reason for this was simply that the beam orbit from the gun to the current monitor was optimized, therefore the other data were also better when optimized. The purity of the single-bunched beam in the storage ring is now being examined. Reduction of the grid emission current will be directly observed by counting gamma rays induced by the grid emission current.

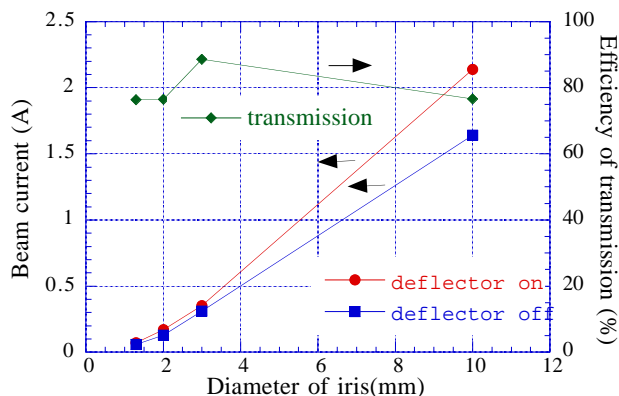


Figure 5: Beam transmission as a function of iris size.

5 SUMMARY

The beam deflector was installed in the linac to kick out the grid emission except for the true 1-ns beam. The deflector gated the 40-ns beam to transport only a 1-ns width beam. In operation, the deflector transported the 1-ns beam at the maximum transmission efficiency of 88%. Thus we confirmed that the deflector worked in principle. This deflector system will be useful to enable variation in the beam pulse width.

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