Multislab Yb:YAG cryogenic gas cooled high average power amplifier delivering 7.4 J at 10 Hz

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Introduction

The next generation of ultra-intense laser facilities, currently being developed in the European projects such as HiPER [1], and ELI [2], require the development of a laser amplifier technology capable of producing kJ-level pulses with nanosecond duration at multi-Hz repetition rate and high wall-plug efficiency. In previous papers we have presented a scalable concept for a diode pumped solid-state laser (DPSSL) amplifier based on cryogenic gas cooled multi-slab Yb:YAG technology with designs capable of generating kJ pulse energies. In order to demonstrate the viability of this concept, a scaled down prototype amplifier, DiPOLE, has been constructed at the Central Laser Facility. DiPOLE is designed to deliver 10 J pulses at 10 Hz repetition rate with an optical to optical efficiency of 25% [3].

In this paper we report details of a recently implemented multi-pass relay-imaging extraction architecture, which includes spatial filtering, allowing up to eight passes through the amplifier head. This has enabled more efficient extraction at higher coolant temperatures, where gain is lower and the impact of ASE is reduced [4], as well as improving the spatial quality of the output beam.

Setup

The amplifier head consists of four ceramic Yb: YAG disks each 55 mm in diameter and 5 mm thick [4]. The current layout of the extraction architecture is shown in **Error! Reference source not found.**. An array of eight 1:1 telescopes are arranged on either side of the amplifier head to relay image the amplified beam back on to itself within the amplifier head using angular multiplexing. Each set of eight telescopes share a single vacuum spatial filter (VSF) tube containing eight individually adjustable pinhole mounts. Space constraints lead to a design; which is folded so that both VSF tubes sit alongside one another on the same optical table. Care is taken to ensure that the path length for each pass is equivalent. The relay-imaging telescopes are formed by a lens array consisting of eight lenses positioned at either end of each VSF tube. The beam is then propagated around the system by a large diameter reflector. Each lens array has a mirror array associated with it for directing the beam through the center of the amplifier or to the next imaging telescope via reflection from a large diameter reflector.

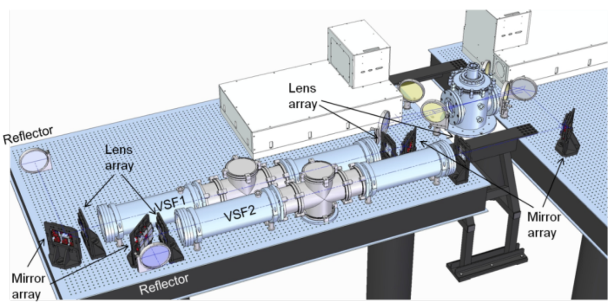

Figure 1 Current layout of the extraction architecture.

Results

Recently, this multi-pass architecture has been used for amplification of ns-pulses at 1030 nm in a six pass configuration, operating at a coolant temperature of 125 K. In this configuration we have measured up to 9.5 J at 1 Hz and 7.4 J at 10 Hz, corresponding to $\eta_{o\text{-}o}$ efficiencies of 24% and 23%, respectively, for seed energies of approximately 20 mJ. The measured dependence of conversion on pulse repetition frequency (PRF) is shown in **Error! Reference source not found.**.

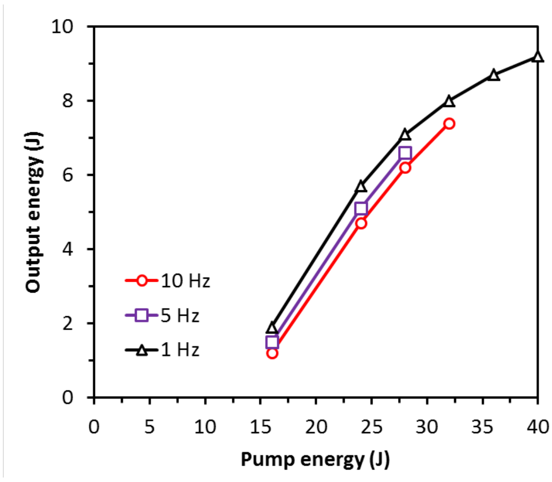

Figure 2 Dependence of 1030 nm output pulse energy on 940 nm pump energy for varying pulse repetition rates at 125K.

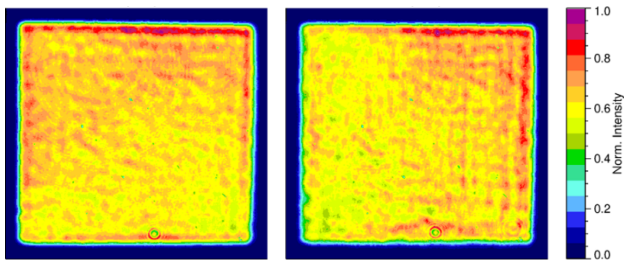

Figure 3 Images of the output near fields at 1 Hz (1.0 ms pump) with an output energy of 9.4 J and also 10 Hz (0.8 ms pump) at an energy of 7.4 J.

Images of the output near field under two different operations procedures are of good quality, taken at 10 Hz and also 1 Hz are shown in Figure 3.

Preliminary assessment of output energy stability has also been undertaken at 10 Hz where stable operation has been achieved for periods of over 5 minutes with a measured rms variation in output energy of 0.7%. Stability was improved to this level by increasing optical isolation between the frontend seed source and the main amplifier through addition of a Pockels cell and several Faraday isolators.

Current plans

We have installed a frontend fiber oscillator and amplifier. This will additionally be able to modulate the temporal profile for SBS suppression. We are also able to modify the temporal input pulse to 120 picosecond resolution to generate a flat top Gaussian at the output. We are currently testing and integrating the system into the front end of DiPOLE.

Conclusions

These results give confidence that the target specification can be reached once greater seed energy is available and round trip losses are reduced further, with the inclusion of two additional passes if necessary.

Acknowledgements

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References

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