Temporal-space transforming pulse-shaping system with "knife edge" apparatus in "Shenguang II" upgrade facility

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ABSTRACT

The temporal pulse shaping was realized by using temporal-space transforming pulse-shaping system with the own-designed "Knife edge" apparatus, for the first time to our best knowledge, in a large energy laser facility with the output energy of 454.37J. A quasi- square laser pulse with the pulse width of 1.16ns, the rising time of 337ps, the falling time of 360ps, and the temporal filling factor of 81.2% was obtained. It is quite satisfied with the requirement of physical experiment. In addition, the further improvements of our system have been suggested in order to enhance the stability and the flexibility as well as the restoring ability of the temporal-space transforming process.

Key words: temporal pulse shaping; "knife edge" apparatus; quasi-square larger energy laser pulse; high temporary filling factor

1. INTRODUCTION

The temporal pulse shaping of the Front-End system is very important for the Inertial Confine Fusion (ICF) experiments. The shaped pulse should not only preheat the target for reducing the Rayleigh-Taylor instability in the ICF process to increase the utilization efficiency of laser driving energy, but also effectively reduce the Stimulated Brillouin Scattering (SBS) effect in the ICF system to prevent damage of the instruments and distorting the waveform of the laser pulse.

The laser temporary pulse shaping technology is a unique technology using active or passive method to change the width, shape and frequency of the laser pulse. It is well known that the passive laser pulse shaping technology is based on passive filtering [1] or the nonlinear effects introduced by the dispersive components such as grating and fiber[2]. Limited by its mechanism, the passive laser pulse shaping technology is generally used in the ultra-short pulse shaping. It is not suitable in the master oscillator of the ICF system. To shape the main pulse of ICF system (nearly ns width), we adopt active laser pulse shaping technology, which uses electric-optics temporal-space transforming pulse-shaping system with "Knife edge" apparatus to realize the pulse shaping.

With the development of the ICF technology, the advanced front-end pulse shaping technology is in need [3]. Various laser temporal pulse shaping systems have been reported in the past time, including static variable impedance lines, such as devices implemented on the OMEGA[4,5] and Phebus facilities; or low-voltage-programmable RF field effect transistors coupled into stripe-lines[6,7] like the ones on the NIF and LMJ facilities. Here, for the first time to our best knowledge, we report a new temporal pulse shaping system-the temporal-space transforming pulse-shaping system with the "knife edge" apparatus. Using this new technology, we successfully got a large energy quasi-square laser pulse which meets the requirements of the physics experiments of "Shenguang-II" upgrade facility. In addition, the further improvements of our system are also suggested in this paper.

2. PRINCIPLE ANALYSIS

The basic shaping process of our temporal-space transforming pulse-shaping system with "knife edge" apparatus is as follows: the temporal-dependent intensity distribution of the input laser pulse is turned into the spatial-dependent intensity distribution by scanning of the electro-optics deflector D_1. The "knife edge" apparatus positioned properly on suitable position acts as an adjustable filter diaphragm. By such a filter diaphragm, we obtain a beam scanning line with an expected shape distribution. The opposite direction scanning of the deflector D_2 with the same optical performance as the D_1's turns the beam with spatial-dependent intensity distribution back into the expected shape one with temporal-dependent intensity distribution.

