Progress on the Astra Gemini project

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Introduction

In the last year there has been a huge amount of activity on the Astra Gemini project, a consequence of the design, planning and building work that has been going on since the start of the project three years ago. The year covered by this Annual Report has seen the handover of the Gemini laser laboratory and the delivery and installation of all the major items of hardware for the project. Essential changes to Astra to provide the seed beam for Gemini have been completed as well, without compromising the very successful experimental programme. Installation of vital infrastructure such as cooling and vacuum systems, the construction of specialised mounts for the compressor gratings and the build-up of the new amplifiers have all been completed. We have verified that the behaviour of the pump lasers and Ti:sapphire amplifiers is as predicted, and are well on the way to a full characterisation of their performance, with the goal of first light into the target area by July. This report describes in detail the various stages of the work carried out during the year. The authors acknowledge the important contributions made by many members of the CLF to the Gemini project, and extend their thanks to all those who are and have been involved.

Installations in the Gemini laser area

Following the handover of the laser laboratory on the first floor of R7 in April 2006, an all-hands meeting was held in the area to inform CLF staff about progress in the project and the next stages. This was the last time that the space was available for such an event, because the installation of the main amplifier tables and the compressor vacuum chambers took place shortly afterwards. Before that, the laser and target areas were surveyed accurately and sets of reference points marked on their floors and walls so the tables and chambers could be positioned with the required accuracy.

Figure 1. Lifting one of the compressor chambers into the Gemini laser area in R7.

Figure 2. The compressor chambers in place in the laser area.

Lifting the six optical table sections, each 1.5 metres wide and nearly 4 metres long, and two compressor chambers, each weighing 2.2 tons, into the first-floor laboratory was done by an outside contractor (Figure 1). The doorway into the area was made wider than normal to accommodate the width of the chambers, but even so there was little room to spare.

The chambers were positioned on their supports, which had previously been fixed to the floor in surveyed positions so that the beam port in the base of each chamber was centred above the floor penetration leading to the target area below. The installation of the chambers and tables took two days. Figure 2 shows the laser area at the completion of this stage of the installation. The mounts for the gratings and other optics will be mounted on internal breadboards with independent supports.

Infrastructure and services installation

The next few months were devoted to the installation of many of the services for the laser and target areas, in particular the vacuum and let-up systems for the three vacuum chambers, the cooling water system and the controls and wiring for the interlock system. The roughing and backing pumps are in the services area, with large-bore pipes from the chambers to ensure high pumping speed (Figure 3), while the turbo pumps are mounted next to the chambers themselves. The letup system consists of a compressor and an air tank, also in the services area. It was decided to use dry air for let-up rather than nitrogen because the volumes are relatively large, and when using nitrogen it is essential, before working inside the chambers, to ensure there has been enough gas exchange with the room air for the atmosphere inside to be breathable. The chillers providing cooling water for the pump lasers and other equipment were installed outside the building, and pipe runs made into the areas as required. The interlock system was built and tested offline prior to installation in the areas. This is a new system based on different, more secure, technology from the PC-

Figure 3. Installation of the main vacuum pipes.

based Cerberus system in use on Astra. As the interface between Astra and the Gemini laser area is a single beam line with one shutter, the interaction between the two systems is minimal, and does not cause any difficulties. It is intended to replace the Astra interlock system with the same new technology when convenient.

Installation and commissioning of the pump lasers

The pump lasers were built by Quantel SA in France, and were delivered to RAL in November 2006 after some delays due to resolving electrical noise problems. The laser tables and some of the electronic racks were lifted into the laser room by an expert contractor (Figure 4). An additional surface table was also moved into the area at this time to give some working space and to accommodate possible future laser systems: to move another table in after the pump laser installation would be extremely difficult. The original specification of the lasers required them to fire once a minute, but the upgraded version has the capability to fire a shot every 20 seconds. One consequence of this is that the second harmonic crystals and harmonic separation mirrors have to be on separate tables from the lasers themselves, increasing the footprint of the system. The four extra 45 mm rod amplifiers also require extra rack space for their capacitor banks. The cable lengths between the capacitor banks and the laser heads were specified as 6 metres, to allow the majority of the capacitors to be installed in the services area below the laser room, with the cables passing up via the floor penetrations. The racks for these capacitors are mounted on frameworks to ensure all the cables can reach the correct laser heads on the tables upstairs (Figure 5). In the final installation, all the capacitors for the 16 mm, 25 mm and 45 mm rods are in the services area, and the remaining capacitors, power supplies and cooling groups are in small racks that fit under the laser tables. Following the delivery of the components, the installation and commissioning of the lasers was carried out by engineers from Quantel over a two-week period in December.

Figure 5. Capacitor racks for the north pump laser.

Installations in the target area

The main piece of hardware to be delivered to the target area was the interaction chamber. This was constructed in two sections, of a size limited by the entrance to the area, and is made of aluminium to minimise the effects of activation. The design incorporates internal breadboards for mounting the optics and other components, and as in the compressors these are supported independently from the vacuum vessel. The chamber support frame bridges the trench in the floor that is used to bring the vacuum pipes from the services area next door. Figure 6 shows the chamber and its support frame after installation of the vacuum components in the trench below. As well as the chamber, large amounts of lead and polythene radiation shielding were installed to block the two wall apertures on the North and South sides of the room. These were built to allow future development of the facility, especially the use of the adjacent room on the north side for long time-of-flight diagnostics. Until such diagnostics are brought online the shielding will ensure the safety of personnel working in those areas.

Figure 4. The second pump laser table on the last stage of its journey to the Astra Gemini laser area.

Figure 6. The interaction chamber in position in Target Area 3.

Figure 7(a) View of the trench used for beam transport, before clearing.

