

EXPERIMENTAL STUDY ON PM-AM METHOD IN PULSE COMPRESSION SYSTEM *

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Abstract

We are preparing for experimentally demonstrating the PM-AM method (Phase Modulation to Amplitude Modulation) at an S-band high-power test stand at Tsinghua University. This high-power test stand consists of two S-band klystrons, a SLED type pulse compressor, and two high power stainless steel RF loads. An LLRF (low level RF) system has been developed to modulate the phases of the two klystrons in real time such that pulse compressor could generate a flat output pulse. The progress of the experiment is described in this note.

INTRODUCTION

Pulse compressors have many applications in colliders and FELs and the injectors of circular accelerators [1, 2]. A pulse compressor shortens the length of RF pulses and increases the output power. Usually the power can be enlarged by a factor of 4 to 5, which reduces the required power generated by RF sources. SLAC Energy Doubler (SLED) and Barrel Open Cavity (BOC) are two widely used pulse compressors [3, 4]. Although they have different exteriors and RF designs, their principles of pulse compression are the same with each other. In their method, one or two high quality resonant cavities store the energy of the front part of an RF pulse, and release energy by reversing the phase of the pulse before the rest part of the pulse goes in the cavity. The reversing time determines the output pulse length, being the length of the rest part of the pulse. The output pulse is of decaying shape due to the dissipations in the resonant cavities. This shape of pulse is only suitable for single beam acceleration. When it comes to multi-beam case, the beams to be accelerated will meet different acceleration voltage due to the decaying shape of the pulse from a pulse compressor, resulting in different energy of beams. To solve this problem of energy difference, amplitude modulation of input pulse fed into the pulse compressor is needed to generate a flat output pulse. Usually, such an input pulse is from klystrons, which can generate pulses with stable amplitude and phase. However, the amplitude of the output pulse from klystron does not have linear relationship with that of the input signal, which makes the amplitude modulation unstable in operation.

Different from amplitude modulation of the klystrons,

the output phase of klystron has linear relationship with that of the input signal, which makes phase modulation much easier than amplitude modulation. By modulating the phase of the two klystrons, a 3 dB hybrid can combine the powers and generate a pulse with modulated amplitude and constant phase. The 3 dB hybrid turns the phase modulation of two klystrons into amplitude modulation of the output pulse.

We will experimentally demonstrate the Phase Modulation to Amplitude Modulation (PM-to-AM) method at the S-band high-power test stand of Tsinghua University. With the help of newly installed LLRF system, the high-power test stand will flatten the pulses from a SLED-type pulse compressor. The progress of the experiment and the RF system are described in this paper.

HIGN-POWER TEST STAND

We have constructed an S-band high-power test stand at Tsinghua University. Figure 1 shows the layout of the system. A 3 dB hybrid combines the powers from two 50 MW klystrons and generates a pulse with high power. And the pulse then goes into a SLED-type pulse compressor. After compression, the output pulse of the pulse compressor is of large power and short pulse length. Two stainless steel RF loads absorb the RF power finally. The SiC RF loads are of low power capacity and installed to the ports with low power.

Figure 2 shows the photo of the system. It has generated pulses with peak power of more than 260 MW and pulse length of 300 ns.

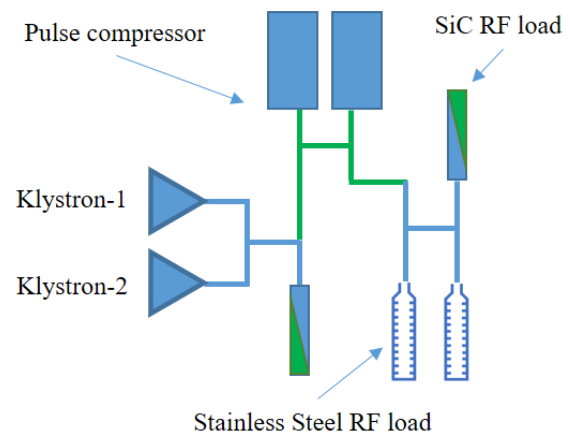


Figure 1: Layout of the S-band high-power test stand.

