Installation of an Independent Probe Beamline in Gemini TA3

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Abstract

A third beamline has been introduced to Gemini Target Area 3 to provide a short-pulse probe beam independently of the two main beams. The beam is derived from a leakage of the Gemini North beam after the fourth amplifier in LA3 and is compressed in the target area using a commercial compressor. This probe is designed to deliver up to 15 mJ in a pulse length < 50 fs with 25 mm beam diameter. Preliminary alignment of the probe compressor achieved a sub-100fs duration that has been used for several user experiments.

1 Design

The probe beam originates as leakage from the mirror at the end of the final pass through amplifier four of the North beam in the Gemini laser area (LA3). Further attenuation is achieved by using a partially reflective mirror. Different combinations of leakage and reflection percentages provide a range of pulse energies. Typically these would be 1% leakage and 20% reflectivity to direct 36 mJ into the probe line for a pre-compression full shot energy of 18 J. The probe beam (ϕ 50 mm) is periscoped and steered underneath the compressor in a shielded box to be directed to the target area from above. An interlocked shutter controls the entry of the probe beam into the target area. The beam is telescoped through two image relays with focal lengths $f_1 = 4$ m, $f_2 = 3$ m, $f_3 = 3$ m, $f_4 = 2$ m, reducing the beam size to ϕ 25 mm. For probe energies $<$ 50mJ, the intensity at the telescope foci remains below the air breakdown threshold. The beam passes through fixed and variable delay stages to compensate for the beam path difference with the main beam, and to provide motorised control of the probe timing. The polarisation is selected as s-polarisation through most of the beam transport to minimise losses from metallic mirrors. The transmission of the beamline is estimated as 82%.

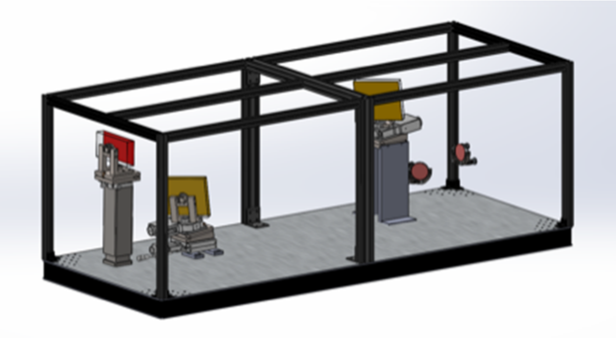

Figure 1: Crunch Technologies quadruple pass compressor design showing turning mirrors at entry on right hand side followed by first grating G1 onto the second grating, G2, before reflecting back through the compressor for the second pass from a plane mirror at the upper left hand side. A mirror located underneath G2 reflects the beam through the compressor a second time.

The probe compressor was supplied by Crunch Technologies[1] and installed on-site. The design, shown in Fig. 1, uses a pair of standard 140 mm, 1480 lines/mm gratings and a plane mirror for double pass compression. This arrangement is then transited a second time to provide 1 ns compression to match the Gemini stretcher. The small grating size and quadruple pass gives the compressor a small footprint. A slight clip of the spectrum limits the minimum pulse duration achievable; this was calculated to be ~ 42 fs for the maximum design beam size of ϕ 30 mm. The throughput of the compressor is expected to be 50% making a probe beam energy of ~ 15 mJ available.

2 Beamline installation

The beamline in LA3 uses a periscope with 4" mirrors that was previously installed to transport the Quantel pump laser beam into TA3. An apodiser can be added before the periscope if a reduction in probe beam size

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[1] `crunchtec.com`

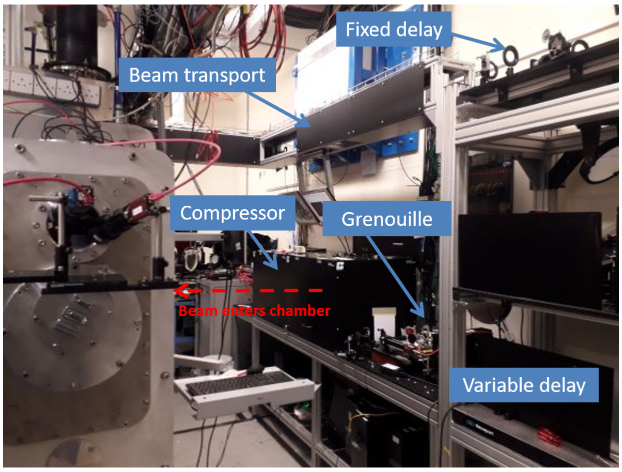

Figure 2: TA3 probe compressor in the central enclosure. The beam enters through the roof in the top left, passing through the gantry line into the delay tables on the right of the figure. After the delay the beam is directed and into the compressor from the right.

is requested. The first lens of the first image relay telescope is located in the shielding box such that the focus falls within the vertical beampipe between LA3 and TA3. Above the target chamber the beam is steered toward the East wall of TA3 inside a gantry surrounded by opaque panelling, see Fig. 2. The second lens is mounted within this structure. The collimated beam then enters a fixed delay line with ~10 m beampath housed on the top level of the framework in the South-East corner of TA3. Steering mirrors in the gantry are fitted with picomotors for remote control and ease of use once the full beam enclosure is constructed. The optical arrangement for the delay (Fig. 3) contains the two lenses of the second image relay. A pinhole could be introduced at the telescope focus if spatial filtering of the beam was deemed necessary. Also this delay can be bypassed completely if the extra beampath is not needed. The beam is periscoped down to standard beam-height on the second level of the framework. Here a manual and a motorised delay stage allow adjustment of the probe timing, see Fig. 4. A static corrector can be used to remove slight astigmatism introduced in the probe beam transport. After this the beam is directed into the compressor through a waveplate and polariser for energy control.

