A stable ultra-broadband OPG/OPA source for the testing of 20 Petawatt Optical Parametric Chirped Pulse Amplifiers

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Introduction

A LBO based OPG/OPA source is demonstrated with an energy exceeding 90mJ with a 6% RMS energy stability and tunability of 300nm between 750 to 1050nm. This novel source will facilitate the testing of MultiPetawatt OPCPA amplification schemes**.**

Background

There is growing interest in the development of optical chirped pulse amplification (OPCPA) laser technologies for Multi-PW applications. Suitable seed sources are needed to enable the evaluation of the performance of these systems. Especially those systems being developed based on KD*P such as the Vulcan 20PW laser upgrade which aims to generate 20fs pulses with over 400J of energy. It has been shown that for KD*P based systems the deuteration level plays an important role in the bandwidth and centre wavelength of the gain bandwidth [1]. In this paper we report on the demonstration of a novel seed source capable of being used to characterize the properties of crystals of KD*P with different deuteration levels. This characterization and the characterization of any large aperture (>20mm diameter) OPCPA crystals requires an ultrabroad bandwidth source with of tens of mJ energy. Optical parametric generation (OPG) sources are typically generated using mJ level femtosecond pulses which when combined with self-phase modulation can result in extreme spectral broadening [2][3]. However these would typically require stretching and further amplification to achieve the required energy and pulse duration compatible with large aperture OPCPA.

2. Optical Layout and Results.

We have opted for a simpler approach to directly generate a seed pulse with a suitable pulse duration and energy. A schematic of our scheme is shown in figure 1. We have built a singly resonant cavity around a 38mm long LBO crystal with high single pass gain in excess of 10000. This crystal is pumped by a pulse with 450mJ in 3ns in a 4mm diameter beam. The cavity length is such that the OPG makes 3 round trips during the pump pulse duration. The cavity is formed simply using an output coupler (which is AR coated at 532 nm) and a high

reflectivity broadband mirror and results in an output exceeding 30mJ. The transmission curve of the output coupler is shown in figure 2. The centre wavelength can be tuned by varying the phase matching angle of the crystal and a broadbandwidth is achieved using a non-collinear geometry.

We then use a double crystal LBO OPA stage for further amplification. We optimize the beam profile before the second stage of amplification by adding an air spatial filter (100 µm pinhole), in which the beam expands to 1 cm diameter. After being spatially filtered we maintain the spectrum but the energy is reduced to 10 mJ. The OPA amplification stage after this is constituted by two 13mm thick LBO crystal pumped by 1.5J of energy at a fluence of 1.9J/cm$^{2.}$ This dual stage arrangement enables the generation of a broad bandwidth by offsetting the respective non-collinear angles (~2.1deg). At the output we obtain an energy of 90mJ, with a stability of 6% rms (over 10000 shots). We have demonstrated a tuning range of 300 nm from 750 to 1050 nm as shown in figure 3. All LBO crystals are configured for Type I phase matching, the generated optimum full width bandwidth at a 10% level of 150nm. Figure 4 demonstrates how the phase matching angle in the second stage for the 2 crystals can be optimized for different wavelengths to achieve a broad bandwidth. Figure 5 shows the output nearfield profile of the seed source demonstrating good uniformity across the beam.

