Recent improvements to the Gemini laser

Contact *Chris.Hooker@stfc.ac.uk*

Chris Hooker, Oleg Chekhlov, Chris Gregory, Steve Hawkes, Bryn Parry and Yunxin Tang

Central Laser Facility,

STFC Rutherford Appleton Laboratory

Introduction

This article describes a number of improvements that have been made recently to the Gemini laser. They are not large-scale facility developments, and do not merit individual articles, but are worth recording here because they represent modest but useful enhancements of Gemini's capabilities.

1. Dual-wavelength CW diode for compressor alignment

Optimising the alignment of the pulse compressors has always been a delicate task when the shortest and cleanest pulse is required. If the compressor is incorrectly adjusted for some reason, or a grating has to be changed, the alignment must be repeated, and this is time-consuming. The original technique was to use the 10Hz pulsed beam from the front end at low or medium power, and adjust the tilts and groove rotations of the gratings to minimise the dispersion in both directions in the post-compressor far-field. Using two separated wavelengths makes the task easier, and in principle allows greater accuracy, as the goal is to overlap two spots rather than minimise the extent of a single spot. One way to achieve this is to place a block in the dispersed beam in the pulse stretcher so that only the wings of the spectrum are transmitted. The disadvantage is that most of the light is blocked, and subsequent amplification can lead to higher than average intensities in the amplifiers, with the risk of damage to optics. A better solution is to use a dual-wavelength CW beam, which is inherently safer for both the operator and the laser while retaining all the advantages of two wavelengths. Such a system has now been implemented on Gemini.

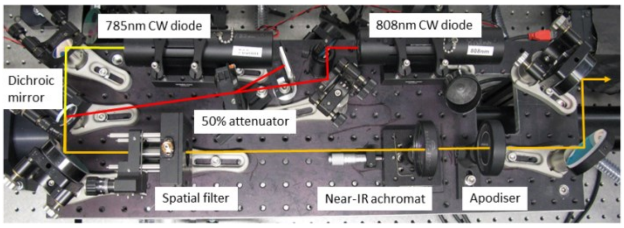

Figure 1. Photograph showing the layout of the dual wavelength CW diodes in the Gemini front end room, with beam lines indicated.

The layout is shown in Figure 1. Two CW laser diodes, of 785nm and 808nm respectively, are combined on a dichroic mirror. The beams are both focused on the same pinhole by a microscope objective, and the expanded and spatially-filtered beams are collimated by a near-IR achromatic doublet lens. The 785nm laser has a power of approximately 50 mW, and the 808nm is more powerful at 100 mW, so the unexpanded 808nm beam is attenuated by a factor of 2 by a metallic ND 0.3 filter. The rejected portion of the beam is dumped safely on a ceramic plate. The beam splitter is a short-pass dichroic mirror, so the 785nm beam is transmitted through it and the 808nm beam is reflected, onto the mirror before the spatial filter. Since the two beams are both focused through the same diffraction-limited pinhole, and the collimating lens is a 50mm diameter near-IR achromat which has the same focal length for both wavelengths, the combined output beam is collimated and contains equal power in the two wavelengths. The degree of expansion is chosen to overfill the lens, and an apodiser after the lens gives the beam a smooth edge, a nearly flat-topped profile, and reduces the diameter to 31mm to match the size of the pulsed beam at the injection points.

The location of the diode setup allows for the dual-wavelength beam to be injected into either the path to TA2 or the path to LA3, so that the beam can be used to set up the TA2 compressor as well as those in Gemini. The setup is built on a breadboard positioned at a height of around 30 cm above the table of Amp3, so that the output beam can propagate to the places where it is injected into the beamlines. The beam path at the higher level is aligned to pass directly over the two beam paths after the split between TA2 and Gemini, so that only very slight realignment is required regardless of which area the beam is being directed to. The injection is done using kinematically-mounted periscopes, located in the beam paths to the two areas.

The dual-wavelength beam is very effective for checking that the alignment of a compressor has not been disturbed, and for restoring the alignment close to optimum when a grating has been changed. The alignment sensitivity is not good enough to achieve the very shortest pulses, but it does allow the gratings to be rapidly moved into positions that are very close to optimum so that fine-tuning of the compressor with the pulsed beam can proceed. Overall there is a significant benefit in having the dual-wavelength beam available as an alignment tool.

2. New TA2 polarisers with improved throughput

Controlled attenuation of the beam into TA2 is provided by an adjustable half-wave plate and a pair of polarisers. In the original setup each polariser was a 20mm thick BK-7 plate with transmissive polarising coatings on both faces. To maximise the separation of the two polarisations the beam was incident at 72 degrees on the plates, resulting in a significant displacement which was compensated by the second plate held in the opposite orientation. The combined transmission of the plates was approximately 67%, thus a significant amount of energy was lost. The energy delivered to the target area could be increased by removing the polarisers and inserting a BK-7 block with the same optical thickness into the beam path, so the compressor length did not need to be changed. This option gave 50% more energy but the amount could no longer be controlled.

An improvement on the original setup has now been installed, using reflective plate polarisers that are much more efficient than the transmissive ones. Two polarisers are used in a dogleg configuration, and the maximum combined transmission of the pair is 95% at the maximum setting of the half-wave plate, dropping to less than 5% at minimum. The combination thus provides a factor of 20 variation in energy and has eliminated the losses inherent in the previous setup.

