The 3rd OPCPA system in the LFEX laser

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INTRODUCTION

The heating laser of 10kJ/10ps/1.06μm (Laser for Fusion Experiment: LFEX) for FIREX-I (Fast Ignition Realization Experiment) is required in order to demonstrate heating of imploded high density plasma to the ignition temperature. The LFEX will be completed in 2008. After the completion of LFEX, the foam cryogenic cone shell target experiment will start in 2008.

The LFEX laser is composed of 4 sector-shape beams and is aimed to establish more than 12 kJ in totality with pico-second pulse duration that is to reach 10 PW laser power. In such an ultra high intense laser, the chirped-pulse amplification (CPA) technique is usually used. When generating a plasma, we have to reduce the pre-pulse, that means improving the contrast to the main pulse, and we also have to minimize the gain narrowing effect from gain media in amplifier chain. An optical parametric CPA (OPCPA) system is very useful and commonly used to solve above problem.

In this paper, we describe the 3rd OPCPA system in LFEX laser.

BASIC CONCEPT IN USING OPCPA TECHNIQUE

There are two reasons why we use the OPCPA technique to get a high intense laser pulse.

1) Since the OPCPA technique shows the wide (about 30 nm) and flat-top gain characteristic curve in wavelength region, the gain narrowing phenomenon is not occurred in a nonlinear optical crystal as seen in a Nd:glass amplifier. Therefore, the pulse retains the spectral shape after the amplification, that means the pulse duration is also kept.
2) As the seed laser pulse is amplified in a nonlinear optical crystal only when the pumping laser during several ns passes through the crystal, the OPCPA technique can reduce the relative intensity of a pre-pulse that is usually generated by mode-locking laser oscillator. The recent study [1,2] shows that the contrast between a pre-pulse and a main pulse is less than 10^{-8}.

Above two reasons are very important for the inertial fusion energy research and the high dense plasma research. Of course, it is difficult to construct such a big laser system by only using OPCPA system. However, we can reduce the gain narrowing by increasing the pulse energy as much as possible.

GUIDELINE FOR DESIGNING 3rdOPCPA SYSTEM

The characters of present oscillator systems, the broadband Nd:glass oscillator, the 1st OPCPA, and the 2nd OPCPA, are listed in Table 1. The chirped laser pulse is delivered to 3rd OPCPA system about 40 m from the 2nd OPCPA through the many optics, such as, special filter, polarizers. After amplified by 3rd OPCPA, the pulse is sent to the succeeding Nd:glass amplifier chain that includes 4-pass amplifier, two RA50 rod amplifiers, and main amplifier of DA400, and then is finally amplified until 3kJ/beam (12kJ in totality).

A measured laser pulse energy reached 3rd OPCPA stage is about 1 mJ with 3 ns of pulse duration and 6 nm of spectral width. The beam diameter is 5 mm at this point, thus, the beam intensity is calculated to be 1.7 MW/cm^2. The maximum pulse energy of a commercially available frequency doubled Nd:YAG laser is 1 J at best and the efficiency of OPCPA system is around 20% [1,2], then the maximum energy of 3rd OPCPA is expected to be 200 mJ. Thus the stable beam pattern is required rather than a high gain operation.

If the output pulse intensity is increasing more than some threshold, the output pulse is influenced by harmonic generation effect, and then the laser pulse produces a dip in special and temporal. According to ref. 1, when an input pulse intensity (pulse energy) is 1.4 MW/cm^2 (130 μJ), the amplified pulse did not show any dip due to harmonic generation in BBO crystal until 300 MW/cm^2 (28 mJ). This is 215 times larger than the input energy.

Therefore, we decided that the maximum gain for 1.7 MW/cm^2 input is set around 100 with the pumping intensity of 300-400 MW/cm^2 from ref.1. As this gain will produce an 170 MW/cm^2 output intensity, the intensity is still lower than 300 MW/cm^2, thus the beam is not influenced by harmonic generation effect.

Of course, the beam pattern of the pumping YAG laser

Table 1 The characters of present oscillator systems

	Broadband Nd:glass oscillator	1st stage OPCPA with a stretcher	2nd stage OPCPA with a stretcher
Pulse duration	150 fs	1.5 ns	3.0 ns
Spectral width [nm]	8	6	6
Peak wavelength [nm]	1053-1055	1053-1055	1053-1055
Pulse energy	~1 nJ	100μJ-1mJ	>10mJ
Repetition [Hz]	100×10^6	6	6
Pumping YAG energy [mJ]	-----	200	500

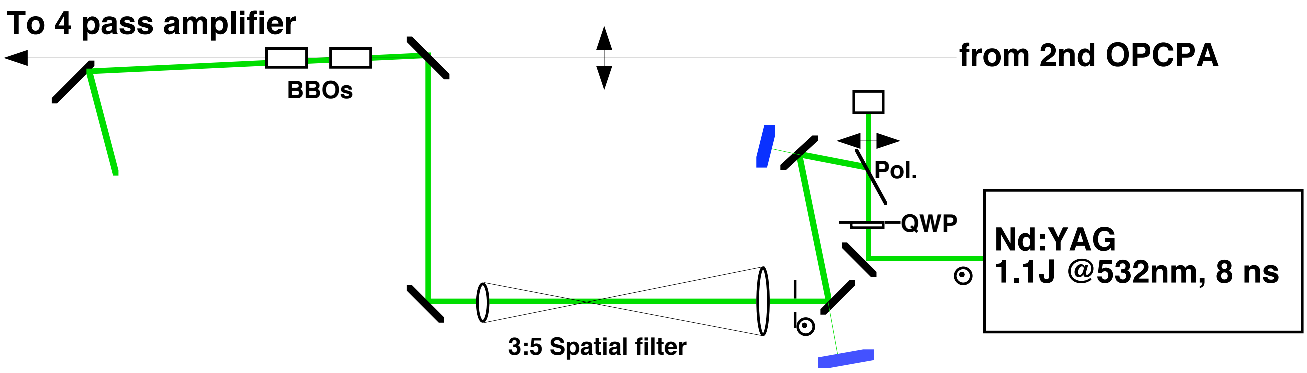

Fig.1 The system layout of 3rd OPCPA in the LFEX laser

should be as smooth as possible.

