A new long pulse beamline for the Gemini facility

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Introduction

Previous experiments performed on the Gemini laser facility [1] have used one of the two Gemini beams in long pulse mode (~1.0ns) to drive a shock in a solid target, while the second Gemini beam was used to produce Betatron X-rays from a conventional gas jet, which imaged the shock and its propagation.

Experience from this previous experiment suggested that both the energies achievable and the pulse shape of a single Gemini beam in long pulse mode were unable to produce the required shocks. To operate one of the Gemini beams in long pulse mode, the pulse compressor was bypassed and the stretched CPA pulse was used to drive the shock. The maximum energy achievable with stretched Gemini pulses is of the order 20J and is limited by the extraction from the final Ti:S multi-pass amplifier. The pulse shape of the stretched Gemini pulses is supergaussian in nature, however the lack of a sharp rising edge proved detrimental to driving the required shocks.

For the March 2016 Eakins experiment [3] a different method of generating the shock driver was implemented. Instead of using one of the main Gemini beams to drive the shock, one of the Gemini Quantel pump beams was used, operated at its fundamental wavelength of 1053nm.

Quantel pump lasers

The final multi-pass amplifiers of the Gemini laser system are each pumped by a commercial Quantel frequency doubled Nd:glass laser system [2]. These lasers produce two 45mm diameter beams at 527nm with 25J in a pulse duration of 30ns. The lasers are based on the MOPA design and take the 200mJ output from an oscillator and amplify through two 9mm and two 12mm flash lamp pumped single pass amplifiers. The pulse is then split into two arms, which are both then amplified by one 16mm and 25mm amplifier, before undergoing final amplification by two 45mm amplifiers. Both beams produce >50J of energy in the fundamental 1053nm before frequency doubling in type 1 KDP.

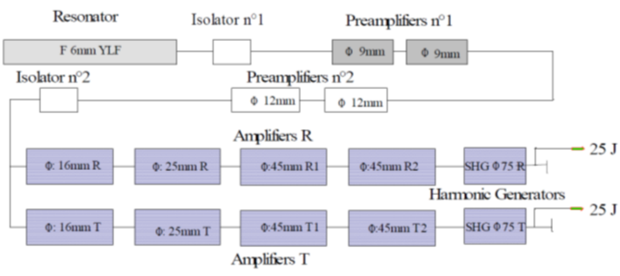

Figure 1. Quantel laser configuration

New long pulse beamline

In order to propagate the Quantel beam to the target area a new beamline was installed incorporating a vacuum relay pipe to provide image relaying and collimation control. The second harmonic conversion crystals of the Quantel laser were removed and a single fundamental beam injected into an expanding vacuum relay pipe which increased the beam size from 45 to 50mm. The beam emerged from the pipe on the Gemini North beam amplifier table and was then routed under the pulse compressor for injection into the Target area. A new beam shutter was installed at the output of the laser area and integrated into the existing Gemini interlock system.

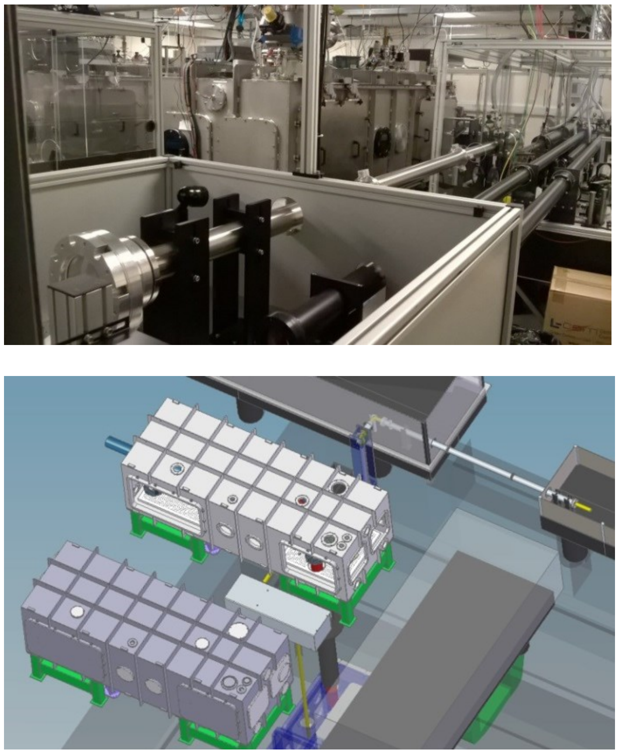

Figure 2. New Gemini long pulse beam layout

Pulse shaping

The temporal pulse duration of the Quantel laser system is 30ns FWHM Gaussian, which is not suitable for driving the shocks required for the Eakins experiment. In order to condition the temporal pulse shape a Pockels cell was installed after the 9mm amplifiers. The Pockels cell was used to suppress the early part of the pulse and was then switched on to produce a sharp rising edge (10% to 90% in ~1.0ns). The pulse energies measured after shaping were up to 50 Joules.