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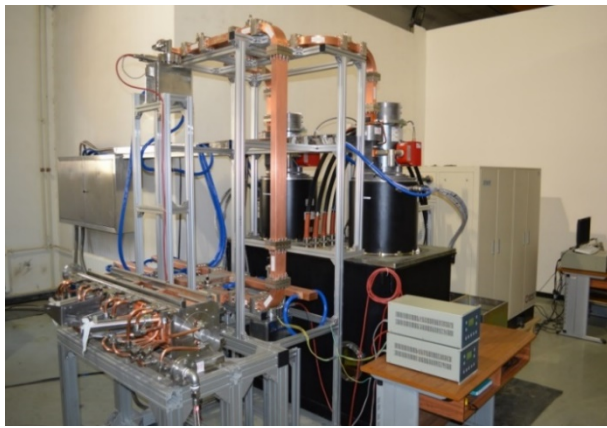


Figure 2: Photo of the S-band high power test stand.

PM-TO-AM METHOD

Two klystrons and a 3 dB hybrid can achieve phase modulation to amplitude modulation (PM-to-AM method) as shown in FIG. 3. Modifying the phase difference between two klystrons can obtain different output power. Further, if the phases of the two klystron are changed by the same amount but to different directions, the phase of the output pulse is constant. Thus, phase modulation of the two klystron simultaneously turns to amplitude modulation of the output pulse.

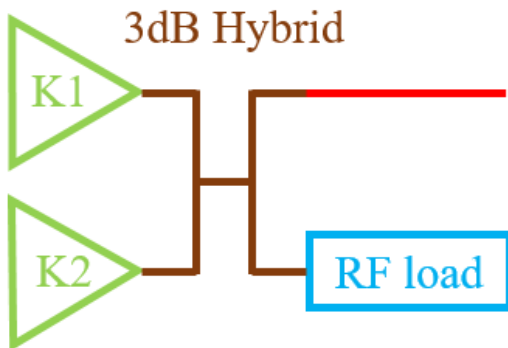


Figure 3: Scheme of PM-to-AM method.

Figure 4 shows the input and output waveforms of a pulse compressor. The amplitude modulation of the input pulse can achieve flat output pulse. Such an input pulse can be generated by the scheme in FIG. 3.

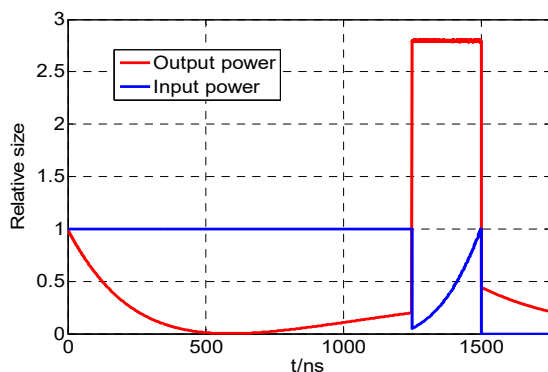


Figure 4: Waveforms of input and output pulses of a pulse compressor.

LLRF SYSTEM

Figure 5 shows the picture of the LLRF system and Solid State Amplifier (SSA). The LLRF system comprises a computer, an RxC, and a SYNChead. The RxC is the central part of the system. It receives signal from SYNChead, downloads the software from the computer, and generates RF pulses with arbitrary amplitude and phase. The SSA amplifies the power from LLRF system and generates pulses with power of 900 W.

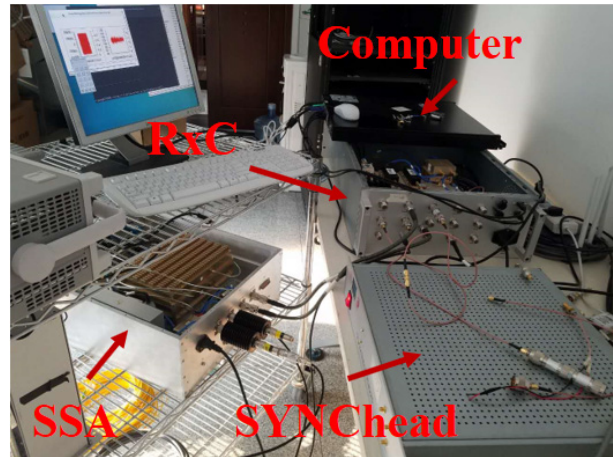


Figure 5: LLRF system and SSA.

Figure 6 shows a simple schematic drawing of signal generator. The frequency of the output signal is 2856 MHz, which is up mixed by the local signal with frequency of 2697.33 MHz and the signal from Digital-to-Analog Converter (DAC). The phase modulation of the output signal is realized by modifying the frequency of DAC. A Berkeley Packet Filter (BPF) and an RF Amplifier (Amp) eliminates signals with other frequencies and enlarges the output power respectively. Two output ports are reserved for the two klystrons in the high-power test stand.

