Progress on Astra Gemini

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Introduction

Astra Gemini has been operational for much of the last year, so there have not been many opportunities for development and improvements to the system. This report describes the changes that have been made and their effects on the performance of Gemini.

Engineering changes

The year has seen the final commissioning of the vacuum system and associated dry air let-up system for the compressor and target chambers. This has greatly simplified measurements of the compressor throughput and operation of the RF cleaning system for the compressor gratings. There is a separate 'RF cleaning' mode of the vacuum system, which can be selected from the vacuum control panel. More details of this are given later.

The design for the sliding doors of the compressor chambers has been changed as a result of the experience with those on the south chamber. In the new design the doors are supported on short shafts with roller bearings (Figure 1), instead of the pivoted arms of the original design. They allow the door to be moved away from the chamber about 15 mm, and then slid to one side to give access to the chamber interior. There is a limitation that only one door on each side of the chamber can be open at any time, but the compensation is that the new system, which has been installed on the north compressor, works far more smoothly than the original. During the summer the same system will be retrofitted to the south compressor.

Operational changes

Another significant change has been the switch to the lower repetition rate of 1 shot per minute for the Gemini amplifiers. This required some intervention from Quantel, as the EPROM software in the laser control system did not allow us to change the firing interval of the flashlamps. Once new EPROMs were installed the system performed correctly, and the time between shots can now be selected from 20, 30, 40 and 60 seconds as required for a given experiment. As part of the change to 1 shot per minute, the lamp voltages in the final rod amplifiers were increased to obtain more energy, and the 9 mm and 12 mm rods, on which the coatings had degraded, were replaced with new ones. The result was pump energies approaching 60 joules at 527 nm, outputs from the south amplifier of 21 to 22 joules, and 14 joules in the compressed pulse delivered to the target area. Measurements of the focal spot showed that the beam quality is excellent: the spot was 1.26 times diffraction limit at the focus of an F/2 parabola, with an estimated intensity within the spot FWHM of 5.6×10^{20} W cm^{-2}. This spot quality is consistent with measurements of beam aberrations made in the laser area using a wavefront sensor at the output of the amplifier.

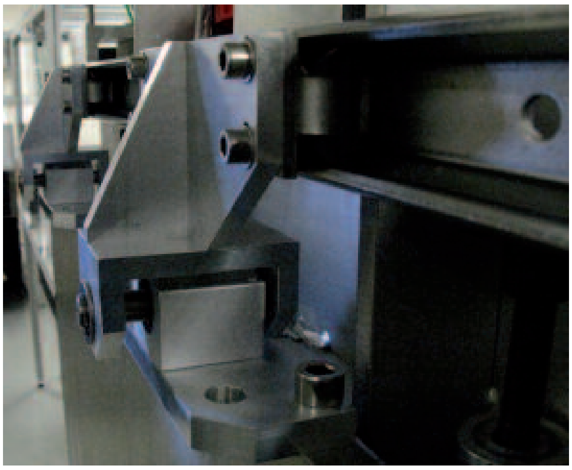

Figure 1. New door mechanism on the Gemini North compressor.

There have been some changes to the alignment procedures to make life easier for the laser operator and to improve performance. The 235 mm input mirror to the compressor is now driven by picomotors, using a joystick controller. This allows very precise alignment of the input beam direction using the far-field image at the compressor output. The remaining 235 mm mirror mounts will be motorized during the coming year.

Another change has been made to the alignment process which significantly improves the performance of Gemini. During evening running the experimenters noticed that a slow drift in beam pointing was accompanied by a lengthening of the pulse, although the movement in the far-field was not consistent with a change in incidence angle on the compressor gratings that could have caused the change. There was also evidence that the spectrum was being narrowed on the blue wing. This was interpreted as the focal spots in

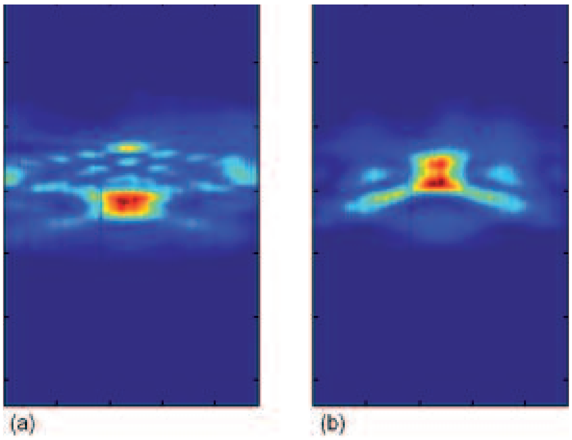

Figure 2. FROG traces illustrating the Gemini pulse compression problem, with the compressor set to optimise (a) the blue wing of the spectrum and (b) the red wing of the spectrum.

the spatial filters drifting to the edge of the pinhole, creating a plasma which partially closed the pinhole and produced the observed effect. A new alignment technique was developed which ensured the foci were correctly centred on the pinholes at the start of the day, and this appeared to eliminate the problem. The technique is described elsewhere in this report[1].

