Operational improvements to the Gemini Facility 2018-19

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Introduction

This article describes several modest improvements that have been made to the Gemini facility as time permitted during the year. Individually these do not merit separate articles but they are nevertheless worth recording, as they have beneficial effects on the usability and the overall performance of the facility.

1. Trial of new drive system in the Gemini south compressor

The optical components inside the Gemini pulse compressors are not accessible during normal operations because the chamber has to be under vacuum. To allow for adjustments, all the mounts are motorized, and the motors are driven from an external driver system. The software was written while Gemini was under construction in 2005 – 2007, and for compatibility the hardware used was common to other parts of the CLF. The components that are adjustable are the two gratings, the retro-reflecting mirror or back mirror, two folding mirrors and the final mirror that sends the beam down to the target area. The drive system handles the motions of the grating and back mirror mounts, a total of nine motorized movements in each of the two compressors.

The compressors are not adjusted very often, but their stability is critical for operations. In recent years, problems have developed with parts of the hardware and in some cases the control software as well. The most typical fault was that while the operator was attempting to make a small change of perhaps a few tens of microns to the overall length of the compressor, the motor would sometimes move the full range of the adjustment at maximum speed, stopping only when the limit switch was reached and leaving the compressor in an unusable condition. To recover from such an event, the operator would have to drive the grating back to approximately its original position, make fine adjustments to the beam pointing, then measure the pulse duration and repeat the positional adjustment until the pulse length was back to its original value. This process could take an hour or more to complete, resulting in lost experimental time and placing an unnecessary burden on the operator. The original author of the software had left the laboratory, so the reason for the unwanted behavior could not be diagnosed.

In the autumn of 2018, a version of a new-style drive system was installed on the Gemini south compressor chamber, which was the one experiencing the most frequent faults. The new system used the same motors and in-chamber cables as the original, but new external cables were installed, along with a new user interface screen and control hardware. The old system was left in place, so it would be easy to revert to it in the event of problems by simply plugging the old set of cables back into the chamber lead-through ports.

The new system is driven through a touch-screen, and provides the same functionality as the previous system, although with less elaborate graphics. The image in Figure 1 shows the controls for grating 1 and the status displays associated with it. The three controls allow the grating to be rotated around horizontal and vertical axes (pitch and yaw) and also in its own plane (groove rotation). Motions can be made either relative to the current position, or to absolute positions determined by calibrated step counts. The position of each drive is shown on the xyz diagram at the top of the page, and can also be found from the displayed step counts.

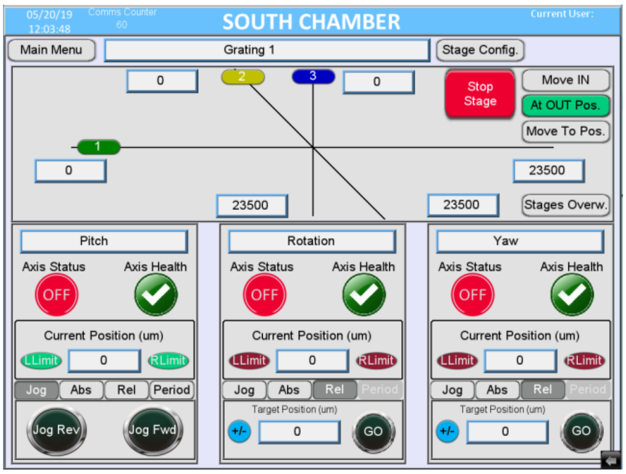


Figure 1. Screenshot of the control interface of the new drive system for the Gemini south compressor.

As with the original system, the operator selects a drive from a menu, activates it and can then use the relative or absolute motions to drive the device to the required position. When the system was installed the limits of each motion were established and recorded one at a time, with the alignment being restored by re-pointing the CW alignment beam to a reference position after each setting. This allowed the new system to be set up without the need to realign the compressor from scratch.

Experience with the new system has been very positive so far. It has worked as required on every occasion it has been used, and there have been no un-commanded drive events like the ones which caused problems with the previous system. The interface is simple and intuitive, so even though it is used rather infrequently, the operators have found no difficulty in making the necessary adjustments to the compressor when required. We plan to expand the scope of the system to include the steering mirrors inside the compressor and the drive-in diagnostic mirror, and subsequently to transfer the control of the north compressor to a similar system.

