33. Development of LD Pumped 10J×10Hz Nd : Glass Slab Laser System

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As a first step of a driver development for the inertial fusion energy, we are developing a diode-pumped zig-zag Nd: glass slab laser amplifier system which can generate an output of 10 J per pulse at 1053 nm in 10 Hz operation. The water-cooled zig-zag Nd: glass slab is pumped from both sides by 803-nm AlGaAs laser-diode (LD) module; each LD module has an emitting area of 420 mm ×10 mm and two LD modules generated in total 200kW peak power with 2.5kW/cm^2 peak intensity at 10 Hz repetition rate. We have obtained in a preliminary experiment a 8.5 J output energy at 0.5 Hz with beam quality of 2 times diffraction limited far-field pattern.

Keywords: diode-pumped solid-state laser, laser fusion, Nd: glass, zig-zag slab, laser amplifier

1. Introduction

A diode pumped solid-state laser (DPSSL) is a promising candidate of reactor driver [1-3] for Inertial Fusion Energy (IFE). The specifications required for IFE driver are 2 – 5 MJ in output pulse energy, 10 – 20 Hz in repetition rate, 500 – 200 nm in laser wavelength, and > 10 % in electrical efficiency. We have newly designed a DPSSL driver module [4] based on a water cooled zig-zag path slab amplifier, which can deliver 10 kJ output energy at 350 nm with 12 Hz repetition. The module consists of 15 beamlets and each beamlet is a double 4-pass amplifier system as it plays a role of both pre-amplifier (4-pass) and main amplifier (4-pass).

As a first step of a driver development, we are developing a small scale DPSSL amplifier module which has a 10 J × 10 Hz laser output at 1053 nm. The module having a water-cooled zig-zag path Nd: glass slab amplifier has a small but enough size to investigate the key issues and to confirm our conceptual design. It will be shown experimentally that the developed DPSSL module can nearly confirm the conceptual design along with the investigation on the key issues of the IFE driver such as thermal effects, beam quality, energy flow and effeciency in the system.

2. Experimental

Figuer 1 shows the experimental setup. The water-cooled Nd:glass slab thickness and the stored energy density were chosen to be 2 cm and 0.2 J/cm^3, respectively. The zig-zag slab of HAP-4 glass (HOYA, Nd: 1.1 wt. % doped) has the size of 523 (L) ×119 (W) ×20 (t) mm, which also matches to a next 100 J ×10 Hz module. The dimensions of the laser head are 40 cm high, 58 cm long and 37 cm wide. The water-cooled Nd: glass is pumped by the 420 nm × 10 mm laser diode array from both sides through cooling water. The 803-nm AlGaAs laser diodes (Hamamatsu Photonics) to pump the slab amplifier have in total over 200 kW peak power and 2.5 kW/cm^2 peak power intensity at duty cycle 0.2 % (10 Hz) (Fig.2). The oscillator is a CW laser-diode pumped, single transverse-and longitudinal-mode, Q-switched 1053 nm Nd: YLF laser. The single pulse laser energy is 1 mJ at 20 ns. The 10 J ×10 Hz driver module consists of four-pass pre-amplifier and four-pass main amplifier, as shown in Fig.1. To compensate for the thermal lens and the thermal birefringence, a Galilean telescope and a 45 degree Faraday rotator are used, respectively. To reduce the contribution of amplified spontaneous emission, a Pockels cell is adopted. The hard aperture (AA2) is image-relayed using a spatial filter. The laser output is extracted using a combination of thin film polarizer and Faraday rotator.

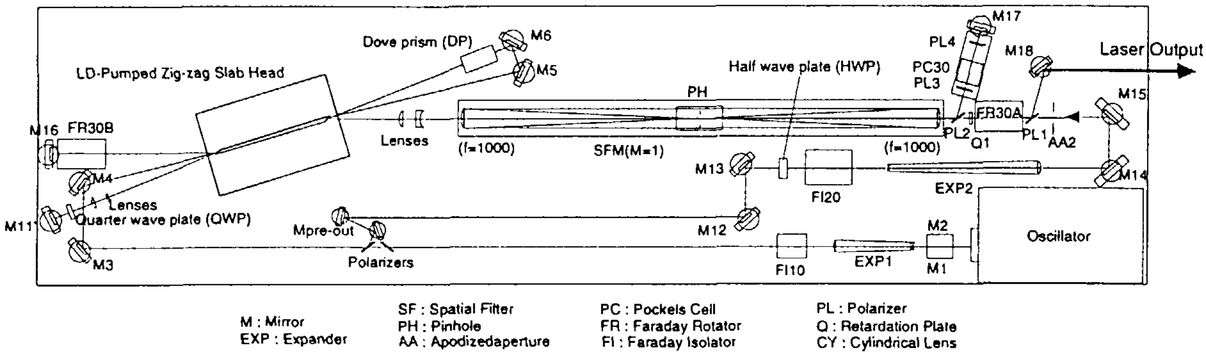

Figure 1. Experimental setup of diode-pumped 10 J ×10 Hz 1053-nm Nd: glass zig-zag slab laser driver module.

