10 PW front-end characterisation

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Introduction

We report progress made on the new front-end development for Phase 1 of the Vulcan 10 PW OPCPA upgrade project [1] over the last year. It is based on the previously reported two stages of broadband (~140 nm FWHM) seed pulse generation centered at 910 nm [2-4] for our system using mJ OPA and its further amplification at J level OPA [5] using LBO crystals. In the latter a narrowband temporarily shaped seed pulse was used to prove feasibility of our front-end. This time both stages have been combined and the evolution of the broadband pulse through our system was studied. Additionally the pulse compression was tested together with a preliminary contrast measurement. Besides DKDP crystal test as a gain medium for future large scale OPA was made.

Multi-stage OPCPA outcome

A broadband laser pulse required for our system has been obtained as the idler of the last stage of the three stage mJ pumping OPA process using LBO crystals. Evolution of the seed spectrum on these three stages is demonstrated in Fig.1, where the final pulse output is centered at about 910 nm, 7 ps in duration with energy ~ 50 μJ and supporting ~140 nm FWHM. This pulse is further stretched to 1.87 ns using a double pass stretcher [5-6] and seeds two J level pumping OPA stages using LBO crystals.

The pump laser for J level OPA stages produces 4.5 J pulses at 532 nm and 2 Hz repetition rate having square temporal profile and spatial top hat profile delivering 3 Jcm^{-2} pump fluence on each crystal. The OPA process is a non-collinear type-1, where the seed and idler have the same polarization (set as P) and the pump is orthogonal to this (set as S). The amplification process involves two stages using 19 mm long LBO1 and 13 mm long LBO2 crystals respectively for each stage. The interacting beams size is about 2 mm in diameter on the LBO1 and 9.5 mm on LBO2.

The maximum small signal gain (SSG) on stage 1 of the J level OPA was detected at ~100, although it was expected to be few times higher. In order to improve the gain value the spatial overlap between the pulses was improved along with the crystal length. First, the pump diameter was increased to 4 mm, keeping the same fluence, and second, an additional crystal, identical to LBO1, was mounted as demonstrated in Fig.2. As a result the SSG was sufficiently improved to ~400 for each crystal and giving over 50 mJ output seed energy at this stage. This pulse was further amplified in stage 2 of the J level OPA getting close to the expected SSG value of ~40 and generating over 0.35 J of output energy.

Evolution of the amplified pulse spectrum on the J level OPA stages is shown in Fig.3. Spectral loss of the input seed is due to the limitation by the gratings size of the stretcher. Further loss in spectra of the amplified pulse is caused by limitation of currently used broadband mirrors, although providing ~100 nm bandwidth of the output pulse spectrum.

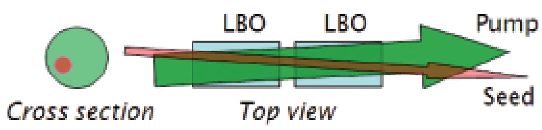

Figure 2. Double crystal arrangement at stage 1 of J level OPCPA.

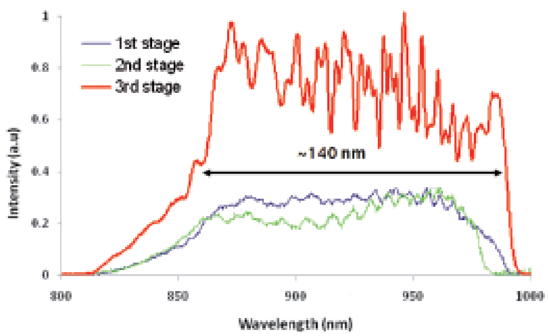

Figure 1. mJ level OPCPA output pulse spectra.

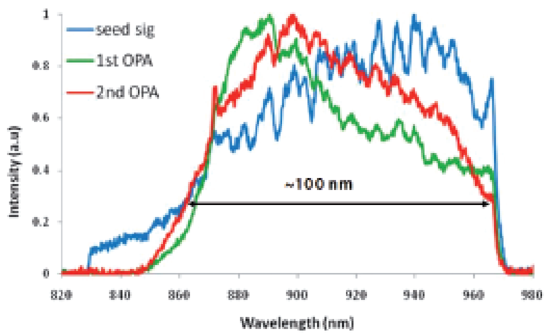

Figure 3. J level OPCPA output pulse spectra.

