Development of the Joule level amplification stage for the Phase 1 of the Vulcan 10 PW OPCPA project

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Introduction

Work on Phase 1 of the Vulcan 10 PW OPCPA project [1] has been arranged as two simultaneously organized activities over the last year. It has involved generating an ultra broad band (~180 nm), >100 µJ, ~1 ps seed pulse centered at 910 nm by mJ pumping [2,3] and its further stretching together with Joule level amplification. Here we discuss the development of the stretcher and the amplification schemes. We also present preliminary results of gain measurements for the system.

Seed pulse stretching

The seed stretching is obtained by using a double pass stretcher [4]. Schematic of the stretcher and the seed pulse injection is presented in figure 1. It consists of two gratings with a grove density of 1200 lines per mm, focusing mirror f = 500 mm and back reflecting mirror providing the double (in and out) pass through the stretcher. The operation condition for our experiment requires a four pass stretcher layout to be arranged. This is achieved by setting up a cavity of a lens and a mirror sending the double passed stretched pulse back to the stretcher for the second pass. The control of the pulse injection to the stretcher, its propagation through the cavity and the final output pulse pickup is achieved by polarization change provided by combination of Faraday isolator, half wave plates, cube polarizer and the Pockels cell. The input and output beam diameters are around 3 mm.

Whilst the work was carried out on developing an ultra broad band seed pulse, a Coherent Mira laser was used for the alignment as a temporary seed. It generates mode-locked train of 190 fs pulses at 75 MHz with about 15 nm FWHM, which can be tuned from around 820 to 950 nm and is currently set up at 910 nm.

The stretcher was aligned on the double pass with about 60 % efficiency demonstrating good support of the specified range of wavelengths. The duration of the stretched pulse was measured at about 90 ps, which is in good agreement with calculated theoretical predictions.

The required four passes through the stretcher have been achieved with this layout, delivering 3 ns pulses at ~180 nm bandwidth centered at 910 nm. However, it was found that the Faraday isolator clipped the stretched pulse due to its small aperture and has had to be replaced with larger one. Meanwhile, our work was carried out using the stretcher on double pass without the cavity.

A beam line has been aligned for the output stretched pulse to the Joule level amplifier involving a combination of lenses resulting in about 3 mm seed diameter for the first stage of amplification.

Joule level amplification system description

The Joule level ampler layout is shown in figure 2. The pump laser has been commissioned for the Joule level

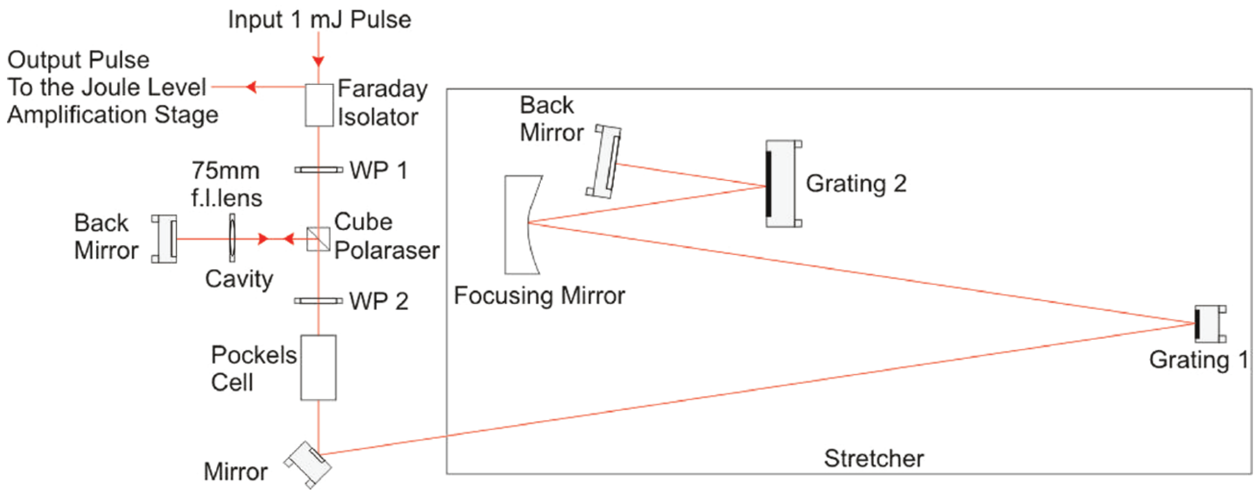

Figure 1. Stretcher injection.

