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Upgrade to the Vulcan laser system to support the TAW upgrade

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Introduction

The Vulcan laser facility has recently been upgraded to deliver an additional short pulse beam to Target Area West (TAW)[1]. This new beamline is capable of operating in the same mode as the previously existing one, at energies up to 100 J in 1 ps. It also allows the laser to reach new, previously inaccessible regimes, with the capability to deliver up to 500 J in pulses of 10 ps or longer (100ps max).

The increase in the delivered energy was made possible by the use of dielectric gratings for this new 10 ps beamline. Laser damage threshold (LDT) tests have shown that the damage threshold for dielectric gratings at 1 ps and 10 ps vary significantly[2]. At 1 ps the LDT of dielectrics are not substantially different from those of gold gratings (~300 mJ/cm^2), whilst at 10 ps this rises significantly, to over 2 J/cm^2.

In addition to a new compressor chamber to house the existing gold grating compressor and the new dielectric grating compressor, the upgrade required various modifications to the amplifier chain. It was necessary to provide higher energy on beam 8, balance the energy on the two short pulse beams and modify the beam sizes and propagation to make optimal use of the gratings at different pulse lengths.

Rod amplifier output modifications

The initial amplification section of the Vulcan laser system consists of two rod amplifier chains; the outputs of which are fed into the disc amplifier chains. One of the rod amplifier beam lines is split into two to form beams 7 and 8, the other is split into beams 1-6. Beams 7 and 8 are normally used as short pulse (CPA) beamlines.

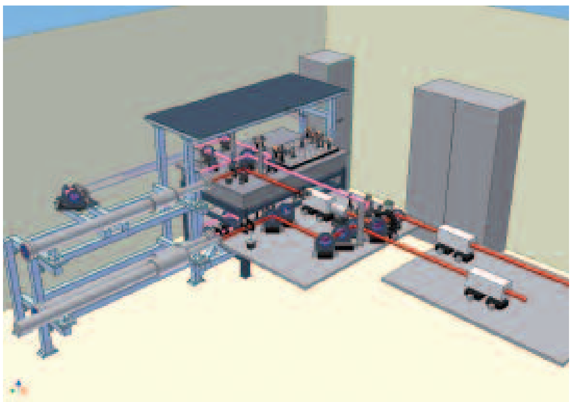

Figure 1. A 3D CAD image showing an overview of the rod chain output changes.

Modelling showed that the extra amplification needed to deliver the increased energy could be carried out at smaller beam diameter while still keeping the B-integral below three, the limit for what was acceptable for a 10 ps pulse. This meant that rod amplifiers, rather than large, costly disk amplifiers, could be used. An additional 45 mm diameter rod amplifier was installed on beam 8 for this purpose, increasing the rod chain output for beam 8 by a factor of six. The 1 ps beamline continues to be limited by the LDT of the gold gratings and the total B-integral, and hence did not require increased energy. The amplifier head used was a CLF custom design which been successfully operated on Vulcan for over twenty five years, combined with a commercially available power supply and control unit (Quantel, APG / CB903 and LCS5).

With the addition of another amplifier, particularly one capable of producing high output energy (>10 J), it was important to isolate the system from back-reflected pulses returning down the rod chain. A large permanent magnet based Faraday rotator (Electo-Optics Technology, model 45R1053) was added between the 45 mm amplifier and the polarising beamsplitter

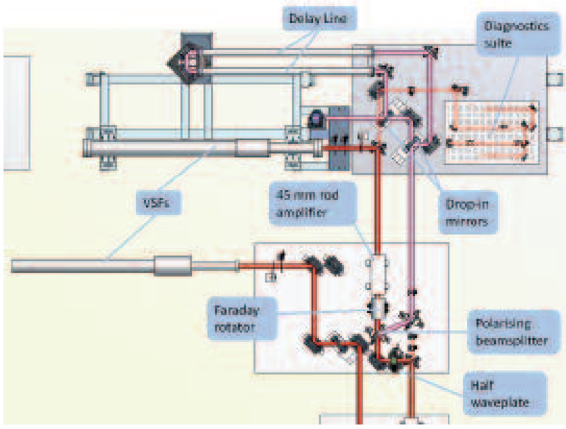

Figure 2. The optical layout: Beam 8 is shown in red, beam 7 is shown in pink. The diagnostics channel for beam 8 is shown as a dashed line (the beam 7 diagnostics are not visible in this view as they are on the lower level beneath the table).

