Research on Arbitrary Electrical Pulse Generation Technology for Laser Pulse Shaping*

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Abstract: To realize intelligently adjustable pulse-shaping, a computer was used to control the gate bias of each GaAs filed-effect transistor (FET) and superpose pulses generated by them. To improve the stability and reduce the trigger jitter of shaped-pulse, the pulse shaping circuit was properly designed. 1～5 V adjustable amplitude, 0～3 ns square wave width, rising edge 250 ps falling edge 350 ps, 4% (peak to peak) amplitude stability, and 200 ps time domain adjustment precision were obtained.

Key words: Arbitrary shaping electrical pulse generator; Time jitter; GaAs FET

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0 Introduction

Since one requirement[1] of the realization of Inertial Confinement Fusion (ICF) is that the ablation pressure on target surface, which is generated by the radiation from high-power laser pulse, should be increased step by step. There is a high requirement on the laser target pulse shape. One requirement of the new generation of ICF driver is that its multi-channel laser output should be arbitrarily shaped. At the same time, it is required that each pulse should have similar waveform to achieve the balance of the power. The acquisition of arbitrary waveform laser pulse can be realized via modulating the *Q*-switched pulse form output of the main oscillator by Pockels cell or optical waveguide modulator. The generation of qualified electrical pulse is a significant technology in the time-shaping research. Considering the advantages of the integrated optical modulator-the replacement of Pockels cell clipping technology by integrated optics and fiber technology which has a low voltage of driver modulator, coupled with shaping electrical pulse source and laser diode-pumped single longitudinal mode oscillator which has high stability, it can greatly enhance the stability and flexibility of the laser pulse shaping. Thus, it is prior to choosing the integrated optical modulator in the high-power laser pulse shaping device. The key integrated optical component used in the pulse-shaping and spectrum-widening is the optical waveguide modulator, and the key circuit is arbitrary shaping electrical pulse generator[2].

1 Arbitrary shaping electrical pulse generator design

1.1 Principle of basic unit circuit

Arbitrary shaping electrical pulse generator is an important component of the integrated optical modulator. The shape and width of shaped laser pulse are mainly determined by that of arbitrary shaping electrical pulse[3]. In order to modulate the shape and width of shaped laser pulse flexibly, the electrical pulse should satisfy the same requirement[4]. Two properties (named current controlled by voltage and switch property) of GaAs FET are always utilized in the design of arbitrary shaping electrical pulse generator[5]. As shown in Fig. 1, the shape and width of the output

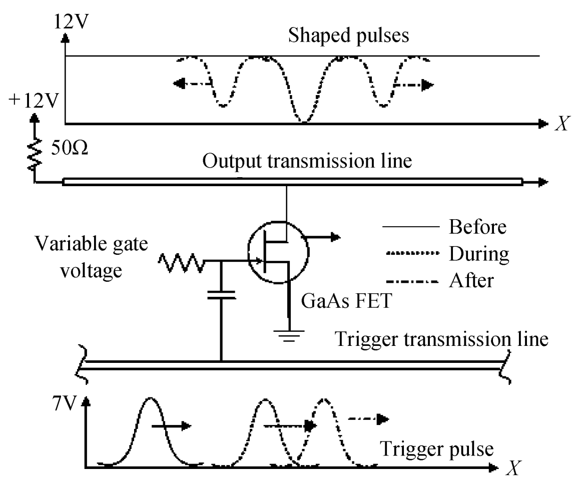

Fig. 1 Principle of basic unit circuit

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pulse generated from the output transmission line of the basic unit circuit are similar to the trigger pulse plus on the gate of GaAs FET, but with reverse polarity. The amplitude relies on the reverse bias supplied on the GaAs FET. Each basic unit circuit is independent from each other. Fig. 1 shows the trigger pulse and shaped pulses (indicated by different type of lines) before, during and after triggering.

1.2　Shaping principle of electrical pulse

Electrical pulse shaping principle was shown in Fig. 2. Shaped pulse generating circuit consists of several (maybe N) wide-band GaAs FET basic unit circuit[6], micro-strip lines and multi-channel high precision bias power supplies. The input of the system is approximate rectangle trigger pulse. Each FET is drived on orderly, and the on-extent of each FET is controlled by the bias voltage on the gate. In this way, N amplitude adjustable pulses are generated from the transmission line orderly. Overlapping the N pulses can achieve a pulse with arbitrary adjustable waveform. The length difference between trigger the transmission line and the output transmission line determines the adjust precision of the pulse. The duration of shaped pulse relies on the quantity (N) of the FETs. Arbitrary adjustable electrical pulse is realized and the output is provided to optical waveguide modulator eventually. Overlapping the pulses from N GaAs FETs can generate arbitrary shaping pulse modulated by a computer, which controls the shape of each electrical shaped-pulse via bias voltage of each FET, respectively.