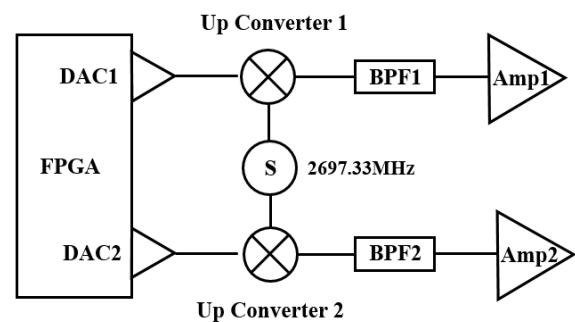


Figure 6: Generation of modulated pulses.

Figure 7 and 8 show the phase modulated signal generated by LLRF system and its waveforms of amplitude and phase. The signal is measured by an oscilloscope with bandwidth of 25 GHz and sampling rate of 40 GHz as shown in Fig. 9. The phase is reversed before the end of the signal, meeting the preset condition. This result indicates that the LLRF system can generate the pulses for pulse compressor.

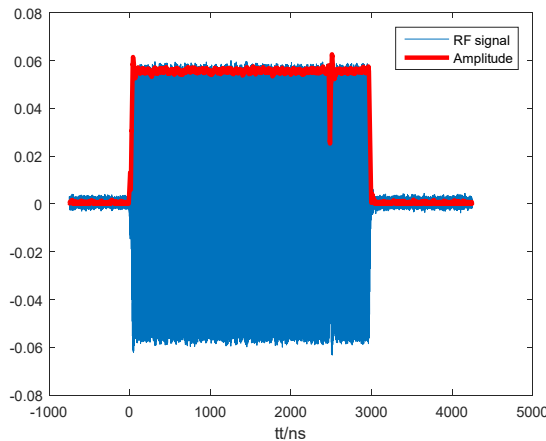


Figure 7: Phase modulated signal and its amplitude from LLRF system.

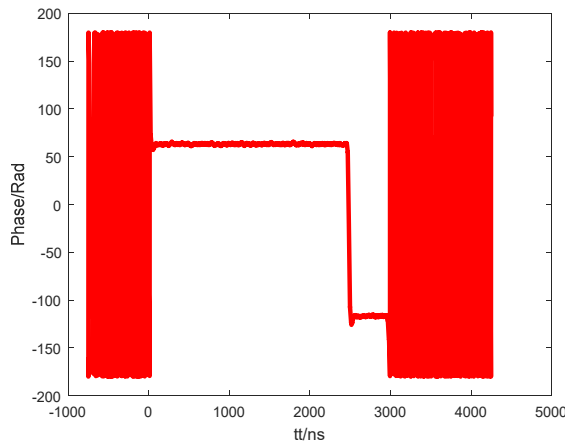


Figure 8: Phase of phase modulated signal from LLRF system.



Figure 9: Experiment setup for testing LLRF system

LOWER POWER EXPERIMENT

A low level 3 dB hybrid is used to combine the powers from SSA, amplifying the powers of LLRF system as shown in Fig. 10. Before the combination, the powers from SSA should be attenuated by attenuators to low level, avoiding damaging the 3 dB hybrid. By modulating the phase difference of the input signals, we finally obtain an amplitude modulated pulse (see Fig. 11), which is

suitable for pulse compressor to generate flat output pulses (see Fig. 4). This result indicates that the LLRF system and the SSA are well prepared.



Figure 10: Energy combination by a low level 3dB hybrid.

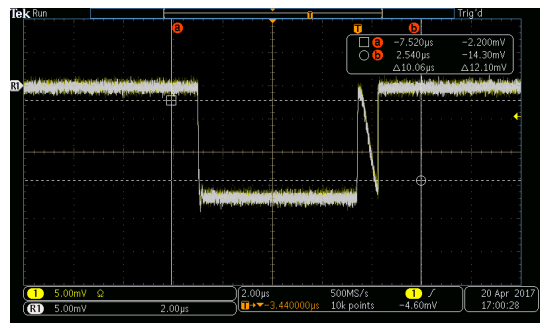


Figure 11: Output waveform after PM-to-AM.

CONCLUSION

We are preparing for experimentally demonstrating the PM-AM method. The S-band high-power test stand is desThe LLRF system and the SSA have been tested and meet the requirement of the PM-to-AM method. The high power experiment will follow in next few weeks.

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