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The experimental study of the KrF excimer laser ASE pulse compression by the way of quenching method

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The ASE (Amplified Spontaneous Emission) pulses, output of the transversely excited atmosphere pumped KrF excimer laser, was compressed experimental by the way of laser oscillation quenching. The effect of mirror position and diaphragm aperture on the pulses compression is discussed in this paper. The experimental results show that, when the angle of the mirror relative to the optical axis is 3.0 mrad and the diaphragm aperture is 4.0 mm, the pulse compression effect is best, and the ideal waveform can be obtain. For the original 12.5 ns pulse, output of the discharge pumped KrF excimer laser, when using the way of laser oscillation quenching to compressed, it can be got the best results of 5.1 ns.

Key words: excimer laser, pulse compression, laser oscillation quenching, ICF.

Introduction

For the short wavelength, high efficiency and well spatial uniformity, the KrF excimer laser has a good prospect in Inertial Confinement Fusion (ICF), and plasma physics research areas. It is one of the main candidates for the light source of the ICF drive [1, 2]. The imperfect of KrF excimer laser pulse compression technology is the main factor to limit its application, so the KrF laser nanosecond pulse compression is currently a hot research topic [3–5]. The methods of KrF laser pulse compression usually are combined SRS (Stimulated Raman Scattering) and SBS (Stimulated Brillouin Scattering) [6], combined SRS and fast Pockels cell [7], the same frequency pulse amplification [8], SRS [9], the plasma switch method [10] and others. These above methods of the ASE pulse compression research have important reference values. However, the ASE pulses outputting from the KrF excimer laser have evident advantages in the spatial energy distribution, incoherent and natural bandwidth than the laser pulses [11, 12]. To our knowledge, they have many potential applications in the ICF studies. ASE pulse output for KrF excimer laser is used for pulse compression research quenching in this paper. This method can achieve shorter ASE pulse. It is also a method to achieve ASE pulse compression.

1. Theoretical analysis

When removing the mirrors of the resonant cavity, the oscillation can not forming. The spontaneous emission radiation pulses are amplified by the process of the stimulated emission radiation. The output light is the amplified spontaneous emission (ASE).

The amplification transmission of the nanosecond light pulses can be described as following [13]

$$\frac{\partial g(x,y,z,t)}{\partial t} = -g(x,y,z,t)\frac{I(x,y,z,t)}{J_s}; \qquad (1)$$

$$\frac{dI(x,y,z,t)}{dz} = \left[g(x,y,z,t)-\alpha\right]I(x,y,z,t)-\gamma I^2(x,y,z,t); \qquad (2)$$

$$g(x,y,z,v,t) = n^*(x,y,z,t)\sigma(v). \qquad (3)$$

Where I is the intensity of the light; $g(x, y, z, t)$ is the gain coefficient of the working medium; α, γ are the related constants; $n^*(x, y, z, t)$ population inversion density; $\sigma(v)$ the stimulated emission cross section.

The principle of the timeshare quenching method to compress the ASE pulses can be described as follow. In the amplifier, the Reversal particles were consumed by the amplification of the ASE pulses. So the gain was reduced. In the process of the aimed ASE pulses (the output compressed ASE pulses) transmission amplification, a few injected ASE pulses (come from its own amplifier or other amplifier) were employed to increase the consumption of the Reversal particle number. In the period of the pulse overlap, the gain rapid decrease, and the amplification of the aimed ASE pulses were suppressed so that the pulses compression were obtained.

For shorter the compressed ASE pulse width and higher stability, It required to control the relative delay and the injected pulse energy. The smaller relative delay, the shorter the rising edge of the pulse waveform. The energy of the injected ASE pulse is inversely proportional to the fall time of the output ASE pulse. If the above two conditions are satisfied

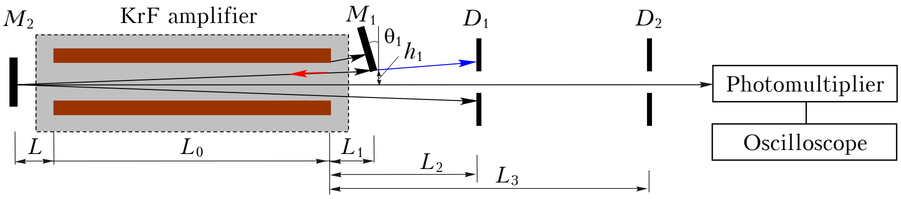

Fig. 1. The experimental schematic

in the same time, the width of the compressed ASE pulse will shorter.