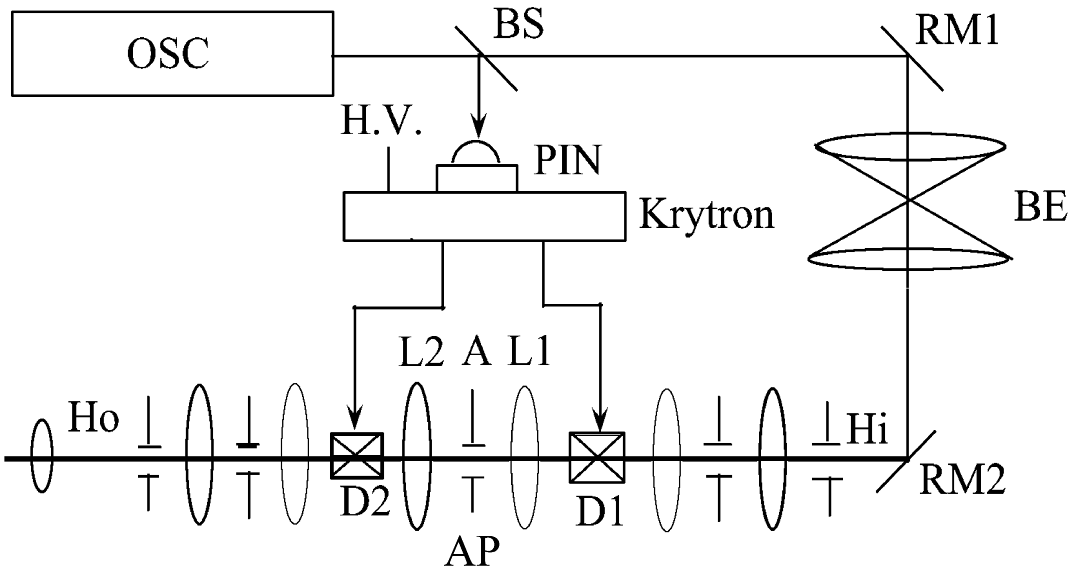


Fig.1 the temporary-space transforming pulse-shaping system containing the "knife edge" apparatus

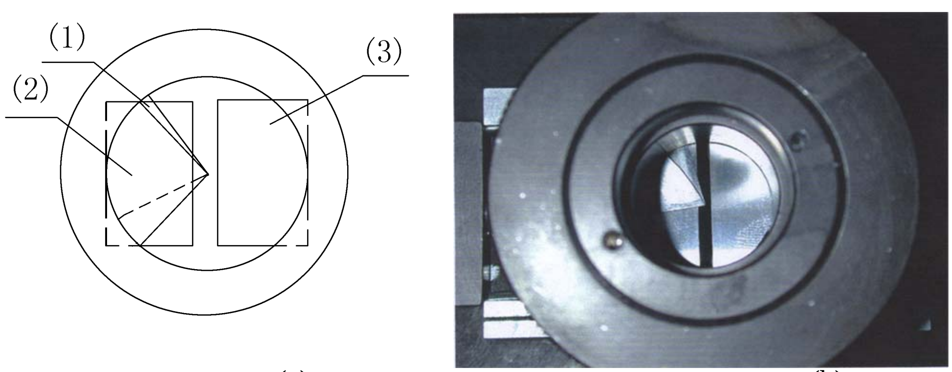
The temporary-space transforming pulse-shaping system with the "knife edge" apparatus is shown in Fig.1. The system we established was a 4f system composed of a pair of $LiNbO_3$ electro-optics deflectors D_1 and D_2 with the same optical performance, a pair of lenses L_1 and L_2 with the same focal length, a cold cathode high voltage pulse producer driven by electronic signal and the "knife edge" apparatus. The plane A is the common focal plane of both lenses L_1 and L_2. The "knife edge" apparatus MP as an adjustable filter diaphragm is on the plane A. The electro-optics deflector D_1 scans the input laser pulse in the time domain (the scanning direction is vertical to the laser beam). The light***s*** at different moment***s*** are deflected to the different positions on the MP, which forms a scanning line. Thus, the temporal-dependent intensity distribution is turned into a spatial-dependent intensity distribution. By adjusting the shape and the size of the specially designed "knife edge" apparatus, we can obtain different laser intensities can be obtained/ at the different position***s*** of the scanning line. The lens L_2 realizes the image relay of optical pulse. Since two electro-optics deflectors have the same optical performance and the electric pulses, synchronized with the laser pulse, in the both deflectors have same amplitude and opposite voltage as well as synchronous with the laser pulse, the two deflector have opposite deflected direction for light pulse. As a result, the deflector D_2 restores the deflected light of the D_1 to the original direction. After traveling through the whole system, the temporal waveform of the input pulse is thoroughly changed. The shape and the size of "knife edge" apparatus determine the shape of output pulse. The scanning speed of the deflectors and the shape of the “knife edge” apparatus determine the temporal width of the output pulse. Therefore**,** the own designed “knife edge” apparatus is crucial for the pulse shaping.

3. SYSTEM PERFORMANCE

In our pulse shaping experiments, the cascade avalanche photoelectric diodes were trigged by some of output laser coming from the master oscillator. The master oscillator we used was a 1053nm single longitudinal mode Nd:YLF Q-switch laser with pulse width of 20ns and the amplitude fluctuation less than 5%. The electric pulse coming from the cascade avalanche photoelectric diode was used to trig the cold cathode high voltage pulse producer. A high voltage pulse with amplitude ~10KV was obtained. The time delay adjustment was realized by changed the length of the transmission line. With this adjustment, the high voltage electric pulse with opposite voltage in the two electro-optics deflectors was synchronized with the output laser pulse of the master oscillator. Thus, the electro-optics synchronization was realized.