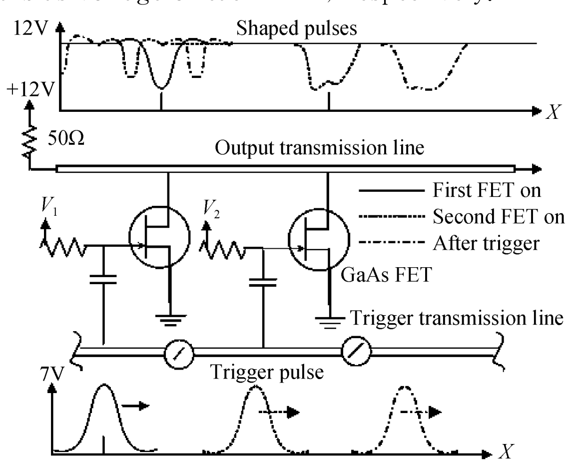

Fig. 2　Shaping principle of Electrical pulse

1.3　Approach to improve the property of shaped electrical pulse

In order to satisfy the requirements of high-power laser device project, it's significant to enlarge the duration of arbitrary waveform electrical pulse[7], improve the amplitude adjusting precision, augment the dynamic range and reduce the trigger jitter of electrical pulse. To summarize the accumulated production of arbitrary shaping pulse technology research, the following skills can be adopted to enhance the specifications of arbitrary shaping electrical pulse: trigger pulse input and output impedance matching study, high-frequency property of shaping circuit, improving the technology of circuit, applying tapered line and multi-layer Print Circuit Board (PCB) making process. These approaches can enhance the bandwidth, modulation precision in time domain, pulse-shaping ability and reduce the top square wave ripple drastically.

In order to further reduce the pulse trigger jitter, selecting high quality high-frequency avalanche diodes[8] to generate pulse with fast rising and falling edge and then differencing it, thus, a very narrow pulse with fast rising and falling edge can be achieved. Take a conclusion of many experiments, diverse types of avalanche diodes generate evident circuit jitter differences. Even the same type device, selecting a variety of operating points or different aging process, the final jitter values of circuit also vary greatly. At the same time, since it is ultra wide-band circuit, the making process influence the shape and parameter of the pulse. Thus, firstly selecting the avalanche transistor seriously, then rigorous testing and aging, lastly, setting the operating point carefully, the trigger jitter values will reduce evidently. Fig. 3 shows the testing waveform and the stability of the trigger pulse.

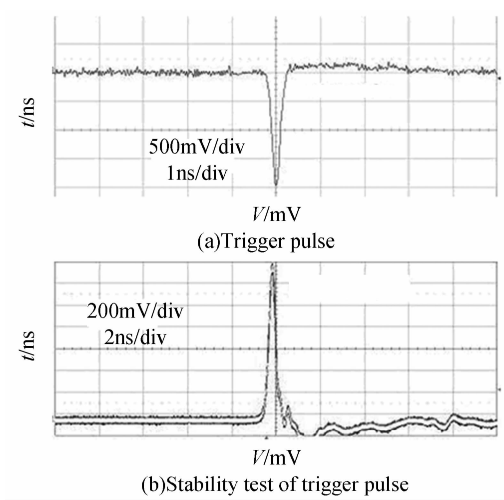

Fig. 3　Trigger pulse and its stability test of basic unit circuit

A lot of methods, such as, high-quality making process of multi-layer board, advanced trigger transmission line with tapered-line structure, selecting superior performance high frequency PCB which is a PTFE dielectric material, can be used to reduce components losses of trigger pulse substantially, further improve the capacity of outputting shaped pulse. Fig. 4 shows the time domain reflect curve of tapered line.

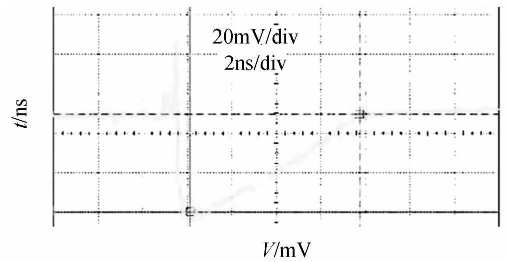

Fig. 4 Time domain reflect curve of tapered line

Designing the circuit operating points reasonably[9], can set the amplitude of output pulse approximate 1 V, with further reduced ripple and greatly increased shaping capacity. This pulse is amplified by a 12 GHz ultra wide-band amplifier. Also it can drive the optical waveguide modulator with adjustable output ranging from 5 volts to 8 volts. As shown in Fig. 5, tapered micro-strip lines can compensate the losses of the trigger pulse amplitude effectively. The before and after improving pulse comparison results prove the virtue and efficiency of our design.