The optical arrangement inside the compressor chamber for extracting short-pulse diagnostic beams has been extensively revised during the year. The requirement is for two beams at different intensities with a ratio of around 100:1, so that the correct energies for both single-shot and 10 Hz pulse diagnostics are available. The challenge has been to derive these two beams from the 15 mm compressed beam that passes through the hole in the final mirror, and bring them out of the compressor chamber through a small, thin, window that keeps the B-integral at an acceptably low level in each case. It was also essential to minimise obscuration of the beam transmitted through the final mirror, as that beam is used for energy and beam profile diagnostics. The new configuration uses a pair of 2 mm thick windows with one surface antireflection coated to give a 1% fraction of the beam, and the remainder is sent via two full mirrors on a path that emerges through the thin window at a slight angle so the beams can be separated on the diagnostics table. The high intensity beam is used at 10 Hz (i.e. without amplification in Gemini) for setting up the compressor, for optimising the pulse using the SPIDER and for contrast measurements. This channel has too much energy for pulse diagnostics when the Gemini amplifiers are fired, but is sent to a photodiode for prepulse monitoring, and a small fraction is sent to a spectrometer. The low intensity beam has the right energy for the Grenouille at 10 Hz, and for full shots an additional filter is inserted to give an on-shot pulse length diagnostic.

Pulse compression issues

The issue that has caused most concern during the year has been the pulse duration. Measurements of the compressed pulse with the Grenouille showed the peculiar effect that only part of the pulse spectrum seemed to be compressible at any given time (Figure 2 a & b). This was confirmed with the SPIDER, which showed a relatively sharp kink in the spectral phase between 800 and 805 nm. Adjusting the compressor length produced fairly flat phase on one side of the kink or the other, consistent with the Grenouille result. The compressed pulse was around 70 femtoseconds in duration, with significant wings on either side that could not be eliminated by adjusting the compressor. Attempts to correct the spectral phase using the Dazzler were unsuccessful. Although with careful adjustment of the Dazzler settings a reasonably flat phase trace could be obtained, it came at the cost of a large degree of modulation in the spectrum which itself made the pulse longer. On further study, an alternative view of the feature emerged, that it was in fact a phase "bump" of height about 2 radians, superimposed on a smoothly-varying phase that behaved in the expected way as the compressor length was adjusted (Figure 3).

Locating the souce of this effect was extremely difficult, because the diagnosis requires the pulse to be compressed, which was only possible immediately after the preamplifier, in TA2 and in the Gemini laser area. After lengthy investigation we found that the output of the preamplifier did not suffer from this problem, and none of the later amplifiers was the cause, as the effect remained when any of them was bypassed optically. The cause was thus isolated to the optics of the pulse stretcher and the single/double pass switching system.

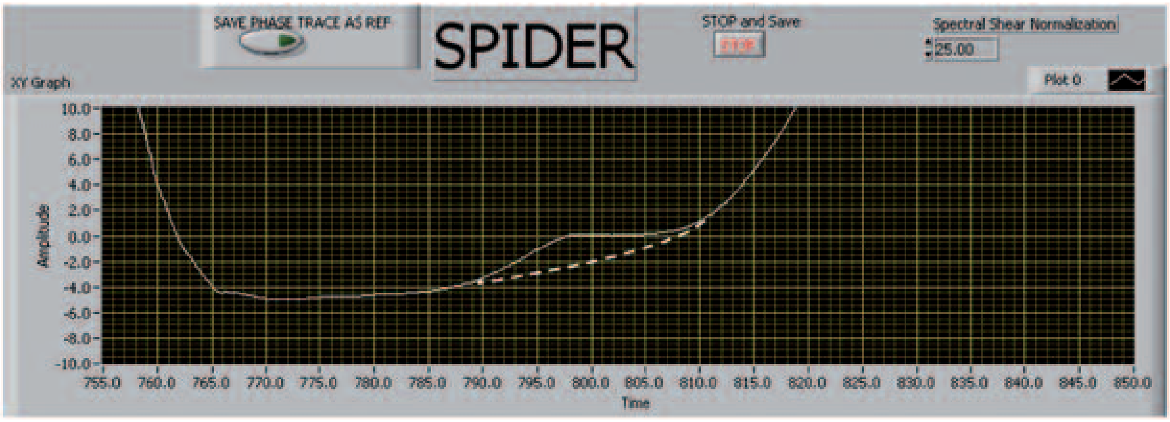

Figure 3. Spectral phase (SPIDER) trace showing the 'phase bump'. The dashed line is an interpolation of the curve on either side, showing the localised phase error.

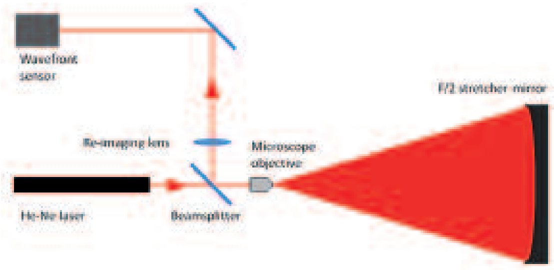

Figure 4. Arrangement for testing the large spherical mirror from the Astra pulse stretcher.