2. Attenuating the Gemini beams with no timing change

The ability to attenuate the 5 Hz beams delivered to the target area is important, especially during the setup and alignment phases of any experiment. The Low-Power configuration used for setup is still, in some cases, too energetic for sensitive diagnostics such as photodiodes, so a means of reducing the energy further has always been needed. Initially the attenuators consisted of layers of lens tissue, mounted on slides that could be moved into the beams at the input to the Gemini amplifiers. A single layer of tissue attenuates the beam by a factor of approximately 10, but stacking more layers does not give the same effect as stacking neutral density filters, so the attenuation factor for multiple layers was determined empirically.

The main drawback with the use of tissues in this way was that a region around the focal spot was illuminated with scattered light, in a circle corresponding to the image of the limiting pinhole of the VSFs in the amplifier. The focal spot was also significantly degraded, which made it more difficult to optimize the spot using adaptive optics. For these reasons, the tissues were replaced several years ago by beam-splitters that transmitted around 1% of the energy. These were 2 mm thick fused silica plates, made to be accurately parallel, and with the partially-transmitting coating on one face and a high-quality antireflection coating on the other. This eliminated the scattering around the focal spot, and also allowed the use of adaptive optics at any power level, as there was no degradation of the focus.

If the two beams required different levels of attenuation for some process, one beam might have two plates in the beam line, and the other only one. Using such a configuration for relative timing of the F/2 and F/20 beams, the timing changed when the attenuators were removed for full energy shots. Consequently, a further adjustment of the relative timing had to be made based on the thickness of the plates. The plates were not specified to be of equal thickness, so the correct zero-delay position had to be re-established by trial and error, which was time-consuming, and could involve using up targets that were intended for the experiment.

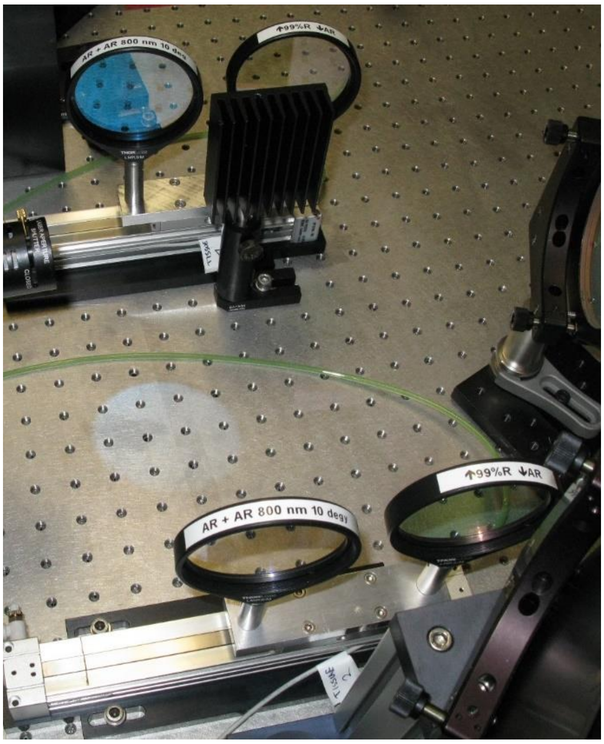


Figure 2. The two pairs of thickness-matched attenuators at the input to the Gemini south amplifier, in the non-attenuating configuration. The beam travels from top to bottom through the left-hand plate of each pair. The square black object near the top is the beam dump for the second set of attenuators.

Recently, following a request from one of the experimental groups, a new set of attenuators has been installed which overcomes these problems. A batch of twelve fused silica substrates was finished by double-sided polishing so that all were the same thickness, measured at 4.058 ± 0.001 mm. Five were coated with a 99% reflecting coating on one surface, and an anti-reflection coating on the other. The other seven substrates were anti-reflection coated on both faces to act as compensating plates. One of each optic is mounted on each attenuator slide, so that the 99%R/AR plates are in the beam path for reduced-energy operation, and the AR/AR plates for normal operation. Each beamline has two such slides, so the plates can provide attenuation factors of zero, 100x or 10,000x in each beam. As before, the coatings are designed for a 10 degree angle of incidence so the reflected beams from the attenuator plates are dumped safely away from the beam path.

The 99% coating has more layers and, according to the coating supplier, the extra thickness is equivalent to 2.65 microns of fused silica, which is more than the variation among the different substrates. To correct for it, the compensator plates were mounted at an angle of incidence 0.43 degrees greater, relative to the beam, than the attenuators. The optical path through the compensating plates is thereby increased by an amount equal to the extra coating thickness of the attenuators, so the time delay introduced by each component is the same. Assuming a worst-case variation within the thickness tolerance for the two substrates on each slide, the maximum timing change between the two beams following a switch from full attenuation to no attenuation would be no more than 15 fs, which is one third of the pulse duration. Other factors typically prevent the mutual timing of the beams being maintained more closely than that.

