Performance of the rod amplifier chain for the 20PW Component Test Lab

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Introduction

OPCPA based laser systems are capable of producing high contrast, high peak power amplification whilst maintaining the large bandwidth required for short pulses of a few tens of femtoseconds. This makes the technology the ideal candidate for future multi-petawatt facilities, such as the proposed Vulcan 20PW upgrade. The Central Laser Facility (CLF) have been at the forefront of this amplification technique, early experiments using large aperture OPCPA crystals [1] demonstrated the scalability of this technology. More recently, we have achieved high contrast intensity of 10^{-10}, seeding the Vulcan using a combination of picosecond and nanosecond OPCPA stages [2]. A component test laboratory is currently being assembled, as the next phase of the Vulcan 20PW project. This laboratory will use the existing 20PW front end to seed a 50mm diameter, OPCPA stage, which corresponds to the booster stage of the Vulcan 20PW laser project. This laboratory will enable us to investigate crystal deuteration levels, damage test optics and new diode pump technology.

Layout

Figure 1 shows the layout of the pump laser and 50mm OPCPA amplifier stage. The pump laser is based upon the Vulcan preamplifiers and is seeded using a shaped long pulse (SLP) ns oscillator. The output of this rod chain is 35J. The beam is then frequency doubled to 527nm and will pump the 50mm OPCPA crystal. The OPCPA amplifier is seeded using the output of the 10PW frontend, located in the laboratory next door.

Due to the 150nm bandwidth of the seed pulse, a chromatically corrected telescope system was designed and manufactured to image relay the 20PW frontend output to the OPCPA stage from the lab next door. The 150nm bandwidth pulse is capable of being compressed to 15fs. Diagnostics monitor near field (NF), far field (FF), calorimetry and spectrum of the pump, seed and idler.

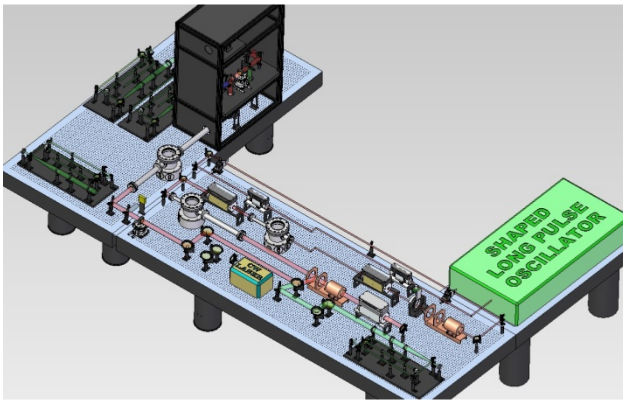

Fig. 1. Shows a CAD drawing of the 400TW OPCPA amplifier stage.

Characterisation of 20J Green Pump Laser

A 22mm type 1 KDP crystal is used to frequency double the 35J infra-red (IR) output of the rod chain to green 527nm. A series of rod shots were taken to characterise the output of the pump laser. Figure 2 shows a graph of the conversion efficiency of the KDP crystal. For IR shot of 30J and greater, a conversion efficiency of 58% or more is achieved, some shots as high as 63%. This shows the CTL is capable of pumping the OPCPA stage with 20J of green energy.

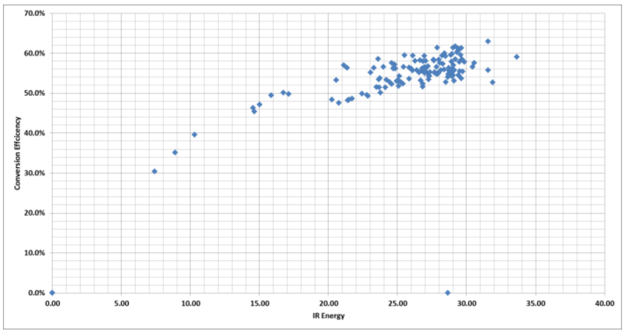

Fig. 2. Conversion efficiency vs. IR energy of the CTL pump laser.

Initial Tests and Phase Matching 80% Deuterated KDP

Initial tests were carried out using a 50 x 50 x 64 mm DKDP crystal, 80% deuteration, pumped using the CTL pump laser. To find a good starting position of the angular tuning of the crystal, a cylindrical lens was placed in the pump beam to increase the angular spread. The NF images of the DKDP crystal were monitored as the crystal angle was tuned. Figure 3 shows the point at which the phase matching was achieved. The spread of angles cased a visible stripe in the NF image corresponding to the narrow phase matching acceptance angle, 0.01 degrees. This result was used as the starting position for a more precise tuning scan.

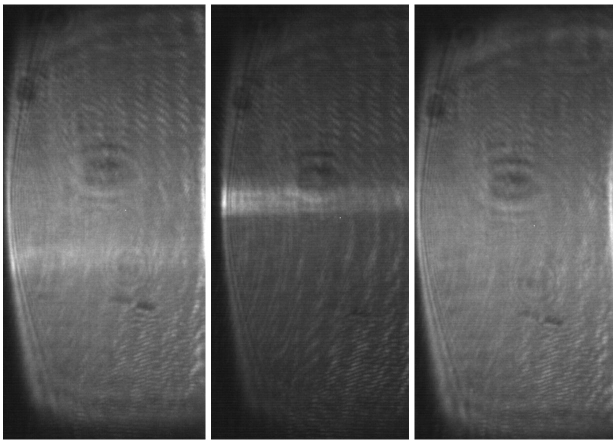

Fig. 3. Three NF images showing the phase matching scan. Left and middle image show a narrow stripe corresponding to 0.01 degree acceptance angle. Image on the right shows the NF after precise tuning.

OPCPA in 80% DKDP

After finding the phase matching angle, the seed beam was sent through from the 20PW front end. The signal had 40 nm bandwidth centred at 940 nm and was injected collinearly with the 16J green pump beam into the DKDP crystal. The signal was amplified from 40mJ to 0.9J maintaining the 40 nm bandwidth, shown in figure 4.

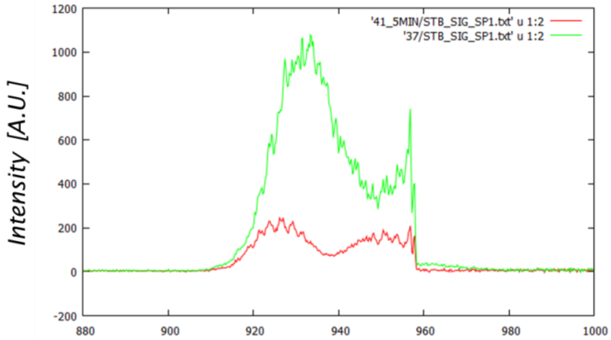

Fig. 4. Seed beam from 20PW front end (red). Amplified seed using OPCPA in 80% DKDP (green).

Conclusion

The CTL OPCPA pump laser was fired and 20J of green, 527 nm, was achieved at 59% conversion efficiency. This was used to initially find the phase matching angle of 80% deuterated DKDP, and then achieved OPCPA using a seed beam, 40 nm bandwidth centred at 940 nm, in collinear alignment. The seed beam was amplified from 40mJ to 0.9J and the full bandwidth was sustained. Though this is not the full 150nm output from the 20PW front end, it suggests that it should be possible to amplify the full bandwidth using a non-collinear geometry.

References

1. O.Chekhlov et al. Optics Letters, Vol. 31, Issue 24, pp. 3665-3667 (2006)

2. I. Musgrave et al. Applied Optics, Vol. 49, Issue 33, pp. 6558-6562 (2010