The requirement to be able to balance the energy on the two CPA beamlines for TAW demanded a more flexible control than the static 50% beam splitter previously used. This was replaced in the new design with a waveplate and polariser combination, allowing a variable split based on the waveplate angle. The waveplate was mounted in a motorised rotation mount with position feedback and integrated into the Vulcan control system. The variable split also addressed the secondary aim of the upgrade, permitting a greater portion of the energy to be diverted to the beamline used for the Petawatt target area [3].

Where the previous beamline expanded the beam to 100 mm diameter before splitting into beams 7 and 8, the new variable split is carried out prior to expansion, at 40 mm diameter beam size. A second identical vacuum spatial filter (VSF) was therefore required to expand both beams to 100 mm diameter before further amplification in the double passed driver disc amplifiers.

The double passed compressor in TAW for beam 8 considerably increased the path length of this beamline. To allow the pulse on beam 7 to reach the target approximately concurrently, an optical delay line of 8 metres needed to be inserted into beam 7, with no degradation of the beam profile. To conserve space in TAW itself, this was implemented at the rod chain output. A pair of one to one telescopes in vacuum tubes were used to image relay the beam between the input and output. The delay line was also designed such that the beam for the Petawatt area could bypass it by the use of two kinematically locating drop-in mirrors on pneumatic slides.

Completely new diagnostics suites were built for each beamline, taking the leakage through 97% reflective mirrors immediately before the two VSFs. Each set of diagnostics consisted of: a calorimeter (Gentec EO, model QE25LP) to measure the pulse energy. Near and far-field CCD cameras (uEye, model UI-1540SE) to view beam profile and to monitor pointing and focal spot quality. A fibre coupled spectrometer (Ocean optics HR4000) to view the spectrum after amplification in the rod chain. A motorised filter wheel containing a range of ND filters was used to attenuate the beam as needed to keep the input energy approximately constant, depending on the amplifiers being fired.

The upgrade entailed significant alterations to the physical and optical layouts, as well as the addition of new hardware and mechanics. To accommodate all the additional components, the existing optical table was moved and a multi-level mechanical framework was constructed around it.

Laser area 3 modifications

To deliver the maximum energy possible in a 1 ps pulse, the limiting factor is the LDT of the gratings. Thus the optimal solution is to fill the whole aperture of the gratings by apodising the beam to a square shape. Conversely, the 10 ps beam is primarily limited by the energy that can be produced from the amplifier chain. Minimal losses through the system are needed to deliver the required energy, ruling out such significant apodisation and maintaining a round beam. These considerations led to a novel design requirement for the final VSF such that it could output different beam sizes/shapes for each pulse length, shown in Table 1.

