Gemini Facility Improvements

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Introduction

Over the course of the year a number of improvements have been made to the Gemini facility that individually are not important enough to require separate articles, but which deserve to be recorded. This article describes those developments and draws attention to the progress they represent.

1. New diagnostics for Amplifier 3

Amplifier 3 is the final amplifier of Astra, and its output feeds both TA2 and Gemini with beams of around 900 mJ per pulse at 5 Hz. Prior to the installation described here, there was very limited diagnostic information available to monitor the performance of the amplifier, and this was the motivation to develop and install the diagnostic package described here.

There was only a small amount of space available on the amplifier table, so a minimal set of diagnostics was chosen comprising near-field and far-field images, plus a moiré collimation diagnostic. Calibration of the near-field image against an energy meter will also provide a measurement of pulse energy. It was decided to use these diagnostics as a test-bed for a new Gigabit Ethernet camera system, which will eventually replace all the FireWire cameras currently in use in Gemini.

The layout of the diagnostic setup is shown in Figure 1. One of the beam steering mirrors was replaced with a 99.5% reflecting optic to provide a diagnostic beam of around 5 mJ per pulse, which was split between the three diagnostic channels.

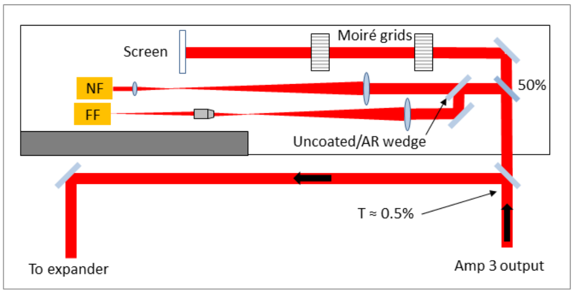

Figure 1. Layout of the new Amp 3 diagnostic suite. The Moiré image on the screen is viewed by a third camera (not shown) mounted above the corner mirror.

The moiré grids are set up to give a set of horizontal fringes when the beam is collimated. The advantage of the moiré technique is that it works with stretched broadband laser pulses, whereas a shear plate does not because the time delay between the two reflections means they do not interfere. As with a shear plate, the direction of rotation of the moiré fringes can be used to identify whether the beam is converging or diverging, and this information can be used to correct the collimation if required. At the time of writing we have not installed such a corrective capability on the Astra system, but it could be included in future developments now that the measurement is available. Figure 2 shows the actual setup of the new diagnostics on the laser table.

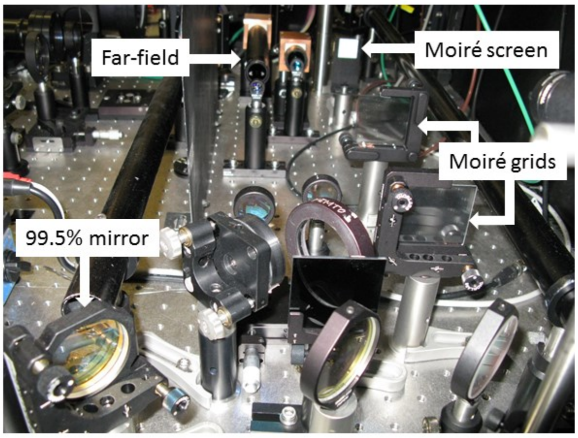

Figure 2. Photograph of the new Amp 3 diagnostic suite.

2. Improved short-pulse beam sampling for Gemini

The beam diagnostics at the output of the Gemini amplifiers fall into two categories: beam properties and pulse properties. The diagnostics for beam properties use the fraction of the beam transmitted through the final turning mirror, which is a 30 mm thick silica mirror at 45 degrees. The transmitted pulse is thus stretched significantly by passing through first the mirror, then the 20 mm thick window of the compressor chamber. The beam for the pulse diagnostics was originally obtained via a 15 mm diameter hole drilled in the final mirror, and the sub-aperture beam brought out of the chamber via a very thin window to avoid introducing any significant stretch.

Many experiments on Gemini now use an F/40 focusing optic for improved electron acceleration. This requires the focusing beam from the F/40 to be folded by a pair of 45 degree mirrors at a point where the beam diameter is around 80mm and the intensity is very close to the damage threshold of the optics. The diffraction fringes introduced by the edges of the beam sampling hole were damaging these folding mirrors after a small number of shots, requiring them to be replaced frequently. To eliminate this, the final turning mirror was replaced with one that does not have a hole.

The absence of a short-pulse diagnostic beam would make it impossible to measure the pulse duration or perform Sequoia scans to measure the pulse contrast, so an alternative beam sampling setup was designed in which a 1-inch elliptical mirror can be driven into the beam path to extract a diagnostic beam. A motorised slide controlled from the compressor drive system carries a periscope consisting of two such mirrors. The first mirror samples the centre of the main beam, which has the advantage that the energy in the diagnostic beam is more than was obtained with the hole, which was positioned close to the edge of the beam where the intensity is somewhat lower. The lower mirror is outside the main beam path. Some additional steering mirrors direct the resulting sub-aperture beam onto the original diagnostic breadboard, to avoid the need to change other parts of the diagnostic setup. Figure 3 shows the sampling periscope in the “IN” position inside the south compressor chamber. In this image, the compressed beam propagates towards the viewer from the large turning mirror on the right. When the diagnostic beam is not required the periscope is moved out of the beam to the right-hand side.