Figure 7(b) Installing the lens at the output of the relay pipe.

Beam transport from Astra to Gemini

Bringing the output beam from Astra into the new laser area was a tricky problem, but the chosen solution of using the floor trench through the target area has proved successful. Many old cables and a water pipe had to be cleared out of the trench (Figure 7(a), and a vacuum relay pipe installed to carry the beam. The 1-metre concrete walls of the target area are supported by platforms built across the trench. After the pipe was installed, shielding walls of lead bricks were built around it at each side of the target area (Figure 7b). Details of the optics of this arrangement are given in another article in this report [1]. The beam path before and after the vacuum pipe is enclosed in a sealed tube that is flushed with nitrogen for cleanliness.

Amplifier construction

A 3D-CAD model of the Gemini laser area was constructed, containing all optical tables, optomechanics, and beam paths. Models for the individual components were either imported from the manufacturers' databases or, for custom made parts, from the design drawings of our in-house mechanical engineers. Figure 8 shows a section of the model containing the north amplifier table.

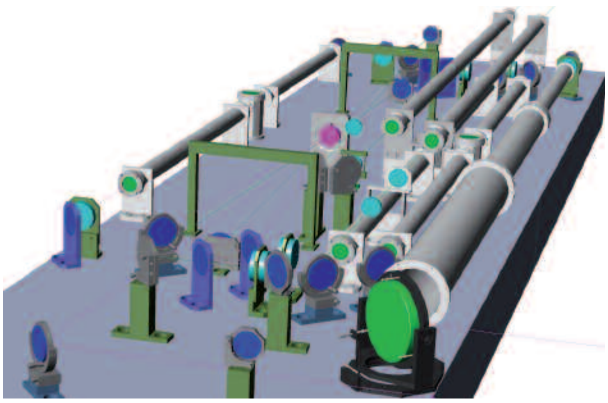

Figure 8. CAD model of the north amplifier table.

Once the design had been fixed, the optomechanical components were positioned on the tables according to the CAD model. This was done using templates which were produced by printing out 1:1 scale top view drawings and cutting out the footprints of the components. The templates were positioned on the tables using the tapped hole pattern for guidance. Fig 9 shows a photograph of the completed north amplifier table.

Figure 9. Photograph of the north amplifier table.

The initial alignment of the optics was carried out with a CW 800 nm alignment beam. A "dummy mirror", i.e. a plastic disk with identical dimensions and a mark in the centre, was used to position the beam correctly on each mount before inserting the actual mirror and moving on to the next mount. Both the Ti:sapphire amplifiers and the pump beam transport system contain vacuum image relay telescopes. The separation of the lenses in these telescopes was set using a shear-plate interferometer (Ocean Optics) to check beam collimation.

Pump laser testing

The scheme for controlling the output energy of Gemini has two parts: initially a reduction in the pump energy to one half of its maximum value (i.e. around 13 Joules per beam) and then attenuation of the seed energy while keeping the pump at the reduced level. The attenuation scheme for the seed beam is described elsewhere in this report [1]. To implement the first part of the scheme we carried out a series of tests to make sure we could control the pump energy with sufficient sensitivity.

The energy of the pump lasers is controlled by varying the timing of the flashlamps in the glass amplifiers. The original version of the control software had provision only for high- and low-energy delay settings, but it was modified at our request to include a large number of different timing configurations. These can be selected by remote control, so the energy of the laser can be adjusted in response to user demand. The eventual goal is for the control system to adjust the pump energy or seed energy using an algorithm that allows for how well both Astra and the pump lasers are currently performing, to hit the requested energy for the shot as accurately as possible.

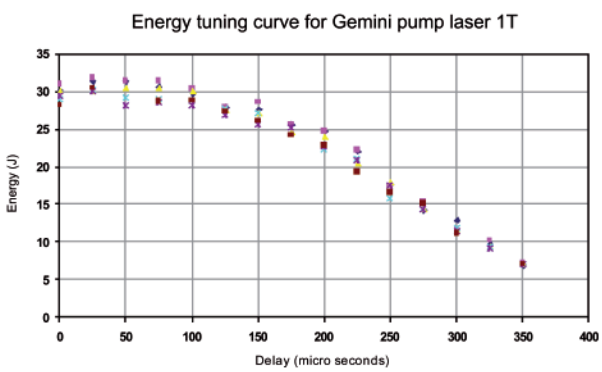

Figure 10. Example of a pump laser energy tuning curve.

For the present set of tests we simply varied the delays of the flashlamps and measured the output on a number of shots at each delay setting. Quantel recommended setting all the amplifier delays to the same value, which simplified the process significantly. The energy meter was placed in the beam reflected from a thin window, to avoid damaging the detector surface, and a correction factor was applied to give the true energy. The results for one of the beams are shown in Figure 10. The maximum energy obtained exceeds the specified 26 Joules by a comfortable margin, but there is a significant spread of points at each delay value which represents the variation in energy from shot to shot. With more experience of the lasers we realised that it takes around ten shots to establish thermal equilibrium in the laser rods, and after that the shot-to-shot variation is rather smaller. The data shown were taken during the settling period, so are not fully representative of the performance. In normal operation the lasers will be run continually at the chosen repetition rate to ensure that thermal equilibrium is maintained.

Future work

At the end of the period covered by this report, the build of Astra Gemini is making good progress. The next phase of the work involves establishing the performance of the amplifiers and testing the techniques for ASE suppression in the Ti:sapphire crystals. Following that, we will begin setting up the compressor hardware and optics and optimising the compressed pulses ready for delivery to the experimental area.

References

1. O. Chekhlov, E. J. Divall, K. Ertel, S. J. Hawkes, C. J. Hooker and J. L. Collier, *CLF Annual Report 2006-2007*.