> 10^{19} Wcm^{-2} irradiances for laser/plasma interaction studies

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Abstract. Peak irradiances in excess of 10^{19} Wcm^{-2} have been delivered to target with the VULCAN Nd:glass laser using chirped pulse amplification (CPA) [1]. Recent developments have achieved sub picosecond pulses with compressed output powers of 35 TW in a single large aperture beam, with focused intensities on target in excess of 10^{19} Wcm^{-2}.

1. Laser system

The input pulse for the system was generated from a novel diode-pumped oscillator [2] providing pulses of 420 fs duration. The oscillator is based on additive pulse modelocking [3] (APM) of Nd:LMA. Nd:LMA was chosen as the active medium since: it has a large bandwidth (4.4 nm centred at 1055 nm); is suitable for amplification in phosphate glass amplifiers; and its absorption bands are at 800 nm enabling the device to be end pumped by a 3W laser diode. The shortest pulse duration achieved by the oscillator was 420 fs (assuming a sech^2 pulse shape), with a time-bandwidth product of 0.32 indicating that the pulses were near transform limited. The average output power from the modelocked oscillator was 115 mW at a repetition rate of 87 MHz , giving a single pulse energy of 1.3 nJ.

The output of the oscillator was injected into a double passed grating pair to produce a stretched pulse duration of ~200 ps. The gratings used were blazed holographic with 1740 lines mm^{-1}, gold coated and operated at an input angle of 73 degrees.

A schematic of the laser amplification system used is shown in figure 1. Three double passed 9 mm rod preamplifiers were used to enhance the oscillator pulse energy from 1 nJ to 1 mJ. It was then injected into the standard VULCAN amplfier chain consisting of rod and disc amplifiers separated by Faraday and Pockels cell optical isolators and air and vacuum spatial filters (ASFs and VSFs respectively) to maintain beam quality.