The change described simplifies the conduct of dual-beam experiments, because the experimenters can now work with any combination of attenuated or unattenuated beams without needing to adjust the relative timing of the beams. The duration of the compressed pulse is also unaffected by changes of attenuation, because the beam path contains the same thickness of optical material at all times.

3. Replacement of the pump beam field lenses

The near-field profiles of the Quantel lasers that pump the Gemini amplifiers are very non-uniform, with peak-to-valley intensity ratios of around 5 or more [1]. To avoid damage to the pump distribution optics and the Ti:sapphire crystals, it has been necessary from the start to homogenize the beams, and initially this was done with customized homogenizers made by Silios Inc., which gave a high-order super-Gaussian profile at the crystal. The homogenizers are placed in the collimated pump beams, and followed by field lenses calculated to yield the required size of beam at the Ti:sapphire crystal: the focal length needed in the Gemini amplifiers was 4.66 metres. The homogenizers are diffractive elements, so they produce multiple diffracted orders, although all except the desired -1 order are very weak, containing at most 1 – 2 percent of the energy.

The efficiency of the homogenizers was measured at nearly 90% when they were first installed, but this gradually degraded, and eventually they were replaced with a different type of homogenizer, which works by refraction rather than diffraction. The efficiency is higher, because the refractive plates do not distribute the light among multiple diffracted orders, but the profile of the homogenized spot is further from a top-hat shape, so there is significant energy roll-off at the edges. This affects the size of the fully-pumped region in the crystal and the energy extraction from the amplifier.

Initially, field lenses with the same focal length as before were used, but this was unsatisfactory because the characteristics of the beam required a longer focal length. Some tests with slightly different focal lengths were inconclusive, and it was realized that optimizing the performance would require trials with multiple different lenses, which would be expensive and time-consuming.

As an alternative, it was decided to use lens pairs, chosen so that the separation of the two lenses allowed for a wide range of effective focal lengths. Focal lengths of 900 mm and -1000 mm at a separation varying from 55 mm to 140 mm resulted in a focal length that could be varied between 5.8 and 3.75 metres, a range that included the original value but allowed for significant change in either direction. The two lenses are mounted in separate holders on a dovetail slide, so the spacing can be changed to be anywhere within the designed range. The entire slide can be repositioned on the amplifier table so that the Ti:sapphire crystal is at the focus of the lens pair as required for correct operation of the homogenizer. The setup in one pump beam of the Gemini north amplifier is shown in Figure 3. The beam passes through the negative lens first and then the positive, then finally through the homogenizer plate. The lenses are oriented to ensure that any back reflections are divergent, to minimize the risk of damage to other optics in the beam path.

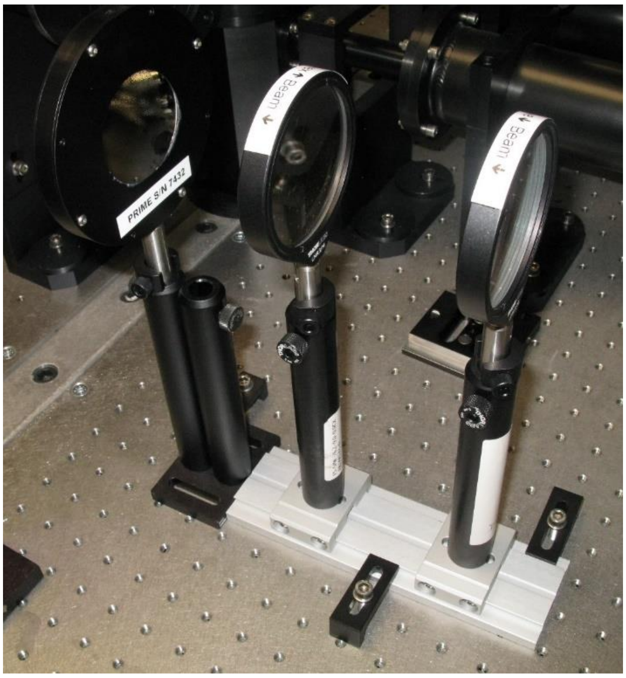


Figure 3. The new lens pair in one pump beam of the Gemini north amplifier, next to the PRIME beam homogenizer. The spacing of the lenses can be adjusted as described in the text to vary the effective focal length of the combination. The beam travels from right to left through the lenses and the homogenizer, then propagates about 4.6 metres to the Ti:sapphire crystal.