The interlocked wall shutter can be activated in any power mode, but because it is a leakage beam the probe is difficult to use in Medium Power mode. For that reason a new operational mode has been introduced that allows the probe shutter to be opened to TA3 while LA3 is operating in High Power mode at 5 Hz. In this mode, the main beam shutters are disabled for radiation safety. This provides ~ 2.5% of the full energy level so typically would operate at ~ 250μJ, which is easy to see with infrared viewers and cameras.

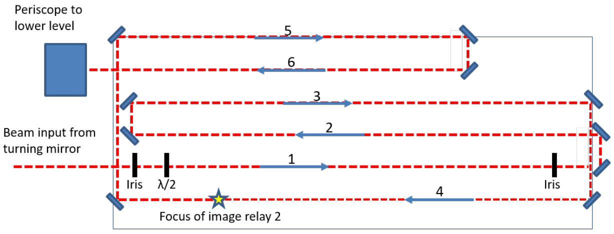

Figure 3: Optical arrangement of the fixed delay line to introduce ~ 10m pathlength to the probe beam.

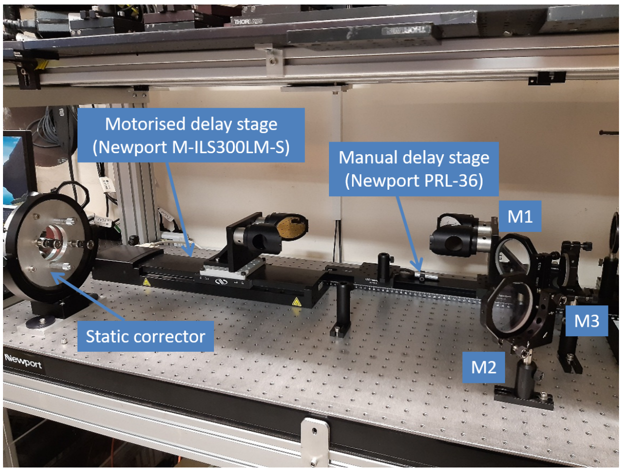

Figure 4: Manual and motorised delay stages for adjustment of probe timing. An optional static corrector is also shown.

3 Compressor

The compressor was installed according to the design shown in Fig. 1. At the exit, the beam was directed into near-field and far-field cameras to check the beam profile and the alignment of the gratings. The focal spot is slightly elongated because of a mismatch in groove rotation (Fig. 5(b)). Presently the grating mount does not have a micrometer adjustment of this motion and this will be addressed with a future modification. Initial attempts to measure a short pulse using a picosecond autocorrelator and Grenouille were unsuccessful. Using a streak camera it became clear that the distance between the gratings needed to be increased and so both gratings were remounted closer to the ends of the enclosure. We suspect that this could be due to a discrepancy between the stretcher design parameters that were provided to the company and the actual values used in practice. Following this modification, scanning the grating distance and angle achieved a short pulse detectable on the autocorrelator and Grenouille. The pulse duration was measured as ~ 87 fs using the Grenouille. However, the FROG trace, Fig. 5(c), contains features that indicate poor compression. This could be a result of the grating mismatch, the transmission properties of the initial

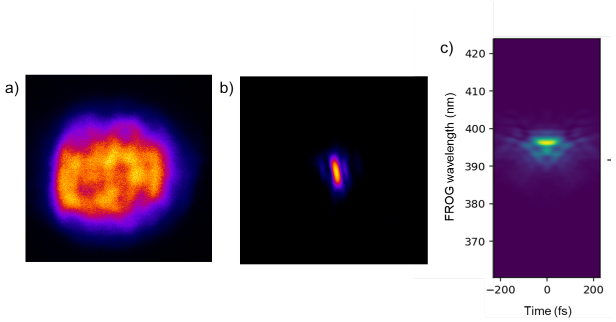

Figure 5: (a) near field profile of the probe beam entering the compressor; (b) far field of the post-compression beam. The vertical elongation indicates residual dispersion; (c) reconstructed FROG trace from a Grenouille measurement giving a pulse duration of $\sim$ 87fs with a central wavelength $\sim$ 795nm.

leakage mirror, or a problem with optics in the transport line. The performance of the probe is adequate for current experimental needs of transverse plasma probing. These issues can be addressed at a later date when the temporal structure of the pulse is important.

4 Conclusion

Production of a leakage line from amplifier four in the Gemini laser area has enabled the installation of a probe beam for use in transverse probing and frequency domain holography among other techniques. De-coupling this diagnostic from the main beamlines with an independent compressor provides more versatility, saves time in experimental set-ups, and avoids the need for cumbersome optical layouts inside the TA3 vacuum chamber. The performance of the probe is not yet fully optimised, but provides a sub-100 fs pulse that can be used for transverse plasma imaging. When necessary, facility access will be scheduled to achieve the design parameters of 15 mJ, 42 fs and up to 25 mm beam diameter. We note also that the optics in the beamline have all been selected to transport a 50 mm diameter beam if required. For example, if a high energy nanosecond pulse was requested, a straightforward method to bypass the compressor would be to remove the image relays and direct the main beam before the beam expander along the third beamline.