mJ-level 5 Hz probe beam for Gemini target area

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Introduction

The Gemini facility, in addition to its twin multi-joule beams, can also deliver a lower energy mJ-level beam to the target area, commonly used for pump-probe experiments. This probe beam is taken from the transmission through a mirror after the Gemini North amplifier, which limits the repetition rate to that of Gemini full shots: 1 shot every 20 seconds. However, a higher repetition rate probe could be used to study the target at multiple times separated by large delays, or to accumulate a large number of background probe shots before and after the main pulse, a feature which was requested by the experimental group led by Prof. Simon Hooker. As the Astra front-end delivers a 5 Hz beam to the Gemini laser area, it is possible to use this input to create a 5 Hz probe beam.

To produce the 5 Hz probe beam, a 5% transmission was taken from a mirror at the input of Gemini, before the fast shutter which selects single pulses for amplification. The beam was then routed onto the Gemini North amplifier table and injected into the existing probe beam path. Since the new beam path bypasses the Gemini multi-pass amplifier, the corresponding optical path must be added for the probe pulse to arrive synchronised with the main pulse. At around 40 m, this additional path length is too long for the beam to propagate without significant degradation of the spatial profile, so a relay-imaging system is necessary.

Due to the limited space on the optical tables dedicated to the probe beam line, the simple solution of a series of relay-imaging telescopes was not possible. The chosen solution was to circulate the beam in an optical cavity containing a 1:1 relay-imaging telescope, allowing the beam to effectively travel a long distance through a series of relay-imaging telescopes in a compact layout.

Experimental setup

Figure 1 is a schematic of the experimental setup in the target area.

The probe beam arrives from LA3 and is initially down-collimated by a 3:2 relay-imaging telescope, reducing the beam diameter from 25 mm to 17 mm. After this telescope, there is a 4-metre manual delay line to provide a rough setpoint for synchronisation. This delay must be at least as long as the delay cavity to ensure there are no blind spots in the synchronisation adjustment. The beam is then sent to the delay cavity.

The delay cavity was made as long as possible in the available space, to minimise the number of passes needed and thus reduce the overall losses. The delay cavity has a 4 m round-trip path in which there is a 4-f telescope using two 1 m focal length lenses, which re-image the beam after every pass and maintain the beam quality.

The beam is $\vec{p}$ polarised at the input to the cavity, and is transmitted through the cube polariser into the delay cavity. During the first pass, the Pockels cell (Gooch & Housego TX 7595) is switched on with a short high-voltage pulse, rotating the polarisation of the laser pulse to $\vec{s}$, which is then reflected by the cube polariser. The pulse then circulates for the desired number of passes to add the necessary delay, after which the Pockels cell is again switched on with a second short high-voltage pulse, rotating the polarisation back to $\vec{p}$ and ejecting the pulse from the delay cavity after transmission through the cube polariser.

The input energy into the cavity was 11.5 mJ and, after the 10 passes needed for synchronisation with the main pulse, an output of 5.5 mJ was measured: a overall throughput of 48%.

The beam is then sent through the probe compressor, with a throughput of 45%, delivering 2.5 mJ to the target chamber. Due to time constraints, and as the probe pulse duration was not critical for the experiment, the pulse duration after compression was not measured.

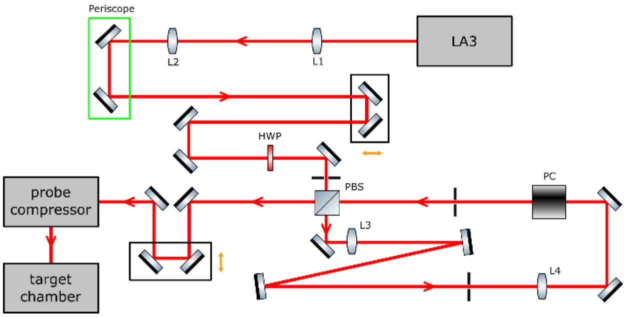

Figure 1: Diagram of the experimental setup. L1: f = 3 m; L2: f = 2 m; L3: f = 1 m; L4: f = 1 m; HWP: Half-wave plate; PBS: Polarising beamsplitter; PC: Pockels cell (Gooch & Housego TX 7595)

Conclusions and further improvements

A 5 Hz mJ-level probe beam with adjustable delay was sucessfully delivered to the TA3 target chamber, with the beam path still available for future use. However, because of delays due to unavailable and faulty equipment, there was a focus on delivering a working probe beam to the target at the expense of thorough characterisation.

Additional work is needed to improve alignment through the compressor, as well as measuring the pulse duration.

Furthermore, the 3:2 down-collimating telescope had a throughput of only 67% due to the large number of losses in the gold folding mirrors used (not shown in the diagram for clarity). Since this telescope is present in both the standard and the 5 Hz probe configurations, these mirrors should be replaced with dielectric-coated optics before the next experiment that requires the probe beam.