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RF SYSTEM BASED ON TWO KLYSTRONS AND PHASE MODULATION FOR PHOTO-CATHODE INJECTOR*

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Abstract

We proposed an RF system with two klystrons, of which the powers are combined by a 3dB-hybrid. By managing the phases of the two klystrons respectively, the two pulses from the two output ports of the 3dB-hybrid can be of different powers, phases, and shapes. One of the two pulses can be set to an RF gun, while the other one can feed traveling accelerating structures. Two methods of phase modulation were proposed based on this scheme. Comparing with the state-of-art RF system, the new one can be of high efficiency or can generate electron beams with higher energy. The detailed analysis of the two methods and some experiments are described in this paper.

INTRODUCTION

RF guns are of low emittance which is significant to Free Electron Laser and Ultrafast Electron Diffraction. This advantage of the RF guns lead to the wide applications of the Photo-cathode injectors based on RF gun in accelerator field. Usually, the photo-cathode injector consists of an RF gun and two or more linacs. And klystrons are used to power the RF gun and the linacs.

In many layouts of the photo-cathode injectors, the RF gun and the linacs are fed by different klystrons. The filling time of the RF gun is several microseconds, which require that the klystron feeding the RF gun should be of long pulse with several microseconds. The filling time of the linac is several hundred nanoseconds. In this case, the klystron can work with short pulse length. However, the klystrons have the ability of generating long pulses. In many case, the injectors can't make full use of the klystrons.

In this note, we proposed an RF system based on two klystrons and an LLRF system. The LLRF system can modulate the phase of the two klystrons respectively. A 3-dB hybrid combines the powers from the two klystrons and generates two pulses which can be delivered to two different RF structures. By modulating the phases of the two klystrons, the two pulses can be of different powers, phases, and shapes, which lead to many work modes of the RF system [1, 2]. We proposed two methods of using the RF system. One of the methods can reduce the filling time of the RF gun and the other one can generate two pulses with one pulse can be used by pulse compressor.

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FIRST METHOD

Figure 1 shows the layout of the first method with two S-band klystrons with pulse power of 50 MW, an RF gun with unloaded quality of 14000 and two SLAC 3-m linacs with filling time of 800 ns. By controlling the phase difference of the two klystrons, the ratio of powers from the two output ports of the 3-dB hybrid was tuned to 1:9. The pulse with power of 10 MW feeds the RF gun, while the pulse with power of 90 MW feeds the two SLAC linacs.

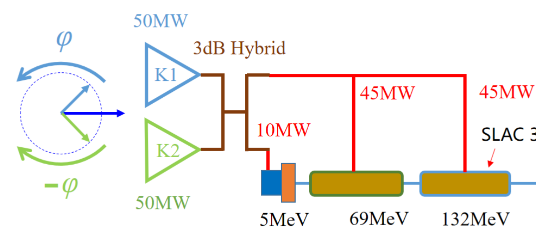

Figure 1: Layout of the first method.

By modulating the phases of the two klystrons, each pulse can be divided into two parts as is shown in Fig. 2. For the RF gun, the ratio of the powers of the two parts is 4:1. For the linacs, the ratio is 1:4. The established fields of the RF gun and the linacs are shown in Fig.3 and Fig.4. Due to the large power at the beginning of the input pulse for RF gun, the filling time of the RF gun was reduced to 500 ns from 4000 ns. After 500 ns, the linacs need 800 ns to establish the field. The total working time of this method is only 1.3 us, which significantly reduce the pulses of the klystrons and the modulator.

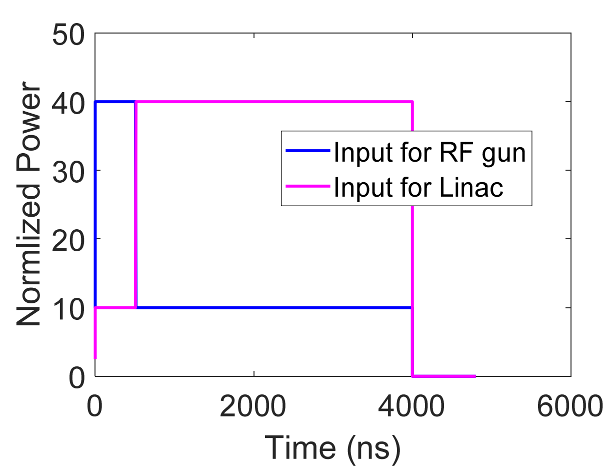

Figure 2: Input powers for RF gun and linac of the first method.

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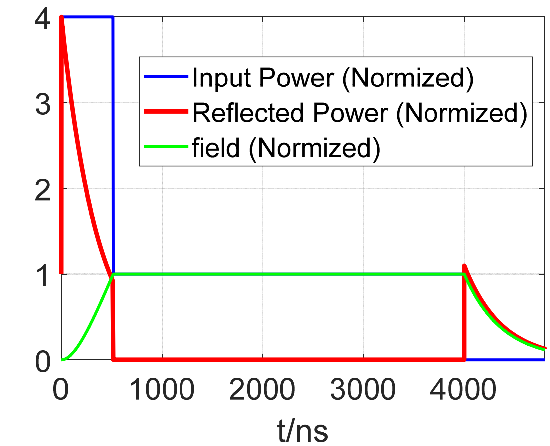

Figure 3: Input and reflected powers and the field of the RF gun of the first method.