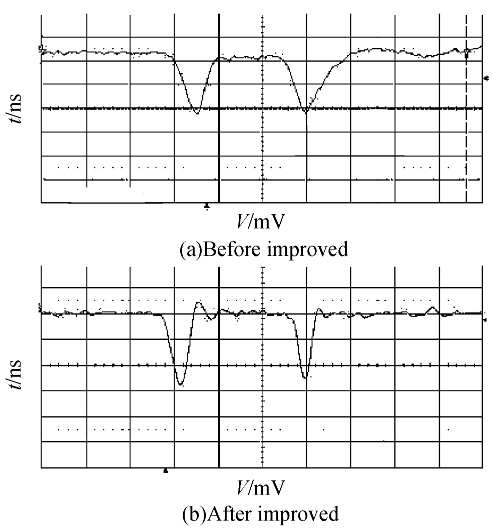

Fig. 5 Basic unit pulse comparison before and after improving

2 The experimental results

Fig. 6 shows the original (without amplifying) accumulate testing waveform via 6 GHz real-time oscilloscope triggered by the external signal. The figure indicates that the pulses with trigger jitter approximate 19 ps and the RMS values approximate 3. 02 ps. Fig. 6 also shows the amplified pulse with trigger jitter peak about 28 ps, RMS about 4. 38 ps. In real-time oscilloscope, resolution is determined by sample rate, interpolating precision, as well as mathematical operation library based on software. Therefore, 19 ps and 28 ps can be obtained in 6 GHz real-time oscilloscope.

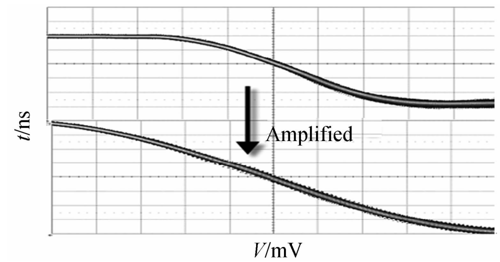

Fig. 6 Trigger pulse jitter test

In this project, arbitrary shaped pulse has the following specification: output amplitude 1～5 V adjustable, output pulse width of square wave from 0 ns to 3 ns, rising edge 250 ps, falling edge 350 ps, amplitude stability 4% (peak to peak), time domain adjustment precision 200 ps.

Fig. 7 shows the laser pulse modulated by arbitrary electrical pulse in optical waveform modulator. The top two pulses are shaped rectangle waveforms which are always used as the gage of the quality of the arbitrary shaping waveform. T bottom two pulses B are usual shaped waveform as examples.

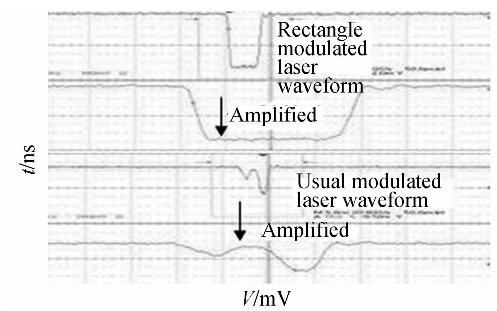

Fig. 7 Laser waveforms modulated by arbitrary electrical pulses

3 Conclusion

With the improvement of shaped pulse circuit, its specification was evidently enhanced. We have achieved these properties in arbitrary shaping pulse generation technology: output amplitude 1～5 V adjustable, output pulse width of square wave from 0 ns to 3 ns, rising edge 250 ps, falling edge 350 ps, amplitude stability 4% (peak to peak), time domain adjust precision 200 ps. In order to enhance these properties further, several pursuits should be carried out, such as new methods to reduce the trigger jitter, new approaches to enhance the stability of pulse amplitude, new research to modulate the pulse time range, new way to upgrade the computer control. Pulse-shaping generation circuit is the key technology in integrated optical modulator, which is significant in the research of ICF. It has been applied in the prototype of "Shenguang-III" high power laser system successfully.

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用于激光脉冲整形的任意电脉冲产生技术研究

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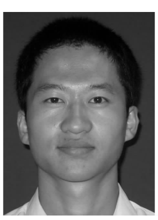
摘　要:为了实现整形脉冲调节的智能化,用计算机分别控制多个 GaAs 场效应管栅极偏压,并对场效应管产生的脉冲进行脉冲叠加,以控制整形电脉冲的形状;为提高输出整形脉冲的稳定性并减小触发晃动时间,优化设计了脉冲整形电路,结果表明:脉冲输出幅度 1～5 V 可调;方波脉冲输出宽度 0～3 ns;脉冲前后沿分别为 250 ps 和 350 ps;幅度稳定性:～4%(峰峰值);时域调整精度 200 ps.

关键词:任意整形脉冲发生器; 时间抖动; GaAs 场效应管



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