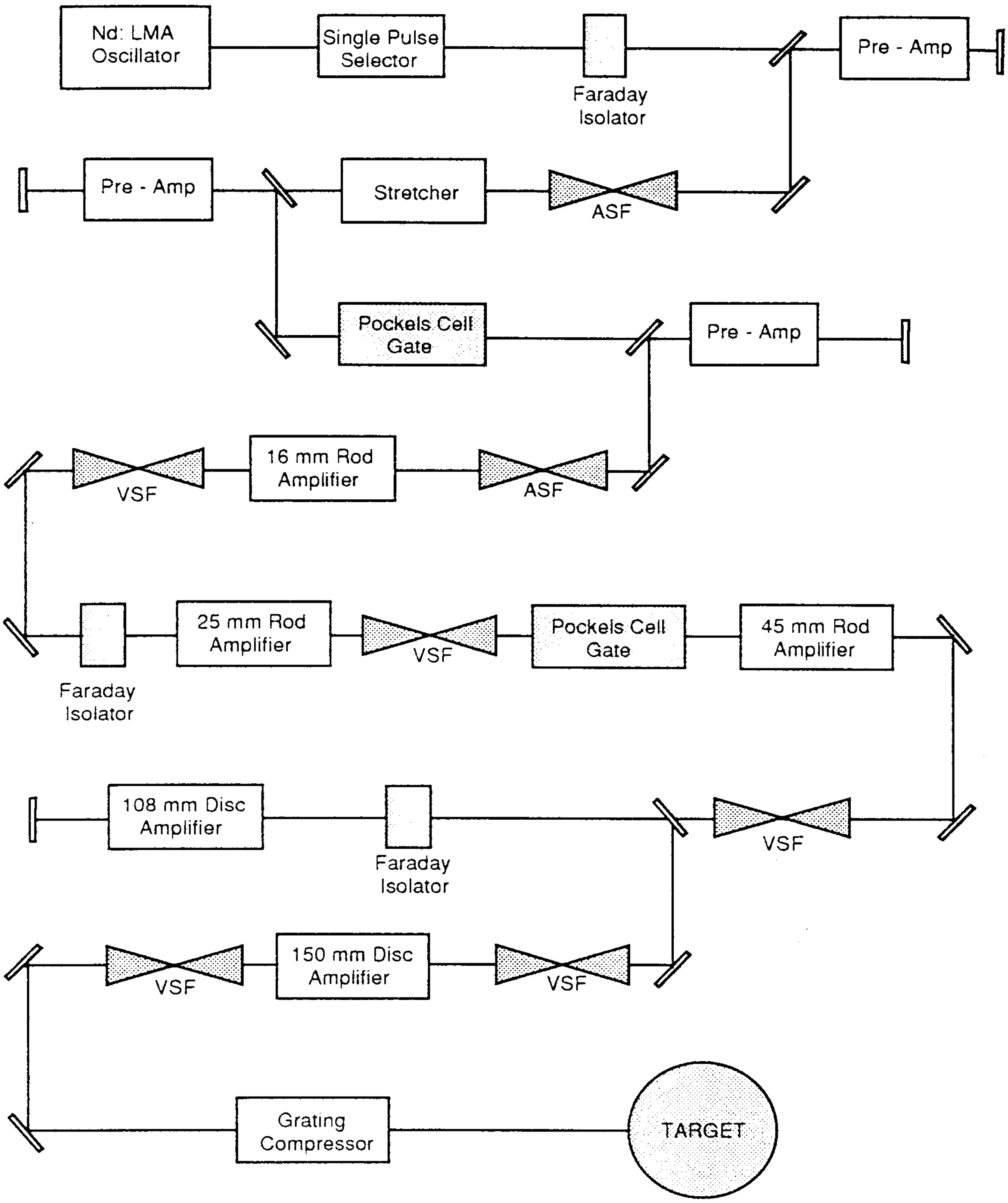

Figure 1. Schematic of the VULCAN Nd:glass laser chain configured for CPA operations.

Previous work [3] indicated that the fidelity of the recompression of the pulse was limited by self-phase modulation (effectively measured by the total B-integral) generated in non-linear media as the pulse passes through the system. It was essential to reduce these effects in order to produce the shortest possible pulse. The greater bandwidth associated with the 420 fs input pulse duration, compared to the original system, gave an increase in the stretched pulse duration to 200 ps, reducing the total B-integral by a factor of 3. The total amplification required in the amplifier chain to produce a given energy was minimised by ensuring good quality anti-reflection coatings on all transmissive optics. This together with limiting the thickness of chamber windows etc limited the B-integral to <1.

2. Compressed pulse diagnostics

The alignment of the large aperture diffraction gratings was optimised using a dual laser wavelength alignment technique [4] which produced a high quality focal spot of less than 3 times the diffraction limit. The focal spot size was measured both before and after grating alignment with low energy shots using a long focal length (10 m) equivalent plane monitor. Full energy shots verified the performance of the compressor, with a focal spot of less than 3 x the diffraction limit (see figure 2) in both the vertical and horizontal planes.

The grating separation was optimised by taking a series of test shots at low energy, and measuring the compressed pulse duration with a single shot second order auto-correlator. The gratings were set to the separation corresponding to the minimum pulse duration.

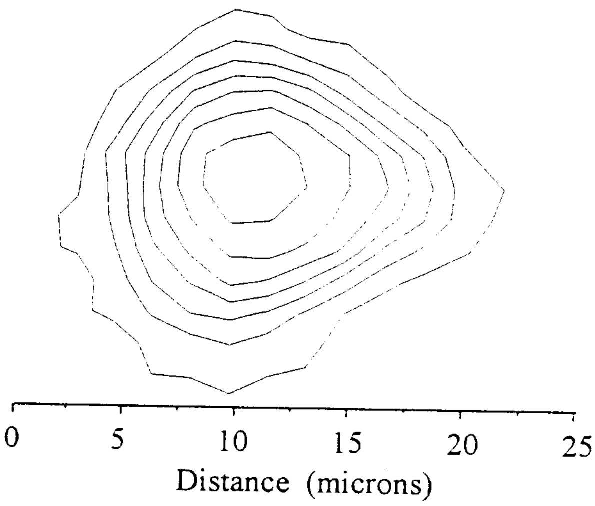

Figure 2. Iso density plot of the far-field image in an equivalent plane monitor. The axis has been scaled to show the expected distribution that would be obtained on target.