2. Setup of the experiment

The experimental setup is shown in Figure 1 M_1 and M_2 are the totally reflecting mirrors; θ is the adjusting deviation angle of M_1; h is the distances between M_1 and the main optical axis. Removing the front mirror of the excimer laser, the ASE pulses output. Part of the ASE pulses reflected by the M_1, oscillate severally between the back mirror and M_1, consume a lot of inversion population. It suppresses the successor part of the gains, and compressed the ASE pulse. The diaphragms are spatial filter. The photomultiplier is used to receive the compressed ASE pulses. The waveform data are collected by the oscilloscope.

The main factors to effect the pulse compression are θ and the apertures r_1, r_2.

3. Experimental results and analysis

Before the ASE pulse compression in experiment, the reflecting mirror of the laser resonant cavity is removed. The ASE pulse waveform before compression is shown in Figure 2. Its rising time is 5.86 ns, and the pulse width is 12.5 ns.

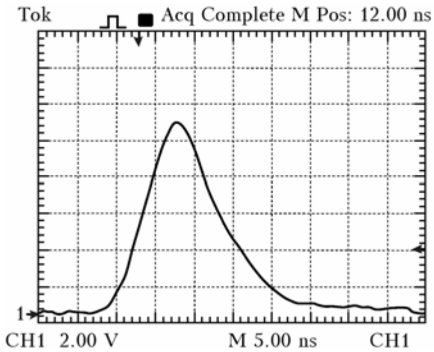

Fig. 2. Waveform before compression

3.1. Influence of θ on the pulse compression

When r_1 = 4.0 mm, r_2 = 4.0 mm, the range of θ is from 2.0 to 5.0 mrad, the outputs of the ASE pulse are shown in Figure 3 are respectively corresponded to 2.0, 3.0, 4.0, and 5.0 mrad of θ. The correspondded pulse widths are 5.3, 5.0, 5.2, and 6.4 ns. When

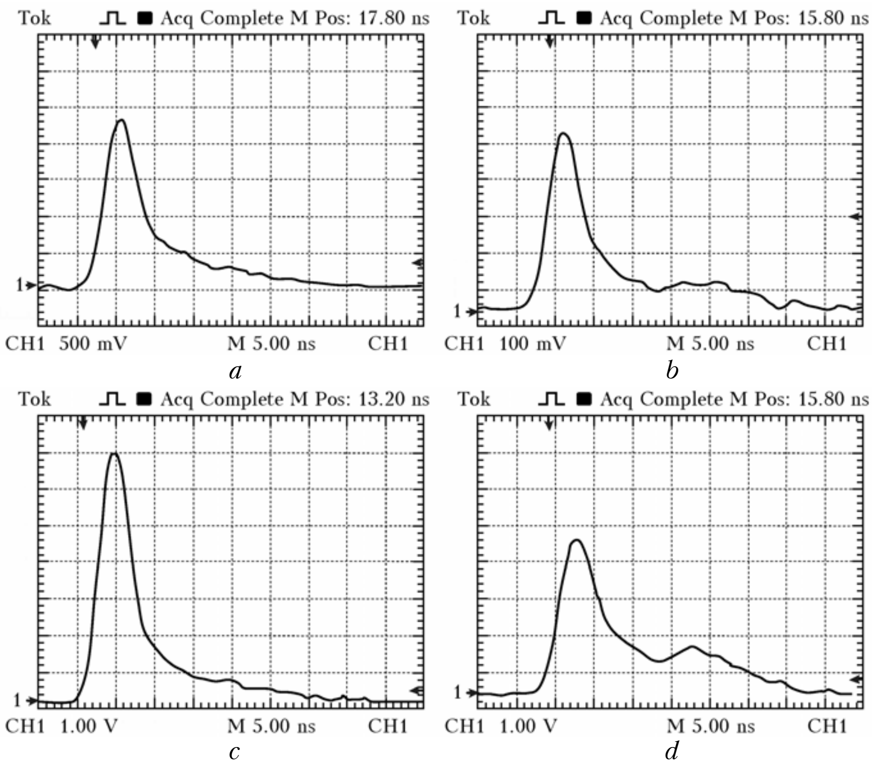

Fig. 3. The ASE pulse waveform θ for different values of pulse compression

θ = 3.0 mrad, the compression effect is best, the pulse width is most narrow, the falling edge of the waveform is more precipitous.