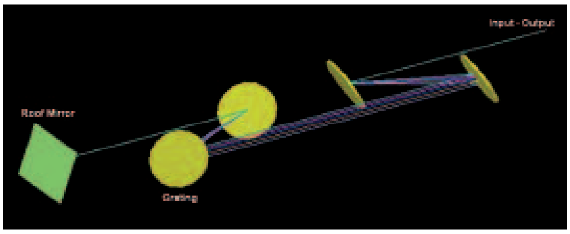

Figure 4. Schematic of the compressor.

Pulse compression

To test how compressible our amplified pulse is, the output beam from the Joule level OPA stages was aligned through a temporary compressor. A schematic of the compressor is demonstrated in Fig.4. Four gold gratings with 1480 l/mm are used in the compressor at Littrow in an out of plane design. It is double passed using a roof mirror to displace the beams on the return path. We were able to compress our pulse down to lower than 30 fs using a FROG for measurements as shown in Fig.5. Preliminary contrast measurements have been taken using SEQUOIA and demonstrating 10^7 at 40 ps. Currently we are working on optimisation of the whole system and improvement of the contrast value. In particular, we are going to increase our initial amplified output seed energy from mJ OPA stages by building up an additional multi-pass Ti:Sapphire amplifier giving more pump energy for the last stage. This amplifier is described in a separate report promising to deliver 1 mJ total output pulse energy from the mJ OPA stages.

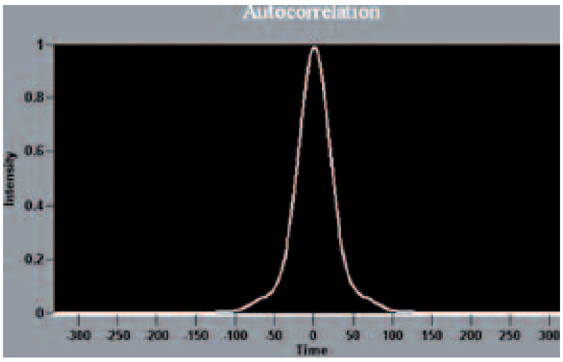

Figure 5. Autocorrelation trace of the final compressed pulse.

DKDP test

Two large DKDP crystals will be used for the kJ level OPCPA amplification in Phase 2 of the project. It was decided to test a small 20×20×30 mm DKDP crystal by replacing the second LBO crystal with it in the J level OPA stages. It demonstrated SSG of about 7, which was lower than expected, but showed amplification within the whole range of available spectrum ~100 nm as presented in Fig.7.

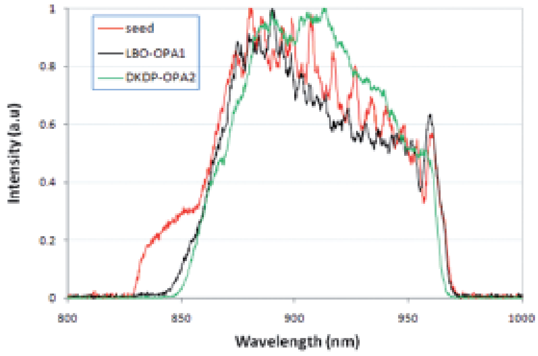

Figure 6. Output spectra of J level OPCPA using DKDP crystal.

Conclusions

In conclusion, we have built up a new front-end as part of Phase 1 of the Vulcan 10 PW OPCPA upgrade project. It is capable of delivering sufficient output pulse spectral bandwidth and energy for seeding the rest of large OPCPA stages of Phase 2 in the future. We have demonstrated promising compression of the final pulse down to sub 30 fs. We are currently working on final front-end optimization to achieve better results and turning the front-end into a day to day facility.

References

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