The pulse width and spectral data for high power shots are shown in figure 3. The data has been sampled from various experiments performed using the CPA system during the past year. The large scatter is due to slight changes in alignment between the stretcher and compressor gratings. Despite this scatter the data is consistent with an assumed $sech^2$ pulse shape (ie. a time-bandwidth product of 0.315). The incident energy onto the gratings for one particular shot (shot number 21281093) was 44 J, with losses due to diffraction efficiency and mirror reflectivity at ~ 50%, giving an energy on target of 22 J. The pulse width was measured at 620+/-100 fs ($sech^2$ profile), and the bandwidth of this pulse was 1.53 nm , giving a delivered laser power to target of 35 TW. The reduced bandwidth to target is mainly due to gain narrowing in the phosphate glass amplifiers. Using the measured focal spot size of ~15 μm diameter for the shot, obtained from an equivalent plane monitor, gives an irradiance on target of $>10^{19}$ Wcm^{-2}.

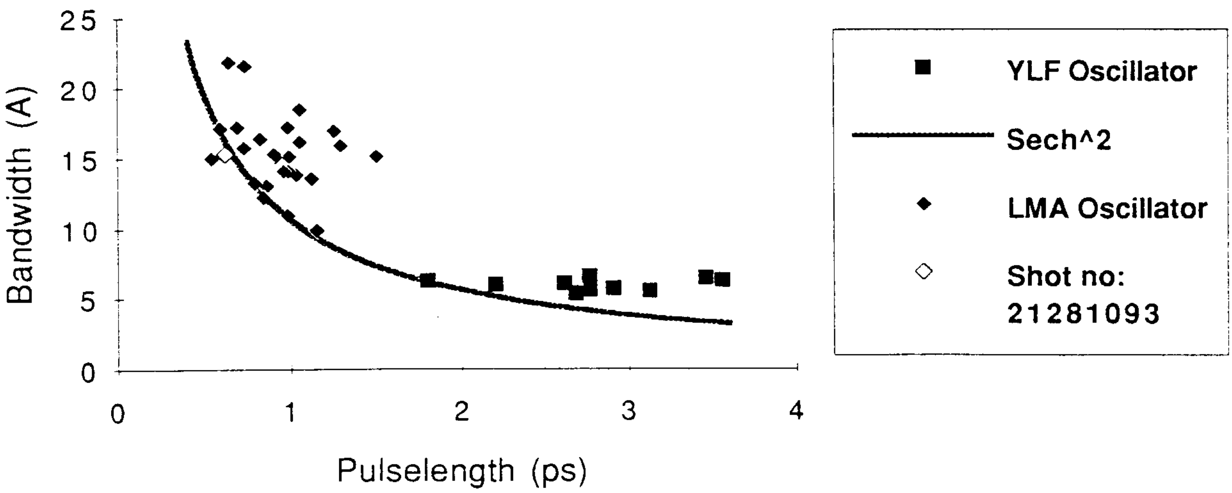

Figure 3. Plot of measured bandwidth and pulselength of the compressed pulse on full energy target shots

3. Laser / plasma interaction experiments

These pulses have been used in a series of laser/plasma interaction experiments to study: recombination x-ray lasers [5]; solid target interactions [6][7]; gas target interactions [8]; and particle acceleration techniques [9]. These facilities will open up new areas of investigations into areas such as short pulse ignitors for Inertial Confinement Fusion [10], particle acceleration by the laser wake field [11], relativistic self focussing [12], filamentation and optically field ionised plasmas and large amplitude plasma waves [13].

References

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