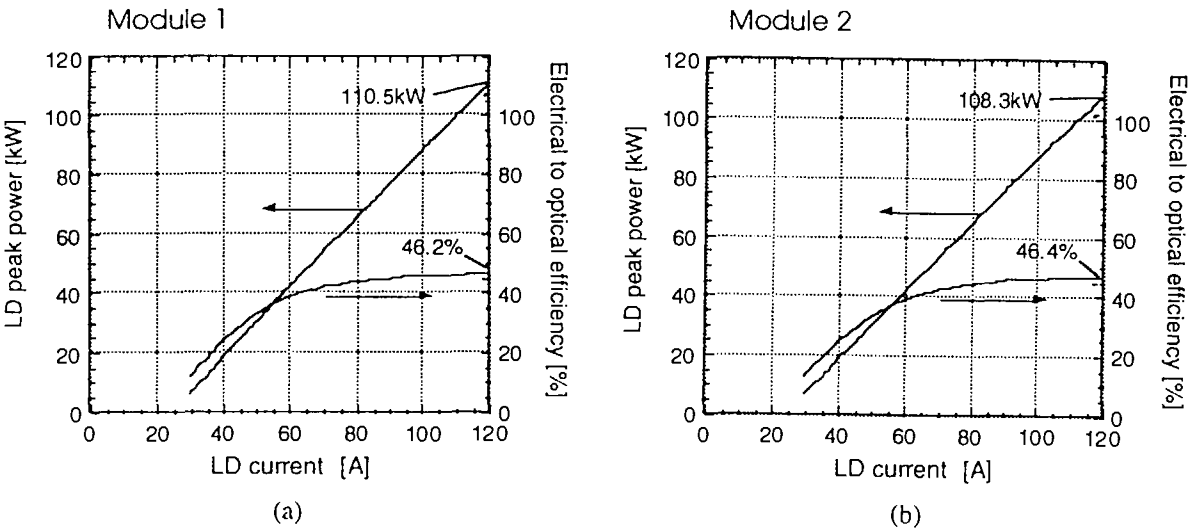

Figure 2. Over 100-kw 803-nm AlGas laser diodes ((a) module1, (b) module2) having 46 % efficuincy, to pump the Nd : glass slab emplifier.

3. Experimental Results and Discussion

The 1053-nm small signal gain of main amplifier was measured to be 15.9 per pass with 0.35-ms LD pumping, which is large enough to have the output over 10 J. The stored energy and pumping efficiency of main amplifier at 1053 nm showing the design points are nearly attained.

The thermal lens effects were measured with horizontal and vertical directions, as shown in Fig. 3. Although the horizontal thermal lensing is completely compensated for due to zig-zag path in the slab, the vertical thermal lens power is proportional to average LD pump power, showing a slope of 0.0052 (1/(m·W)). Extrapolating to 10 Hz operation, the focal length of

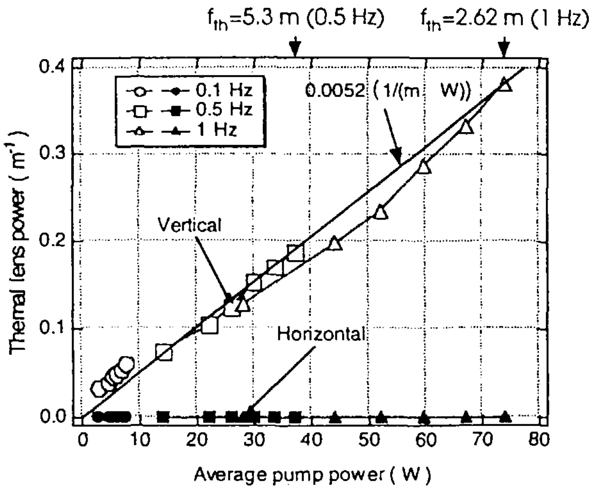

Figure 3. Thermal lens power (1/m) plotted as a function of average LD pump power with horizontal and vertical directions at 0.1, 0.5 and 1 Hz.

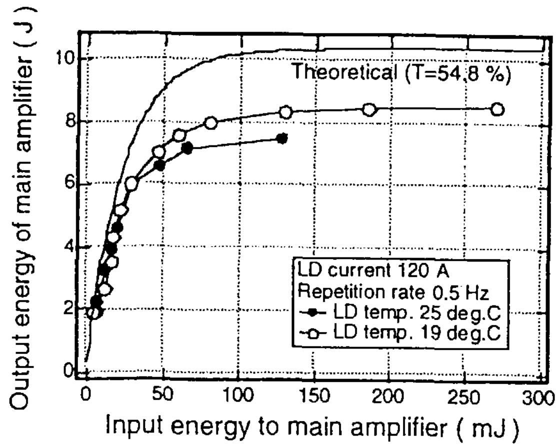

Figure 4. 1053-nm output energy of main amplifier at 0.5 Hz versus input energy to main amplifier at 19 and 25 °C of LD temperatures. Theoretical curve shows that 10 J output is achievable.

thermal lens is estimated to be as short as 26 cm. This thermal lens, however, can be compensated for using two Galilean telescopes set at both sides of the slab.