Given that the phase error was localised within the pulse spectrum, the stretcher optics where the beam was dispersed were the most likely candidates. The large grating and the plane rear mirror were tested in the interferometer, and although neither was as accurately plane as expected, there was no sign of any localised change of gradient that would produce the observed phase error. We considered testing the large (350mm diameter) spherical mirror in the interferometer, but concluded it would be extremely difficult, as its radius of curvature is 1400 mm, so the focal ratio is actually F/2. A different technique was required, which is illustrated in Figure 4. A He-Ne laser was expanded into a cone by a 40× microscope objective, positioned so its focus was at the centre of curvature of the curved mirror. The light reflected from the mirror was recollimated by the objective, and sent via the beamsplitter to a wavefront sensor (SID4). This method is a variant of the technique used for testing large telescope mirrors at their centre of curvature. The result from the SID4 (Figure 5a and 5b) showed there is a peak in the centre of the mirror surface, which we presume to be a polishing defect.

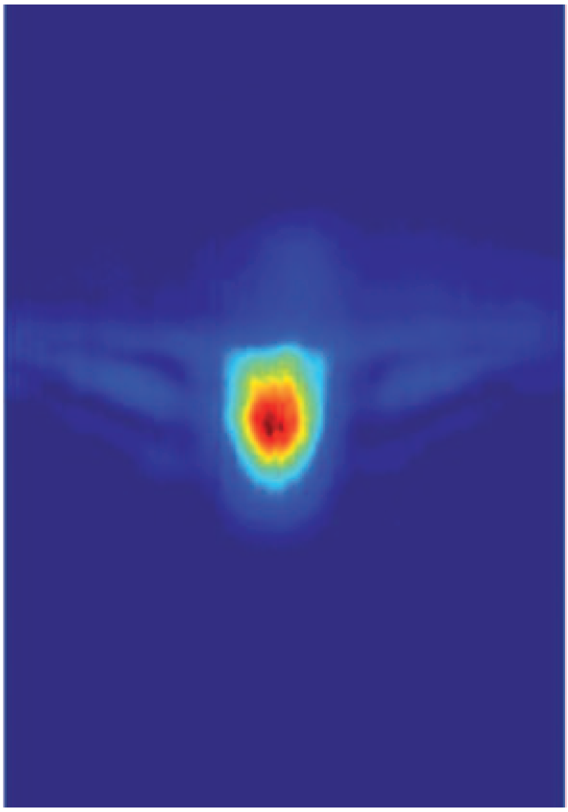

Figure 6. FROG trace of the improved pulse after changes in the stretcher.

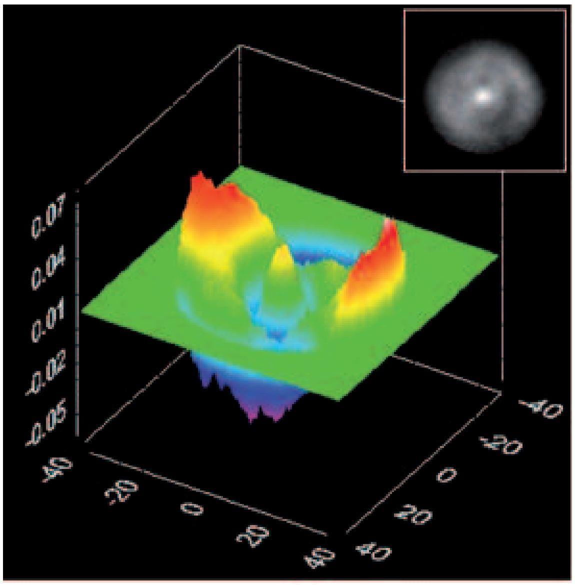

Figure 5. 3D plot of the surface of the large mirror, showing its central defect, with (inset) the SID4 image.

The height of the peak is approximately λ/25, which given that it is multiplied by four in double-stretch operation is consistent with the phase error of 2 radians measured in LA3. The original specification of the mirror is unknown, but it is unlikely to have been better than λ/10, and in fact the overall errors on the mirror are significantly smaller than that.

The observed phase bump lies in the part of the spectrum that falls on this feature in the centre of the mirror. It was therefore possible to position the spectrum on a different part of the mirror, avoiding the defect, by installing spacer blocks to raise the mirror mount by 50 mm. As the mirror is spherical, there is no preferred position on the surface, and the alignment could be restored by adjusting the tilt. This change did indeed eliminate the original phase bump, although the rest of the mirror is not especially accurately figured, and some new errors were introduced as a result. We rotated the mirror in the mount by steps of 30 degrees to find the position which gave the flattest spectral phase. After the change, the pulse could be compressed to around 50 femtoseconds, and the Grenouille trace (Figure 6) showed a significant improvement from before. Work to shorten the pulse length to its design specification of 30 femtoseconds will continue in the coming months.

Reference

1. B. Parry and K. Ertel, Pinhole alignment system for the Gemini amplifiers, pp 225-226.