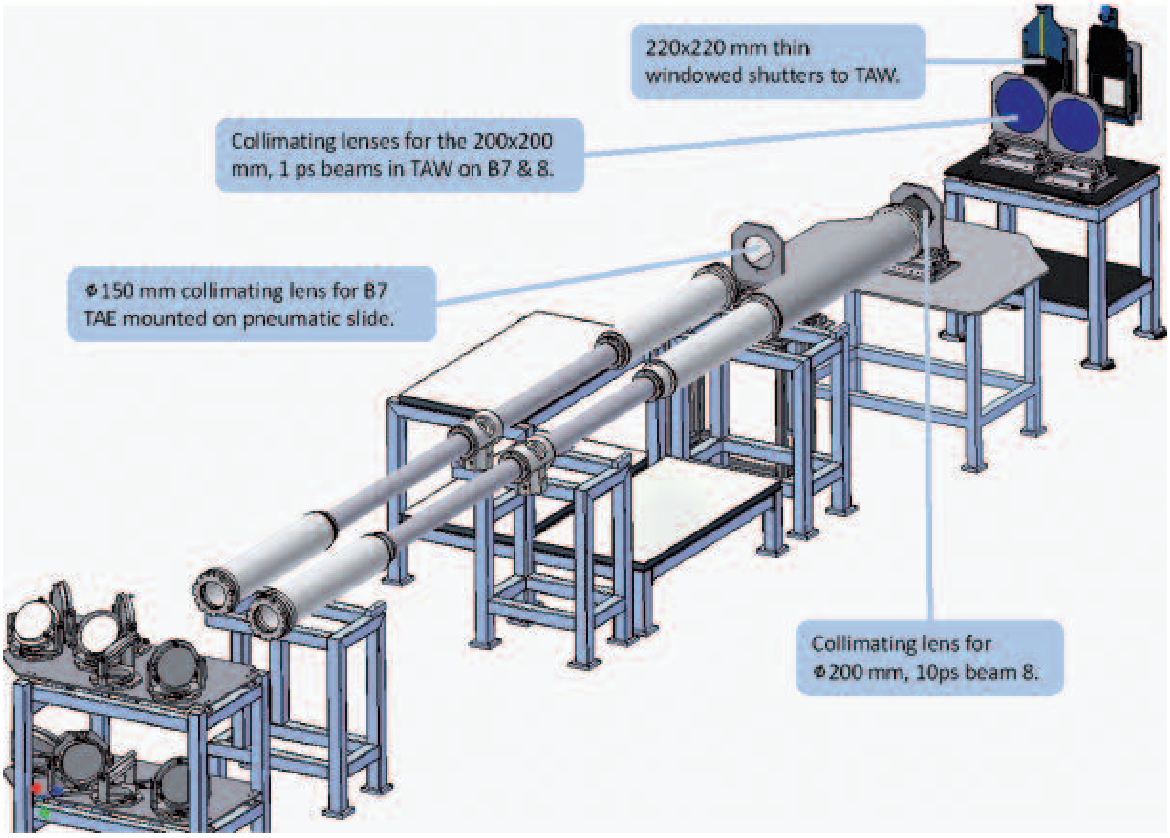

Figure 3. A 3D CAD image of modifications to beam lines 7 and 8 in laser area 3.

Beam	Small beam size	Large beam size
7	150 mm dia (TA East)	200 × 200 mm (1 ps TAW)
8	205 mm dia (TA East & 10 ps TAW)	200 × 200 mm (1 ps TAW)

Table 1. Combination of beam sizes required.

The selected design consisted of two VSFs, with the output end of each VSF containing an anti-reflection coated fused silica window, such that the beam emerging from the VSF continued to diverge. This could then be collimated by one of two lenses located outside vacuum, which can be changed over on a per-experiment basis, producing two different beam sizes. Apodisation to a square shape is performed earlier in the disc amplifier chain using a serrated-aperture immediately prior to a VSF.

To meet the operational requirement for a switchable system between TAW and TAE on a shot to shot basis, the beam collimating optic for TAE was mounted on a pneumatically operated slide linked to the Vulcan control system.

A new diagnostics suite was designed and built to characterise the beams at the output of the disc chain prior to their injection in Target Area West, a description of which can be found elsewhere in this annual report [4].

The beam shutter architecture located between the laser area and TAW was modified to allow the larger 200 × 200 mm beam to enter the target area. This required two large thin windows to act as air tight seals between the laser and the target areas, to prevent different operating pressures of the air conditioning systems affecting beam stability.

Conclusion

The Vulcan Laser has been successfully upgraded in support of the Target Area West upgrade. This has brought increased capability and flexibility to the Vulcan laser system in support of the Central Laser Facility user programme.

References

1. C. Hernandez–Gomez *et al.*, *'An overview of the Target Area West Short pulse upgrade'*, CLF Annual Report 2007-08.
2. M. D. Perry *et al.*, *Opt. Lett*. **20**, 940-942 (1995).
3. C. N. Danson *et al.*, *Nucl. Fusion*, **44**, S239-S246 (2004).
4. M Galimberti *et al.*, *'New short pulse diagnostics for the Target Area West'*, CLF Annual Report 2008-09.