The 8.5 J × 0.5 Hz 1053-nm output energy was obtained as shown in Fig.4. The extraction efficiency was 24 % in this case. The optical to optical conversion effeiciency was 10.9 %. The output pulse width was measured to be 20 ns (FWHM). The near-field pattern of 20 mm × 10 mm with a filling factor of 50 % and 2 times diffraction limitted far-field pattern were observed.

In Fig.4, the theoretical curve, taking into account the estimated system transmission of 54.8 %, shows that 10 J output can be realized with extraction efficiency of 41 %, although the measured system transmission of 20 % was too low to achieve the 10 J output. This low system transmission of 20 % will be increased to 55 % by reducing the internal bounce numbers from present 14 bounces to 12 bounces, because 14 internal bounces are very near to the critical angle of internal reflection.

The temperature rise of glass slab under LD pumping was measured by means of interferometory, as shown in Fig.5. Extrapolating to the 10 Hz operation, the design point just at the one third of fracture limit will be still in a safety region.

The resistivity of Nd:glass surface against flowing water versus time was evaluated by measuring the scattering loss at 632.8 nm, as shown in Fig.6. After over five months, the scattering loss was as low as 1 % through 14 bounces path with HAP-4 Nd: glass.

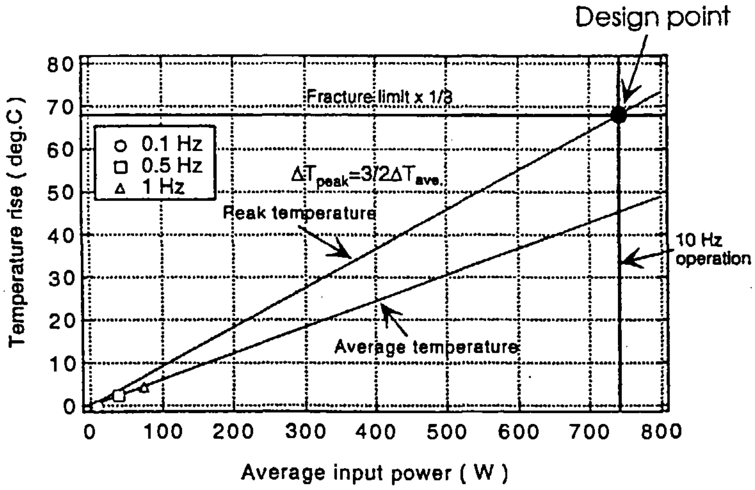

Figure 5. Temperature rise of glass slab versus average LD pump power.

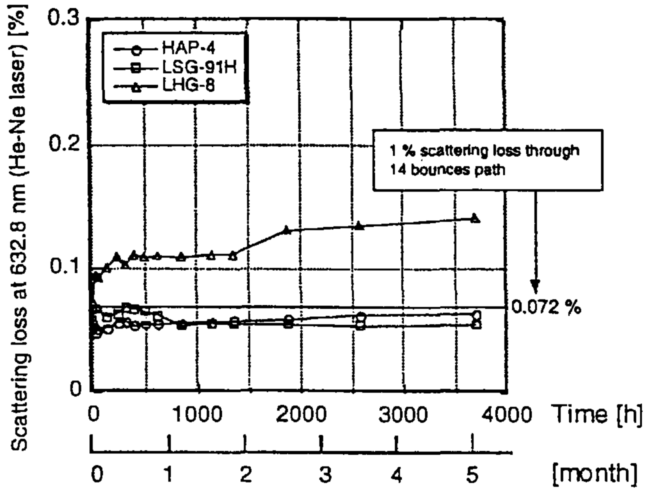

Figure 6. Scattering loss at 632.8 nm with Nd:glass surface under flowing water versus time.

4. Summary

We have designed and constructed a 10 J ×10 Hz, 1053-nm DPSSL driver module for IFE which consists of a water-cooled Nd:glass (HAP-4) zig-zag path slab amplifier. We have obtained in a preliminary experiment a 8.5 J output energy at 0.5 Hz with beam quality of 2 times diffraction limitted far-field pattern, which nearly confirmed our conceptual design[4]. With increasing the system transmission in the multi-path amplification from 20 % to 55 %, the 10 J ×10 Hz output at 1053 nm can be realized by compensating for simultaneously the thermal lens, thermal birefringence, and thermal aberration.

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