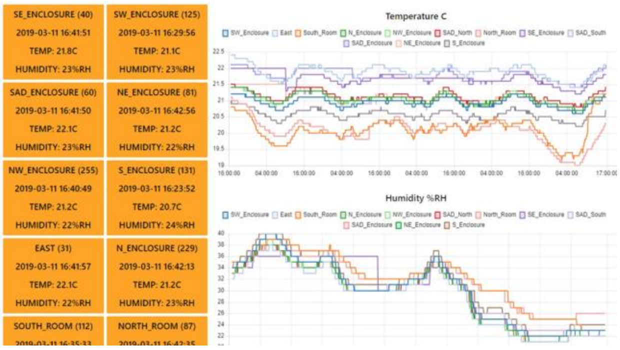
The new lenses were first installed in the north amplifier, where they have worked satisfactorily, but time constraints have so far prevented the same change being made in the south amplifier. [Note added in proof: the final sets of new lenses were installed in the Gemini south pump beams in October 2019.]

4. Improved temperature monitoring for Gemini

In a recent CLF Annual Report [2] it was suggested that temperature gradients within the laser area may play a significant role in the temporal drift between Gemini's North and South beams. A diagnostic has been constructed which allows accurate monitoring of the relative timing of the beams in LA3 [3]. Similar measurements have been made in TA3 which show a fluctuation in relative timing that appears to correlate with the air-conditioning cycle. At the time of those measurements the temperature monitoring was very limited, which is why a better monitoring system was developed.

Prior to the installation of the system described here, the temperature in the laser room was recorded with two sensors located at opposite ends of the room, and temperatures were logged in eCat. The new improved temperature monitoring system consists of 12 sensors distributed around LA3 along the beam paths and on each of the North and South sides of the room. These communicate via radio signal to a receiver connected to a raspberry pi. Each sensor was calibrated against a temperature reference sensor.

An application was written in Javascript to display and log temperature and humidity recorded by the sensors. Figure 4 shows real time information accessible from a web page; the temperature and humidity are displayed on separate graphs allowing easy comparison of temperature differences around the room.



SE_ENCLOSURE (40)
2019-03-11 16:41:51
TEMP: 21.8C
HUMIDITY: 23%RH

SW_ENCLOSURE (125)
2019-03-11 16:29:56
TEMP: 21.1C
HUMIDITY: 23%RH

SAD_ENCLOSURE (60)
2019-03-11 16:41:50
TEMP: 22.1C
HUMIDITY: 23%RH

NE_ENCLOSURE (81)
2019-03-11 16:42:56
TEMP: 21.2C
HUMIDITY: 22%RH

NW_ENCLOSURE (255)
2019-03-11 16:40:49
TEMP: 21.2C
HUMIDITY: 22%RH

S_ENCLOSURE (131)
2019-03-11 16:23:52
TEMP: 20.7C
HUMIDITY: 24%RH

EAST (31)
2019-03-11 16:41:57
TEMP: 22.1C
HUMIDITY: 22%RH

N_ENCLOSURE (229)
2019-03-11 16:42:13
TEMP: 21.2C
HUMIDITY: 23%RH

SOUTH_ROOM (112)

NORTH_ROOM (87)

Figure 4. Web page displaying real-time measurements of temperature and humidity in the Gemini laser room.

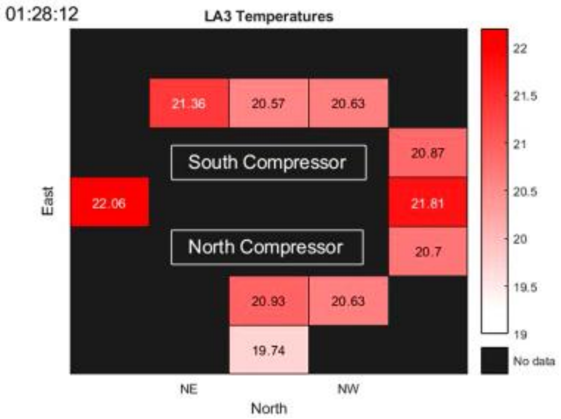


Figure 5. Heat-map showing the approximate positions of the sensors in LA3 and the temperatures recorded.

Since the monitoring system was installed there has not been an opportunity to investigate the suspected correlation between the temperature variation and the relative timing of the beams. This will be done when facility access time allows.

References

1. K Ertel *et al*, Optics Express **16**(11), p 8043 (May 2008)
2. R.J.Shalloo, CLF Annual Report 2015-16, p32
3. N Bourgeois, CLF Annual Report 2017-18, p29