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Repeatable DPSS pump laser developments for ultrahigh-average power TW/PW lasers

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Nowadays, the average power of 100 J class diode-pumped solid-state lasers (DPSSL) has been exceed to 1 kW [1]. However, some applications, e.g. particle acceleration, neutron generation, and laser inertial fusion, need a high energy-class DPSSL with a further average power. So, we have started a development of a 10 kW (100 J, 100 Hz) DPSSL based on Yb:YAG ceramics. Using a conductive-cooled active-mirror configuration, it is possible to achieve 100 Hz repetition rate and 100 J pulse energy. Here, we have developed a Yb:YAG active-mirror amplifier system with a large aperture of 50 mm in diameter using a closed-cycle liquid-nitrogen cooling system. Aiming to develop a 10 J, 100 Hz amplifier system, a prototype of active-mirror laser head was tested. By measuring the small-signal gain and the wavefront distortion, it is indicated that the prototype has a high thermal capability that enables 10 J, 50 Hz operation.

Figure 1 shows a schematic of the laser system. The front end for the laser system consists of CW single-longitudinal mode fiber oscillator, EO pulse slicer and cryogenically cooled Yb:YAG regenerative amplifier, which pulse amplified to 2 mJ pulse energy, 10 ns duration at 1029.5 nm. The multi-pass amplifier consisted of cryogenically cooled Yb:YAG single crystal rod. It amplifies the pulses to an energy of 500 mJ at 100 Hz. The beam is then spatially shaped from circular to hexagonal using a serrated aperture and vacuum spatial filter (VSF). A deformable mirror is used for wavefront compensation of the main amplifier. The pulse energy of the main amplifier input is 324 mJ. The main amplifier consisted of four liquid nitrogen cooled Yb:YAG ceramics active mirror laser head. The size of Yb:YAG ceramics is 45 mm in diameter and 7 mm in thickness. The gain media are bonded to the heat sink using a metal solder, and the heat sink is cooled by liquid nitrogen flow. The amplifier was pumped by two laser diodes (940 nm, 50 kW). The 4-passed seed beam is output by thin film polarizer.

The gain media pumped by a total peak power of 81.2 kW in a 0.5 ms at 1 Hz, 10 Hz, 25 Hz, 50 Hz repetition rate and 100 Hz burst mode (10–20 s). The input pulse energy was attenuated to 12.6 mJ. The thermally-induced wavefront distortion was measured by a wavefront sensor, by setting a non-pumping state as a reference wavefront. The temperature of the edge of the gain media and the heat sink were measured with a resistance temperature detector. The small-signal gain was measured with repetition rates of 1–100 Hz. The small-signal gain at 25 and 50 Hz gradually decreased after pumping and became steady after about 30 s. At 100 Hz, the temperature of the gain media increased to ~115 K within 10 s, and the gain was steeply decreased. The total change in wavefront distortion was about 1.2 λ in P-V at 50 Hz and 100 Hz. As a result, the thermal wavefront distortion in single reflection is very small, as low as 0.15 λ in P-V.

By measuring the small-signal gain and the wavefront distortion, it is indicated that the prototype has a high thermal capability that enables 10 J, 50 Hz operation. At 100 Hz operation, however, the small-signal gain was considerably decreased due to the temperature rise of the gain media. Improving the thermal contact between the heat sink and the gain media, 100 Hz operation can be realized. Furthermore, since this active mirror system can be scaled up 100 mm aperture, it is expected that 100 J class system can be realized.

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References

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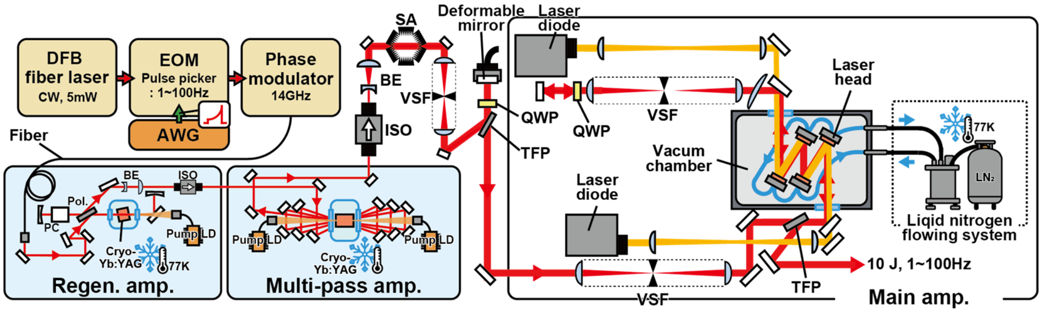

Fig 1. System layout of 10 J class Yb:YAG cryogenically-cooled active-mirror amplification (DFB: Distributed feedback, EOM: Electro-optic moderator, BE: Beam expander, SA: Serrated aperture, VSF: Vacuum spatial filter, TFP: Thin film polarizer).