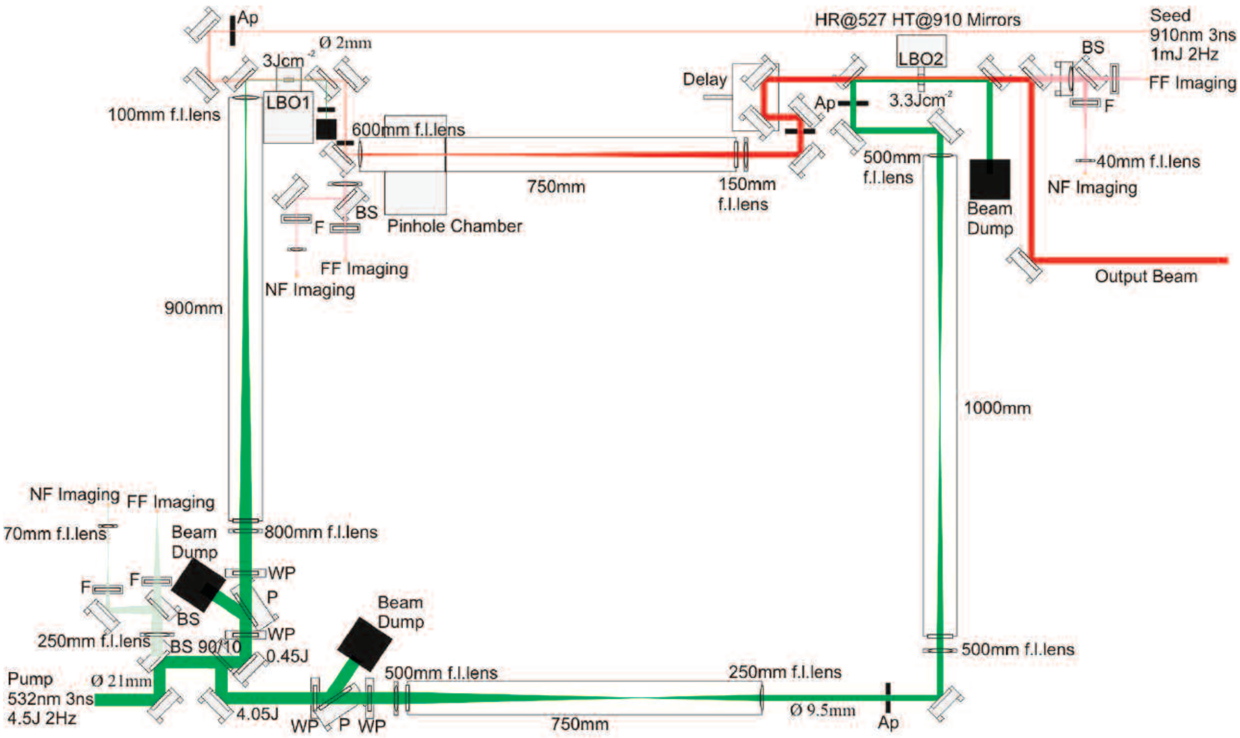

Figure 2. Joule level amplification layout.

OPCPA amplification stages and delivers 4.5 J pulses at 532 nm and a 2 Hz repetition rate with top-hat spatial and temporal profiles. 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 crystals have been placed into electrically heated metal ovens mounted on 4-axis stages. The pump beam line has been built up involving three vacuum telescopes to provide collimated and image relayed beams of about 2 mm in diameter on the LBO1 and 9.5 mm on LBO2. The undepleted pump beams are dumped after each crystal.

Half wave plates, polarisers and beam dumps have been arranged to provide the pump energy control for both stages of amplification. A procedure of setting them up was realised to deliver 3 Jcm^{-2} pump fluence on each crystal.

Synchronization of the pump laser trigger with the seed oscillator's RF signal was achieved using Bergman PC cards. This PC card also provides adjustable delay to set appropriate timing between the interacting pulses on LBO1.

The seed beam line from the LBO1 to LBO2 has been established using a spatial filter. It is arranged with a pinhole on a motorized remote controlled 2-axis stage, which is placed in a telescoping vacuum chamber. The pinhole plate acts as a block for the idler beam after the first stage of the amplification. All telescopes have been evacuated down to about 5×10^{-2} mbar pressure. The seed arrives to LBO2 collimated at about 10 mm in diameter. An optical delay line is introduced between the spatial filter and LBO2 providing the timing adjustment between the interacting pulses on LBO2.

Near field and far field diagnostics have been aligned for the pump laser at the vicinity of the layout and for the seed beam on the crystals by picking up laser radiation from back of mirrors and demonstrating good images of the beam profiles.

Average intensity gain was measured at about 400 and 65 on LBO1 and LBO2 respectively at 910 nm. These results are in good agreement with theoretical expectations.

Conclusions

In conclusion, we have proved the feasibility of the system built up for the seed pulse stretching and Joule level OPA amplification of the Phase 1 of the Vulcan 10 PW upgrade project. It is straight forward to use this system for the final ultra broad band seed pulse stretching and amplification. A parallel work is currently taken on compressor maintenance for the amplified pulse compression down to about 12 fs. A SPIDER has been built up for the output pulse duration measurement.

References

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