When θ is small, the direction of propagation of the pulse reflected by M_1 is smaller than deflected main optical axis. It is difficult to completely filter by the diaphragm so that the width of ASE pulse was broadened. When θ is large, the pulse reflected by M_1 oscillated less in power chamber. Quenching is not completed; finally the falling edge of ASE pulse is relatively slowly. Based on the above, θ = 3.0 mrad is selected.

3.2. Influence of r_1 on the pulse compression

When θ = 4.0 mrad, r_2 = 4.0 mm, the compressed ASE pulses with different r_1 are shown in Figure 4, *a–d* are respectively corresponded to 2.0, 4.0, 6.0, 8.0, and 10.0 mm of r_1. The corresponded pulse widths are 5.0, 5.0, 5.3, 5.2 and 10.5 ns.

The increase of r_1 increases the proportion of stray light, broadening the ASE pulse width. When the r_1 is large enough, bimodal of ASE pulse waveform appears. When the r_1 decreases, energy of the ASE pulse decreases. The spot shape, energy and pulse width have a significant impact by the diaphragm 1. Based on the above, r_1 = 4.0 mm is selected.

3.3. Influence of r_2 on the pulse compression

When θ = 3.0 mrad, r_1 = 10.0 mm, the influence of r_2 size on pulse compression is analyzed. The proportion of the stray light changing with the size of r_2 is shown in Figure 5.

When θ = 3.0 mrad, r_1 = 10.0 mm, the influence of r_2 size on pulse compression is analyzed. The proportion of the stray light changing with the size of r_2 is shown in Figure 5. The first peak is noted as A_1. The second peak is noted as A_2. The proportion of the stray light changing with the size of r_2 is shown in Table 1.

Table 1

Analysis of stray light

r_2, mm	4.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00
A_2/A_1	0.38	0.47	0.59	0.66	0.73	0.77	0.80	0.84

The increased r_2 increases the proportion of the stray light, and deteriorated the waveform of the ASE pulse. The decreased r_2 is benefit to obtain well compressed ASE pulse. Taking into account the energy of the compressed ASE pulse, r_2 = 6.0 mm is selected.

Considering the energy, pulse width and waveform of the compressed ASE pulses, the related