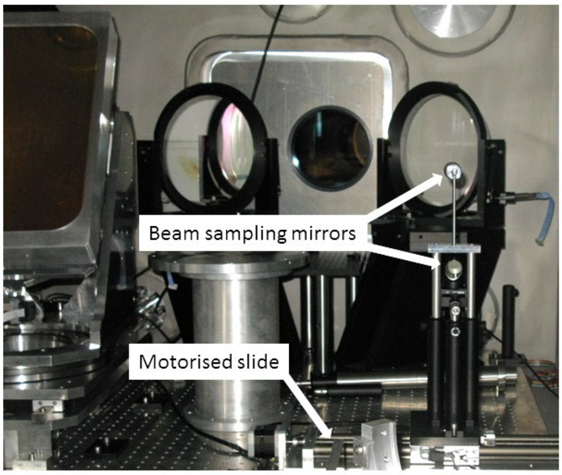

Figure 3. The new beam sampling setup in the south compressor.

Previous experience with Gemini operations showed that the measured pulse duration changed little during the course of the day, so a measurement on each shot was unnecessary. With the new diagnostic configuration, the pulse duration is checked as part of the laser run-up, using shots fired at reduced energy with the beam sampling mirror in position. The mirror is then removed from the beam before the final test shots are fired at full energy. This procedure works well, and the rate of damage to the beam folding mirrors in the F/40 focal line has been greatly reduced. If a future experiment does require a pulse measurement on every shot, the periscope can be lowered so the sampling mirror is at the edge of the beam, and remains in place for laser shots.

3. New polarizers for the Gemini pulse stretcher

The Gemini pulse stretcher has a requirement to generate either singly or doubly stretched pulses, depending on whether the shot is intended for TA2 or Gemini. This is achieved by the pulse stretcher being located (optically) inside a cavity. The pulse from the front end is switched into the cavity by a Pockels cell placed between two polarizers, then switched out again by the Pockels cell being fired a second time, after the pulse has made either one or two passes through the stretcher. The pulse passes through each of the polarizers either three or five times, with equal numbers of transmissions and reflections. The spectral transmission properties of the polarizers are therefore significant, as any losses accumulate pass by pass.

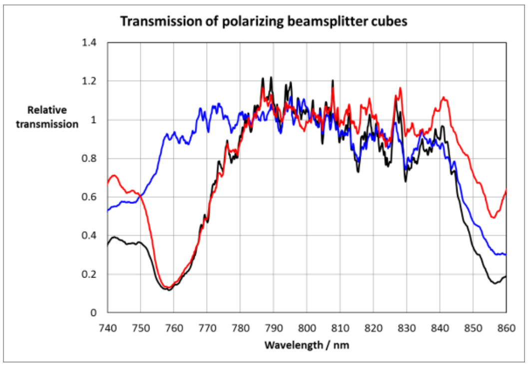

Figure 4. Effect of five passes through a polarizing beamsplitter cube. Red: 5 x transmission; Blue: 5 x reflection; Black: 5 x both.

The polarizers formerly used for this purpose were polarizing beamsplitter cubes, made by optically contacting two silica prisms, one of which has a polarizing coating on the hypotenuse face. The cubes are 10 mm on a side. Measurements of the spectral transmission of the cubes, plotted in Figure 4, showed that there were slight losses in reflection at longer wavelengths, and more severe losses in transmission at shorter wavelengths. The combination is enough in a multiple-pass configuration to affect the bandwidth of the stretched pulses, in particular the doubly-stretched pulse.

The transmission properties of various types of polarizing components were investigated, and the one with minimum losses appeared to be a calcite Glan-Thompson type. This is a variant of a Glan-Taylor polarizer, in which both the transmitted and rejected polarizations can be accessed. One polarization is totally internally reflected at a 22.5 degree interface, and emerges at 45 degrees to the direction of the transmitted polarization. These prisms show none of the absorption that occurs with the polarizing cubes, so their effect on the bandwidth of the stretched pulses will be minimal. However, the cubes deflected the beam through 90 degrees rather than 45, so a physical change to the optical layout was needed to make the change to Glan-Thompson polarizers.

The new layout is shown in plan view in Figure 5. GT prism 2 deflects the beam upwards at 45 degrees, and it is then steered into the pulse stretcher.

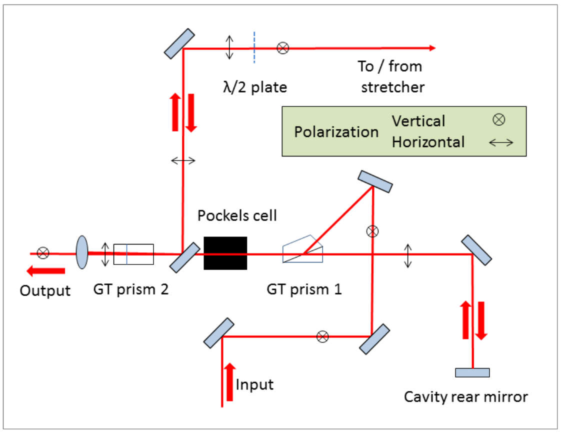

Figure 5. Schematic of the new stretcher input configuration.

The impact of the change on operations has been negligible, but spectral transmission measurements around the early part of the laser showed that the losses from the beamsplitter cubes had been eliminated. The effect of this change on the overall spectral throughput and the final pulse duration is still being evaluated.

Control system changes and new software

There have been a number of improvements and upgrades to parts of the Gemini control software and associated applications. These are described in a separate article.

Conclusions

During the period covered by this report, a number of modest changes have been made to the Gemini system to improve its performance and streamline operations. These have been done in a way that did not affect delivery of beam to the users, which was important at a time when the laser was heavily scheduled.