The layout is shown in Figure 2. The polarisers are held in custom mounts that provide rotation about vertical and horizontal axes intersecting at the centre of the face of the optic. The optical layout that feeds the beam to TA2 was modified slightly, and the waveplate was moved to a position ahead of the polarisers. The polariser plates are wedged, and when the beam is being strongly attenuated, some of the light reflected from the rear surfaces emerges, and must be blocked by the metal screens that can be seen in the photograph.

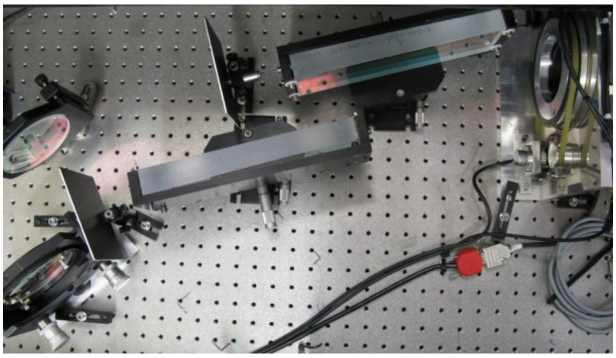

Figure 2. Layout of the new polarisers for TA2. The beam enters through the waveplate at upper right and is steered via the polarisers to the folding mirrors at left, where it is injected into the original beam path.

3. New attenuation scheme with partially-transmitting mirrors

Another improvement made to the Gemini system is the replacement of the slide-in attenuators that were used to reduce the energy in the target area for various setup procedures. The original attenuators consisted of layers of lens-cleaning tissue mounted on frames, and provided 2 or 3 orders of magnitude attenuation depending on the number of layers. The attenuation was due to scattering of the light except for small regions where the direct beam could be transmitted, so the focal spot showed a halo of scattered light, and could not be used for accurate measurements of the beam quality. However, a large degree of attenuation is essential for timing, diagnostics setup and other activities that require very low energies in the target area.
The original lens-tissue attenuators have now been replaced with partially-transmitting thin mirrors. The mirrors are only 2mm thick, but specified to a high degree of parallelism and less than 1/8-wave error in the transmitted wavefront. They can thus be inserted or removed from the beam without affecting the pulse duration, the pointing or the focal spot quality in any way. The reflectivity is slightly greater than 99% across the laser bandwidth, so each attenuator effectively gives 1% transmission. Two such attenuators can be inserted in series in the input beam to each of the Gemini amplifiers, allowing energy reduction factors of either 100 or 10^4. The reflected beams are dumped on absorbers placed outside the beam path, to avoid disturbances of the air path due to convection. The attenuated beams can now be used for focal spot quality measurements and for setting up the adaptive optics.

4. Independent fine energy control for the Gemini beams

One of the experiments performed on Gemini last year needed the capability to have fine control of the energies of the two beams independently. The normal techniques for energy control are to reduce the input from the front end, which affects both beams, and to vary the timing of the flashlamps in the Quantel pump lasers, which can be done separately for each laser and offers a degree of independent control for energy scans during an experimental run. The experiment in question needed more accurate control to be available during a shot firing sequence, and this is not possible with the Quantels because the laser energy variation via the target area control program is not well-calibrated.

The chosen method was to install a rotatable half-wave plate and polariser in each beamline, in order to provide the required degree of control on the attenuation. These components were placed immediately after the final pass of the Ti:sapphire crystal. At this point the beam is still 50mm in diameter, but the energy is a maximum. Attenuating the beam elsewhere in the amplifier is less effective because gain saturation makes up most of the losses due to the attenuation. In this new mode the Quantel pump lasers were operated at a constant (usually maximum) energy. To fit the new components in the space available, the beamline had to be modified as shown in Figure 3. The space at the end of the amplifier table was used for the additional optics, and the mirror before the 3x beam expander was moved further from the input lens. The polarisers are reflective types, working at 72 degrees incidence, and in the layout shown the mirror before the polariser has to work at 27 degrees incidence. This is not the optimal angle for mirrors that are designed for 45 degrees or 0 degrees, as the majority of our optics are, so some customised mirrors were purchased that work efficiently at the required angle.

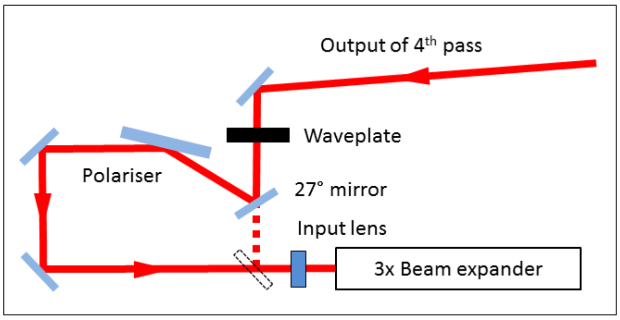

Figure 3. Output section of a Gemini amplifier showing the new (solid line) and old (dashed line) beam paths, and the integration of the energy-control waveplate and polariser.

The motion stages have been network-enabled by use of a cgi-bin Python script, and each can be controlled via a custom application run at the point of use. Figure 4 is a screenshot of one of the applications. Users and Operators can set a specific orientation for the stage, or "jog" it to pre-set positions corresponding to percentage transmissions of the wave plate. The application is also integrated with the Gemini shot number broadcast system so that wave plate orientations can be recorded on-shot. The software records the stage positions, i.e. waveplate orientation rather than transmission; typically in each experiment the waveplates are calibrated to give a conversion table between orientation and energy.

Figure 4. Screenshot of the waveplate control app, showing the controls for setting the stage position, and the buttons for the preset positions.