SYSTEM LAYOUT

The system layout of the 3rd OPCPA system in the LFEX laser is shown in Fig.1. As the diameter of a laser pulse from 2nd OPCPA is 5 mm, the diameter of the frequency doubled Nd:YAG laser is minified to be 6 mm diameter by a special filter with the ratio of 3:5.

We prepared two BBO crystals for the 3rd OPCPA. The crystal sizes are both H(10mm) x W(10mm) x L(15mm) with wedged angle at 2 deg ± 15 min. The cut angles are θ=22.8 deg ±0.5deg, ϕ=90 deg ±0.5 deg (Type I cutting). The both end surfaces are polished at flatness of $\lambda/10$ @633nm. The damage threshold of BBO crystal at 532nm: a-plane ; 8±1 J/cm^2(0.89 GW/cm^2), c-plane ; 20±2 J/cm^2(2.22 GW/cm^2), therefore, the pumping intensity is three times lower than the a-plane damage threshold.

The pumping YAG is Quanta-ray PRO-350 (Spectra-Physics) with an injection seeder and an enhanced spatial mode option. The output energy was measured to be 1.1J/pulse, the pulse duration was 8 ns, and the repetition rate was 6 Hz.

The pumping energy is controlled by a quarter wave plate (QWP) with a succeeding polarizer. Fig. 2 shows the pumping energy on BBO crystal depends on the rotation of the QWP.

The output energy of chirped pulse from the 2nd OPCPA at the 3rd OPCPA system in LFEX laser is shown in Fig.3. The maximum output of 81 mJ is obtained at 225 MW/cm^2 pumping power.

CONCLUSIONS

We designed the 3rd OPCPA system in LFEX laser, and the maximum output energy of 81 mJ is obtained. This system can help to reduce the gain narrowing and to improve that the contrast between a pre-pulse and a main pulse is less than 10^{-8}.

REFERENCES

[1] "Development of a front-end-system for high-intense Nd:glass laser used in optical parametric chirped pulse amplification",.H. Yoshida et al., Rev. Laser Eng., **34** (2006) 174.

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[3] H. Yoshida, "Improvement on the optical devices in high-average-power laser", a doctoral dissertation of Osaka University, January, 1999, p203.

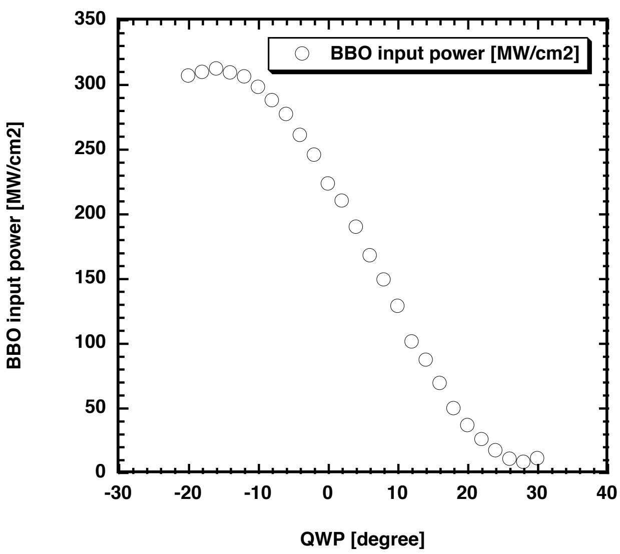

Fig.2 The pumping energy on BBO crystal depends on the rotation of the QWP.

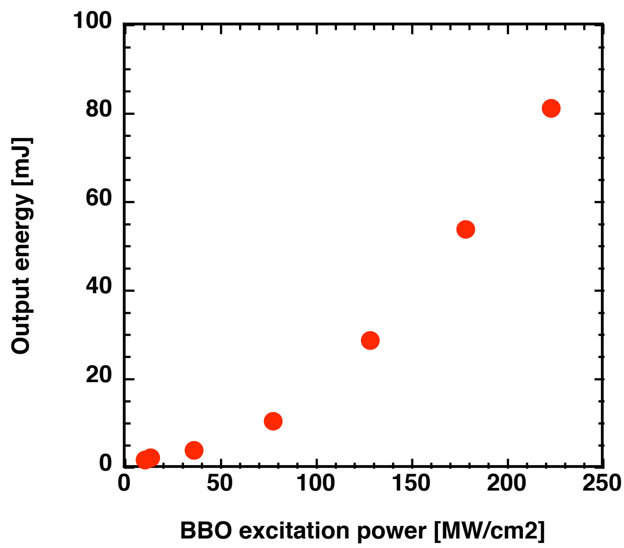

Fig.3 The output energy of chirped pulse from the 2nd OPCPA at the 3rd OPCPA system in LFEX laser