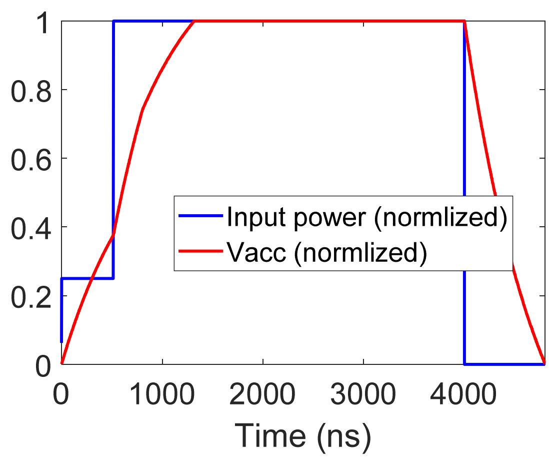

Figure 4: Input power and normalized accelerating voltage of the linac with filling time of 800 ns of the first method.

As we know, the first method described above can reduce the working time of the RF system. However, to reduce the working time, the reflected power of the RF gun is to large (see the red waveform in Fig.3), which is dangerous to the klystrons. To reduce the reflected power, we can modulate the phases of the two klystrons to get a ramp pulse for the RF gun as is shown in Fig.5. By this operation, the reflected power was reduced to 1.7 from 4 as is shown in Fig.6. However, the length of the pulse with large power was increased to 600 ns. And the working time of the RF system is 1400 ns.

The first method uses a pulse with large power of the first part with ramp shape to reduce the filling time of the RF gun. The reduction of the filling time of the RF gun can significantly reduce the working time of the RF system while generating the electron beams with the same energy. The efficiency of the RF system is increased. The reduction of the pulse length of the klystrons and the modulator can enhance the stability of the RF system.

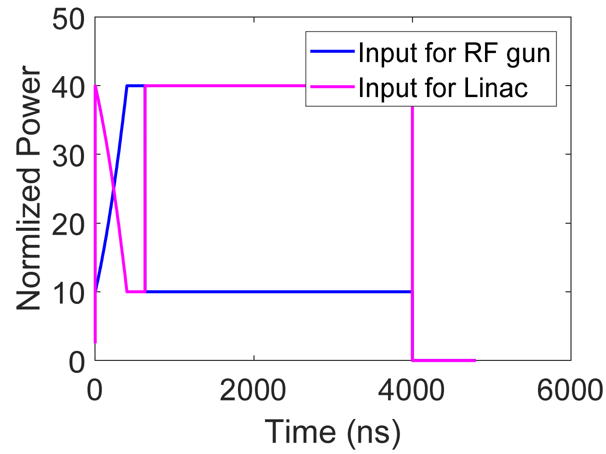

Figure 5: Input powers for RF gun and linac of the first method with ramp input power for RF gun.

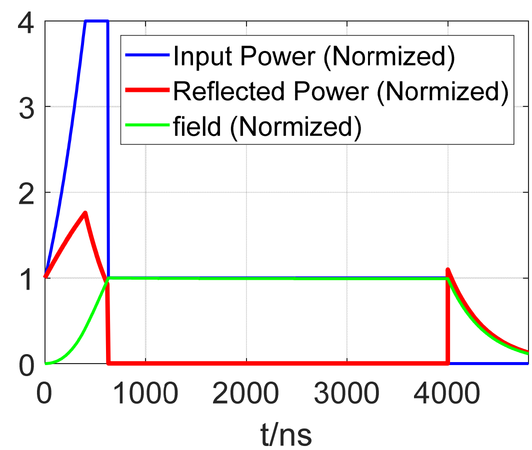

Figure 6: Input and reflected powers and the field of the RF gun of the first method with ramp input power for RF gun.

SECOND METHOD

Figure 7 shows the layout of the second method. In this method, an RF pulse compressor with unloaded quality factor of 100,000 was introduced into the RF system. By modulating the phases of the two klystrons, the pulse from one port of the 3-dB hybrid can be of constant phase and amplitude while the other pulse can be of constant amplitude and reversal phase with phase reversal time of t_1. The pulse with constant phase and amplitude feeds the RF gun while the other on feeds the RF pulse compressor. The power from the pulse compressor is enlarged by a factor of 5 which can enlarge the accelerating voltage of the linacs.

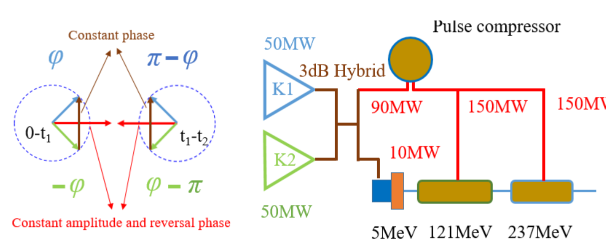

Figure 7: Layout of the second method.