To ensure good suppression of the foot of the rising edge, critical alignment of the Pockels cell was performed as part of the daily startup procedure.

Figure 3. Pulse shaping Pockels cell

Characterisation

In order to determine if the Quantel beam was of suitable wavefront quality for driving a shock, the focused beam was measured using a 500mm focal length lens and a Wincam. Figure 4 shows the focus of a full power (50J) IR shot from one arm of the Gemini North laser system. This focal spot was qualified as being of good enough quality to provide the required shock.

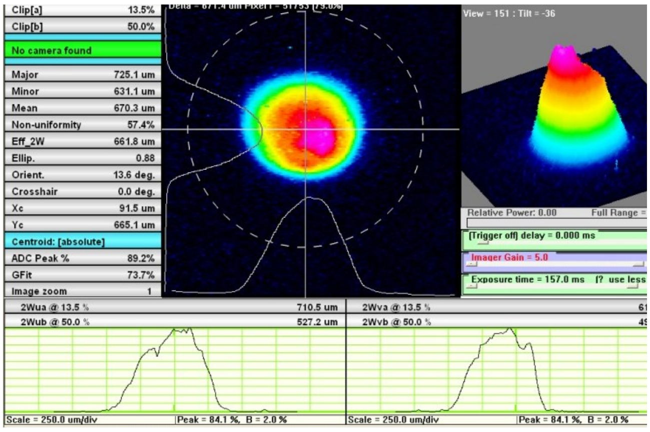

Figure 4. Quantel beam full energy focal spot

For the temporal characterisation an Electro-Optics Technologies ET200 Silicon PIN detector photodiode and Tektronix DPO 4054 oscilloscope were used to measure the full power pulse shape. This was done using the leakage of one of the beamline transport mirrors. A typical pulse shape that was obtained during the experiment is shown in Figure 5.

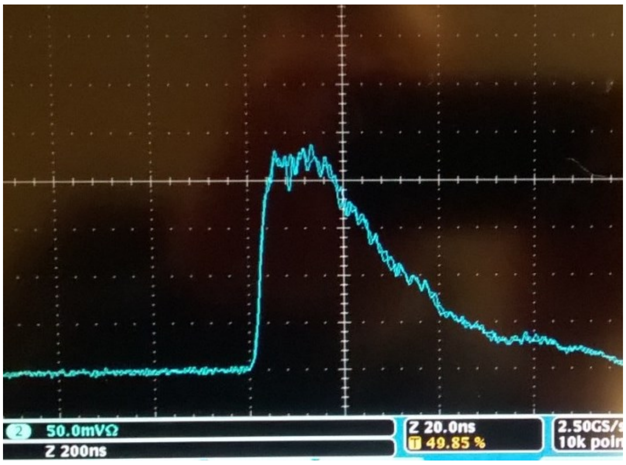

Figure 5. Temporal profile of a full energy shaped Quantel pulse

Daily operations

In order to safely align the beamline during commissioning, and for daily alignment of the beamline in the target area, a CW alignment beam was injected into the early part of the Quantel optical chain, using a New Focus high precision flipper mount. The beam was co-aligned with the Quantel pulsed beam using a camera at the output of the Quantel system to view the far-field of the beam on a screen.

Target Area installation

The long-pulse beam enters TA3 above the North-East corner of the chamber, alongside the North beam. It has a separate beam-pipe – which is not under vacuum – and uses one of the holes in the ceiling that were included during the design of Gemini to allow supplementary beamlines.

The entry point into the chamber is above the plasma mirror system, and given the 50 mm diameter of the beam it can easily be directed along the internal surface of the chamber roof.

Alignment within the target area is done using an injected CW beam, as stated above. The interlock system at present does not allow the pulsed Quantel beam into the area, at any energy level, unless the target area is searched and empty. As a result, beam timing and focal spot optimisation is done from the TA3 control room using unamplified 5 Hz pulses from Quantel oscillator.

To adjust the relative timing between the long-pulse and the short-pulse (South beam), the input to the Quantel Q-switch can be switched from the master timing system (as for normal operations) to the TA3 control room patch panel. Using a delay generator the beam timing is then easily adjustable.

Results

For a full description of the results obtained with the new long pulse beamline, please refer to the article by M E Rutherford elsewhere in this report [3].

References

1. J. C Wood *et al* Ultrafast Imaging of Laser Driven Shocks using Betatron X-rays from a Laser Wakefield Accelerator, *2014-15 CLF Annual report*
2. http://www.quantel-laser.com/en/products/item/ndglass-lasers-.html
3. M E Rutherford *et al* Density measurements in shock-compressed aluminium via betatron x-ray radiography *2017 CLF Annual report*