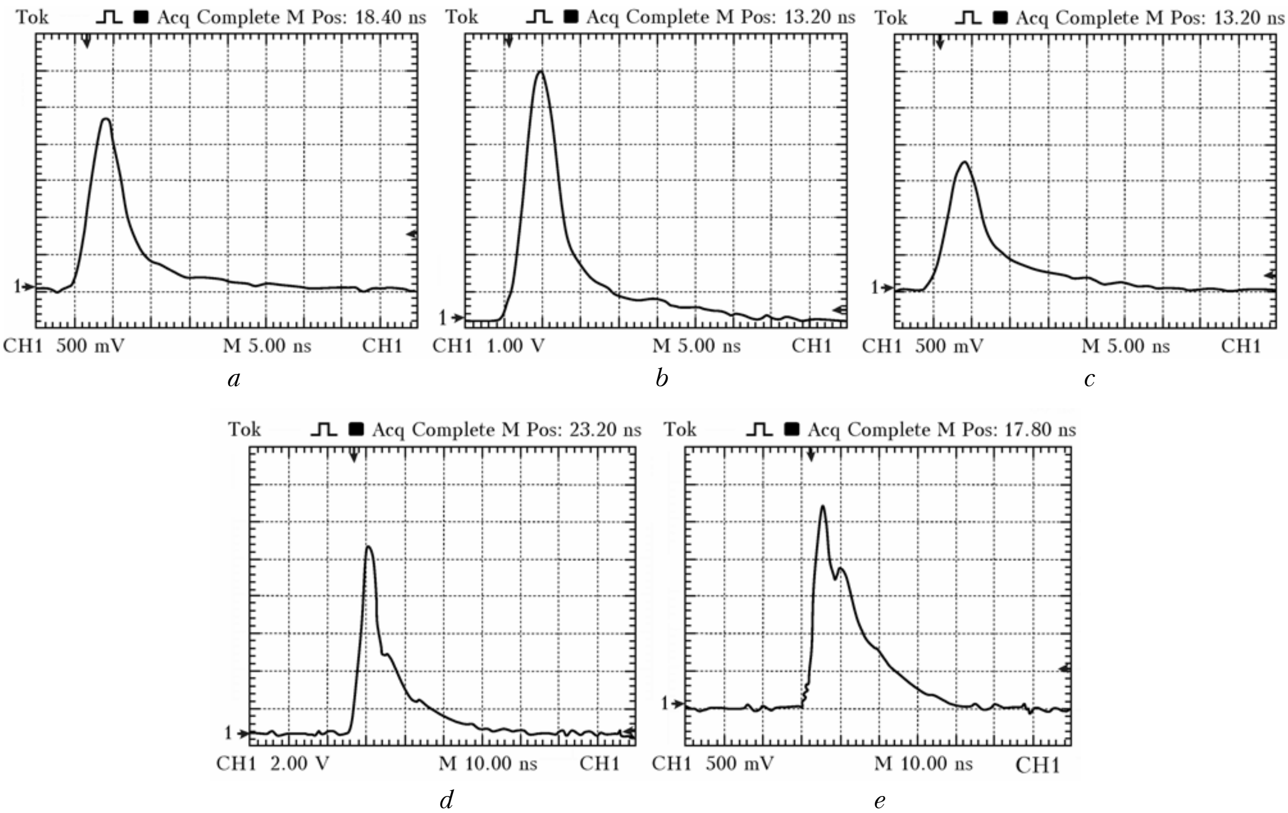

Fig. 4. The ASE pulse waveform r_1 for different values of pulse compression

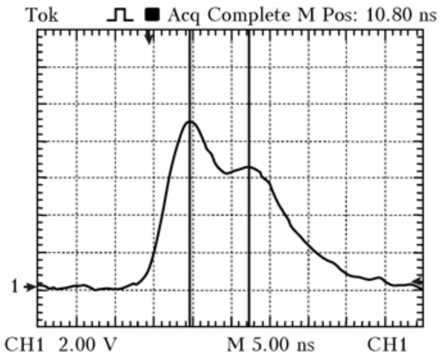

Fig. 5. The compressed ASE pulse waveform

parameters are selected as follows: $\theta = 3.0$ mrad, $r_1 = 4.0$ mm, $r_2 = 6.0$ mm, $L_0 = 732.2$ mm, $L_1 = 362.0$ mm, $h = 1.0$ mm, $L_2 = 549.2$ mm, $L_3 = 1353.8$ mm, and $L = 25.0$ mm. The output ASE pulse is shown in Figure 6. A 5.1 ns of pulse was obtained.

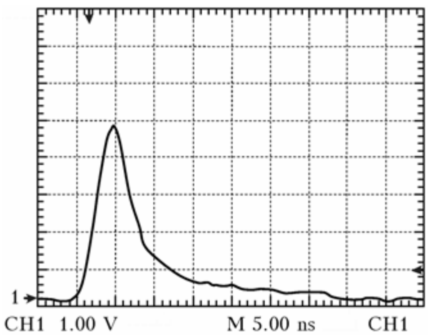

Fig. 6. The compressed ASE pulse waveform

Conclusion

The method of time-sharing quenching was proposed to compress the KrF excimer amplifier ASE pulses in this paper. Short pulses of 5.1 ns were obtained from the 12.5 ns oscillator output. The experimental results show that it can be effectively compressed the ASE pulse. This is a simple and effective method to extend to the other UV preionization discharge pumped gas laser.

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