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In this method, the filling time of the RF gun is 4000 ns. And the time for pulse compression is also 4000ns. The established fields of the RF gun and the linacs are shown in Fig.8 and Fig.9.

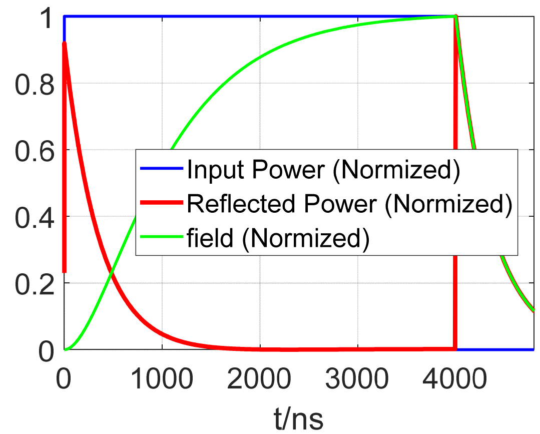

Figure 8: Input and reflected powers and the field of the RF gun of the second method.

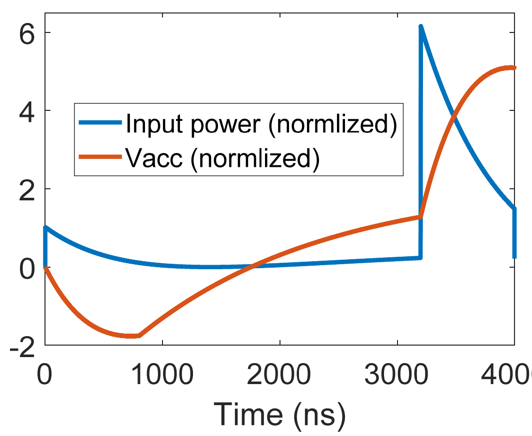

Figure 9: Input power and normalized accelerating voltage of the linac with filling time of 800 ns of the second method.

EXPERIMENT

Figure 10 shows the layout of the experimental setup. Even there are no RF gun and linacs, the principle of the second can be tested by this scheme. The input waveforms ware obtained from the RF system as is shown in Fig.11 and Fig.12.

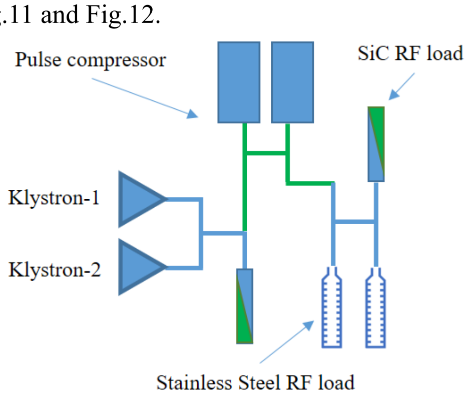

Figure 10: Layout of the experimental setup.

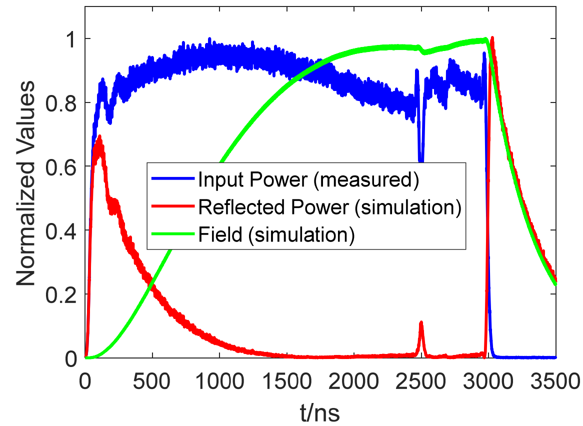

Figure 11：Measured input power of RF gun and calculated reflected power and field with respect to the input power.

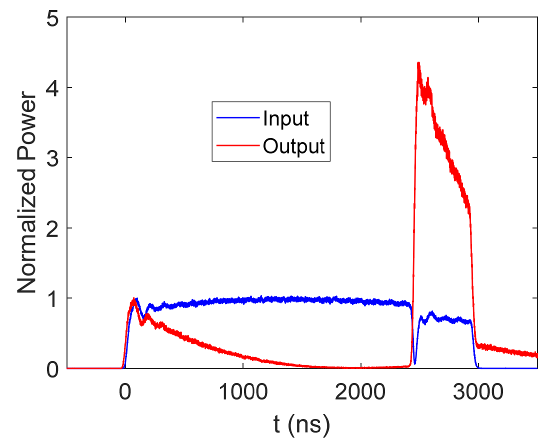

Figure 12: Input and output powers of the SLED from the experiment.

CONCLUSION

We proposed an RF system based on two klystrons and a LLRF system. Two methods were described for the applications of this RF system. The first method can significantly reduce the working time of the RF system and the second method can make full use of the klystrons. And the second method was partially tested by the experiment. We hope that the two methods be applied in the future photo-cathode injectors.

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