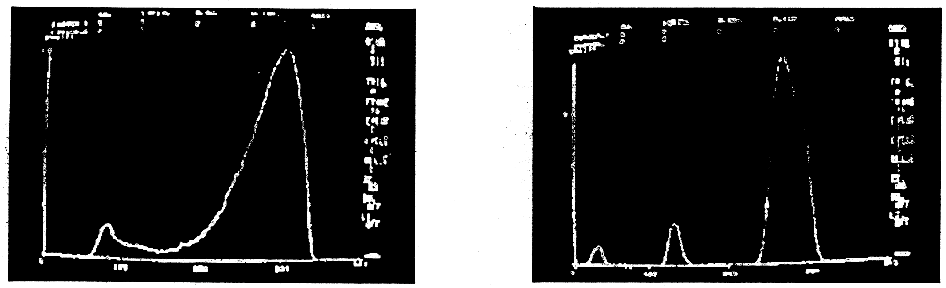
A real “knife edge” apparatus and its structure map are shown in Fig. 2(a) and (b) respectively. Using this apparatus, we can study the temporary waveform of laser pulse by adjusting the shape and size of “knife edge” apparatus as well as the scanning speed of the deflectors. It can be seen from Fig.3a and Fig.3b that the complicated shape pulse (Fig.3, a) and the fence pulse (Fig.3, b) can be obtained by using this technology. The temporal-space transforming pulse-shaping system with the “knife edge” apparatus has demonstrated good pulse shaping ability in our experiments.

For our ICF system**,** after amplified by the gain systems of the ICF facility, a square laser pulse with about 1ns width is required in the target of the terminator. To realize front end pulse temporal shaping**,** adjusting the position of each knife in the “knife edge” apparatus changed the shape and size of the “knife edge” apparatus. The temporal waveform of front-end pulse after temporal shaping is shown in Fig.4. The fluctuation of front-end output was less than 10%. The shaped front-end pulse was amplified by the gain systems of the ICF facility. **T**he terminal shaping pulse with output energy of 454.35J was obtained and its temporal waveform is shown in Fig. 5. It can be seen from Fig.5 that the terminal shaped pulse is a quasi-square laser pulse with 1.16ns pulsed width, 337ps pulse rise time, 360ps pulse fall time and 81.2% temporary fill factor. It meets the requirements of our ICF physics experiment.



(a) (b)

Fig.2 Structure of the “knife edge” apparatus (a) and the practicality photo (b) (In Fig.2 (a), (1) and (2) are two rotation knives, (3) is a vertical knife)



(a) (b)

Fig.3 Complicated shape pulse (a) and fence pulse (b) obtained by using the temporary-space transforming pulse-shaping system "containing own-designed "Knife edge" apparatus"

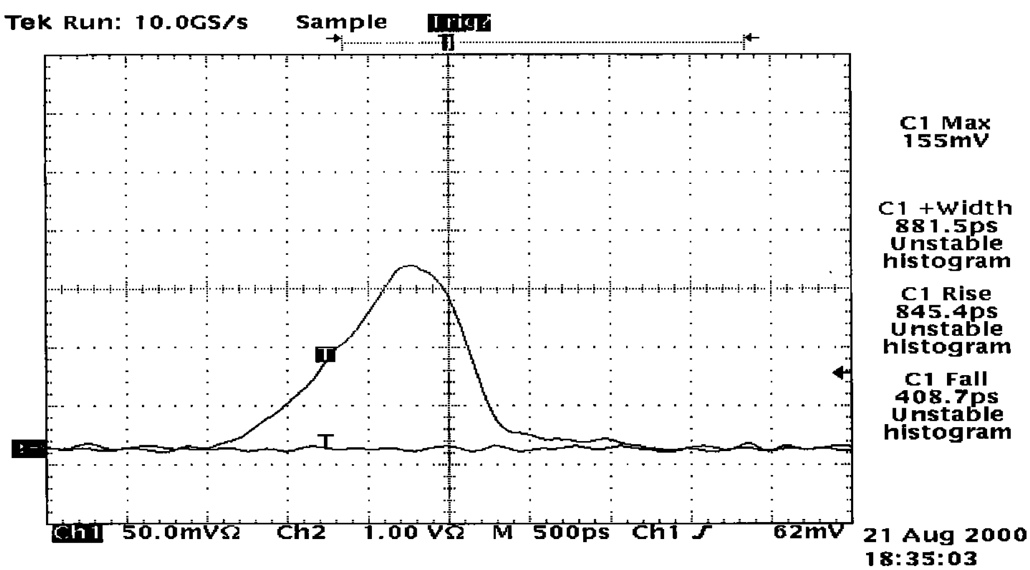


Fig.4, The temporary waveform of front end forming pulse obtained by "knife edge" apparatus (Measure by Tektronix TDS694C)