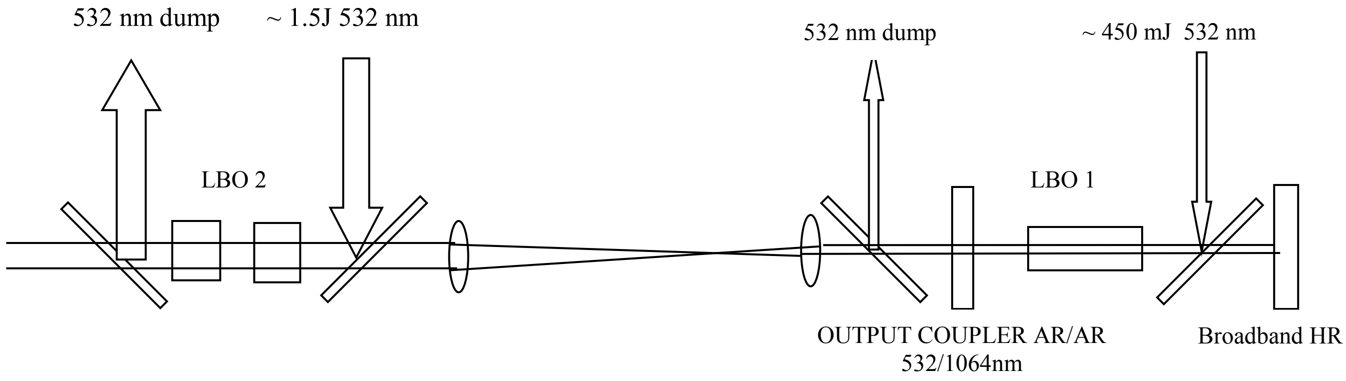

Fig. 1 - OPG/OPA optical scheme

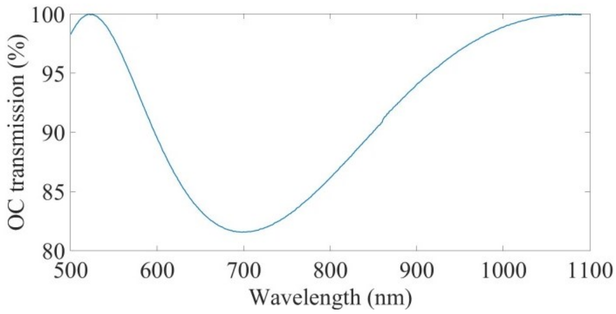

Fig. 2 - Output coupler transmission profile

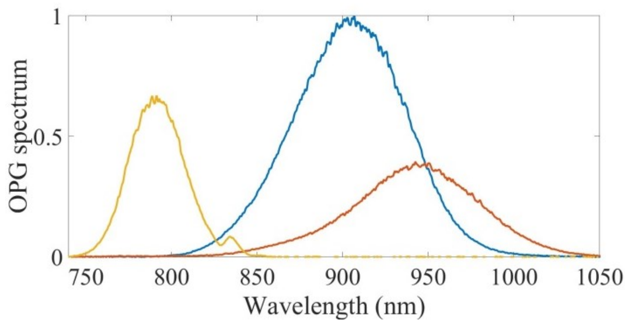

Fig. 3- 3 OPG spectra, centered at 790, 910 and 950nm obtained by changing the phase matching angle**.**

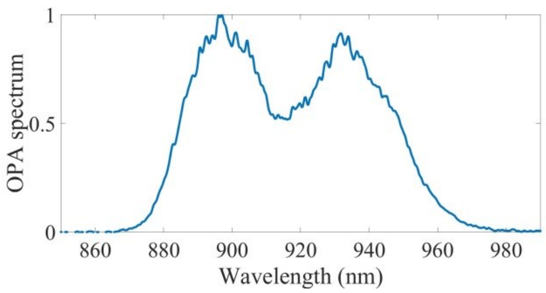

Fig. 4 - An optimized spectral output obtained with non-collinear optimization of the dual stage LBO. The two gain peaks are equivalent to the optimum phase matching for each one of the crystals.

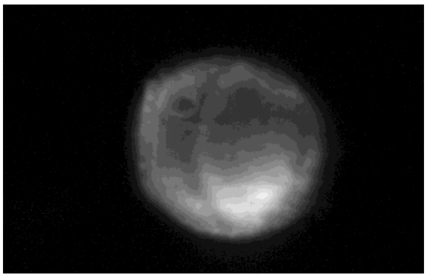

Fig. 5 – Characteristic OPA near field profile

Using the current source, we have obtained broad bandwidth gain in KD*P, which will be a crucial element in large aperture OPCPA. This will be pumped by a frequency doubled > 30J 3 ns pump source generated using Nd:glass amplification chain seeded by a RAL build temporally shapeable 3ns, 1mJ pulse [4].

4. References

[1] M. Galimberti, C. Hernandez-Gomez, I. Musgrave, I. Ross and T. Winstone, 'Influence of the deuteration level of the KD*P crystal on multi-PW class OPCPA laser.' Optics Coms. **309,** 80-84 (2013)

[2] M Breuer, C Homann and E Riedle. Ultrafast PhenomenaXV1: Proceedings of the 16th International Conference, Italy June 2008.

[3] http://www.photonicsolutions.co.uk/product-detail.php?prod=6042

[4] I. Musgrave, A. Boyle, A. Frackiewicz, M. Galimberti, S. Hancock, C. Hernandez-Gomez, P. Oliveira, D. Pepler, I. Ross, W. Shaikh, T. Winstone, A. Wyatt and J. Collier 'Development of OPCPA Technologies for Multi-PW Applications.' Proceedings of ICUIL conference 2014, GOA, India