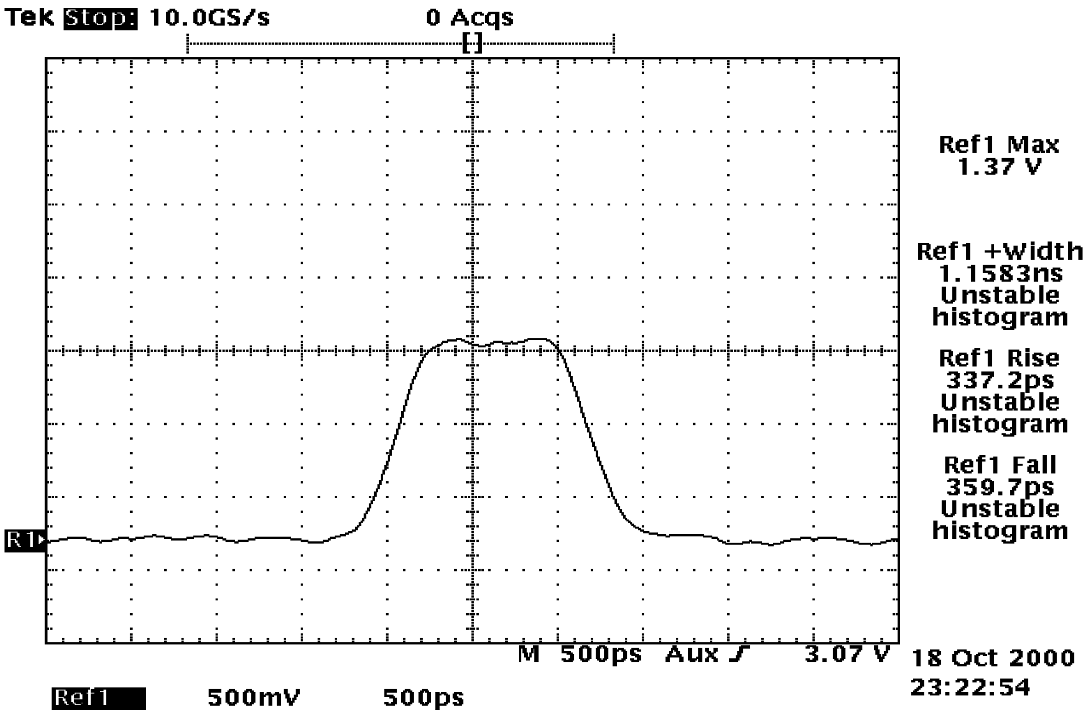


Fig.5, the temporary waveform of terminal laser pulse with output energy of 454.35J (Measured by Tektronix TDS694C)

4. IMPROVEMENT IN THE FUTURE

After several runs of experiments, it was found that the temporal-space transforming pulse-shaping system with the own-designed “Knife edge” apparatus worked very well with ICF system. However, there were some problems that need to be addressed for future improvements.

Firstly, a computer-controlled auto-collimation system should be used in order to enhance the stability of shape of output laser. In experiment, if the spot of laser beam changes, especially in the radial direction, the shape of output laser will also change. To keep the shape of output laser unchanged, the “knife edge” apparatus must be adjusted. Therefore, a computer controlled auto- collimation system should be used to insure the same input position of laser beam on the “knife edge” apparatus and then to avoid the artificial adjustment difference and difficulty.

Secondly, the ICF physics experiment requires not only 1ns width but also 2ns width quasi-square pulse. When the voltage applied on the electro-optics deflector decreases, the scanning speed get slower, the output laser width is widened accordingly. Therefore, the 2ns quasi- square pulse can be produced by changing the voltage applied on the $LiNbO_3$ electro-optics deflectors without necessary to adjust the size of the “knife edge” apparatus after 1ns quasi-square pulse had been obtained. This method simplifies the system adjustment.

Thirdly, because the main optical component—electro-optics deflector of the system must have high optical quality, and two deflectors must have completely identical performance. It is hard to select and process the optical material. In order to overcome these difficulties, the single mode fiber will be suggested to replace the D_2 deflector to realize restoration of temporal-space transform. This idea has been verified in our previous experiments. This measure can enhance the restoring ability of the temporal -space transform process.

5. CONCLUSION

In conclusions, we have demonstrated a new technique, which possesses good optical pulse temporal shaping ability in nanosecond domain by a new temporal-space transforming shaping system with “knife edge” apparatus. After amplified by the gain systems of the ICF facility, a quasi-square waveform larger energy laser pulse has been achieved. It meets requirement of physics experiment of our ICF system. The further improvements of our system have been suggested in order to enhance the stability and the “flexibility” as well as the restoring ability of the temporal-space transforming process.

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