

New CLF Adaptive Optics Development Lab

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Introduction

Adaptive optics systems to correct wavefront aberrations are a vital part of large high power lasers such as Vulcan. In order to achieve the highest on target intensities, a close to diffraction limited focal spot is required. The CLF has previously developed 150 mm aperture bimorph mirrors for the Vulcan Petawatt upgrade^[1] and fabricated monolithic mirrors up to 250 mm diameter^[2].

The full experimental schedule of the high power lasers leaves little opportunity for AO trials on the systems themselves. To facilitate the ongoing development program, a new permanent, dedicated lab has been established. We will be investigating new designs for high damage threshold dielectric coated mirrors, integration of existing systems with new commercial software; ‘sensorless’ AO for direct focal spot optimisation and the offline testing and verification of system spares.

Design

The setup in the development lab is designed to emulate some of the conditions of the large high power lasers; large beam size, long propagation distance and spatial filtering between the adaptive mirror and wavefront sensor. To this end, the beam diameter is variable up to 150 mm diameter, the total path length is ~10 m and there is an optional 4f telescope with pinhole to investigate the effects of spatial filtering. There is a diagnostics suite comprising a commercial Shack-Hartmann wavefront sensor (HASO – Imagine Optic), and cameras for the near field (NF) and far field (FF). Both the HASO and NF cameras are placed in conjugate planes of the AO mirror. The FF is magnified to show details of the focal spot image. The full optical layout was designed in 3D CAD software, shown in figure 1.

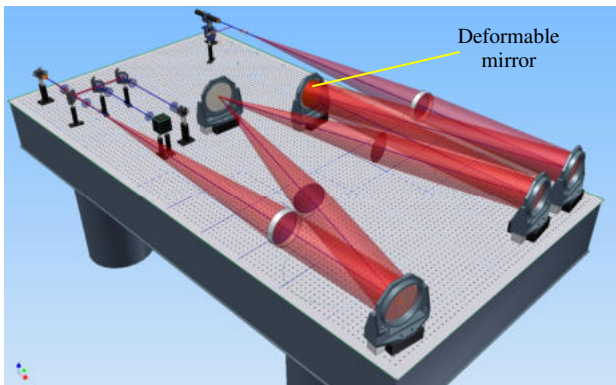


Figure 1: The optical layout of the new AO development lab

The new lab includes visible (635 nm) and infrared (808 nm) CW laser sources which are injected through a diffraction limited spatial filter before being collimated using a simple plano-convex singlet at 150 mm diameter. Protected silver coated mirrors are used due to their high reflectivity at these wavelengths. The 808 nm source is for the testing of new

dielectric coated adaptive mirrors for Astra-Gemini, described later in this article.

Initial tests

The first challenge was the integration of the existing home made deformable mirror and driver with new commercial software (CASAO – Imagine Optic). This is intended to replace the current software, written in house over ten years ago and no longer actively supported. One of the spare gold coated, 150 mm Vulcan mirrors was used with the 635 nm source. Initial tests revealed that the mirror was unable to compensate its own defocus, implying that the curvature was greater than the stroke of the piezo ‘actuators’ at the maximum voltage applied. It is unknown whether this was originally the case, or has developed while the mirror was in storage. It was possible to overcome this problem using the bias feature on the driver, which applies an additional voltage offset across all the piezo elements, imparting extra static curvature to the mirror. With this, the new setup was successfully able to correct the focus, as shown in figure 2. The HASO measured 0.17 waves p-v wavefront distortion.

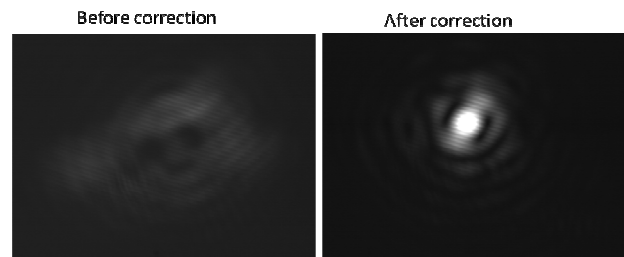


Figure 2: Focal spot correction using the existing Vulcan adaptive mirror in the new lab

Dielectric AO development

The use of deformable mirrors in CLF high power lasers is currently limited by the metallic coating. Gold was chosen for its high reflectivity at the 1053 nm wavelength of Vulcan, but the laser damage threshold (LDT) is typically only a few 100s of mJ cm^{-2} . Dielectric coatings have significantly higher LDT, but the large internal stresses can easily deform the thin AO substrate by more than it is able to correct.

A successfully functioning dielectric AO would be able to replace the static astigmatism correctors^[3] currently used on the Vulcan TAW 500 J, 10 ps beamline^[4] and in Astra Gemini. In the latter case, it is not the fluence that limits the use of AO, but the high repetition rate. The reflectance of silver over the bandwidth of Astra is >98%, but at 10 Hz the absorbed power is sufficient to heat the mirror, causing additional deformation which the mirror then corrects. When the 10 Hz alignment beam is shut off in preparation for a shot, the mirror is no longer heated, and relaxes to a state of different curvature. However, the 10 Hz beam is no longer present on the wavefront sensor, so the AO system is unable to correct the change in curvature. The single laser pulse that is fired for the high-energy shot is not focused at the same point as the alignment beam, resulting in a

failed shot. With the development of new multi-Petawatt lasers, such as the proposed Vulcan 10 PW, and high peak & average power sources such as DiPOLE^[5]; high LDT, high reflectivity deformable mirrors will be increasingly important.

Previous attempts to produce a dielectric AO have explored reduced stress coatings deposited at lower temperatures^[2]. On a standard 50:1 aspect ratio substrate this still resulted in curvature averaging 7.5 waves. Attempts were made to produce pre-compensated substrates, figuring in the opposite amount of curvature in the polishing phase. The flaw in this approach was the inconsistent amount of curvature produced by a coating, making it impossible to accurately cancel the effect.

The new approach being tested is to coat both sides of the substrate with the same coating. Since the stresses should be balanced, this has the advantage that standard high LDT (and hence high stress) coatings can be used. The adhesion of a piezo slice to dielectric coating has been checked, no delamination of the substrate, coating and piezo was seen even under load. Several 3" and 150 mm diameter mirrors with TLMB coatings (CVI Melles-Griot) are currently being manufactured for use on Astra-Gemini; we aim to test the completed AOs in the coming months. A prototype mirror is shown in figure 3, The piezo has been bonded to the rear surface and ground to required thickness, but the electrode pattern has not been added.

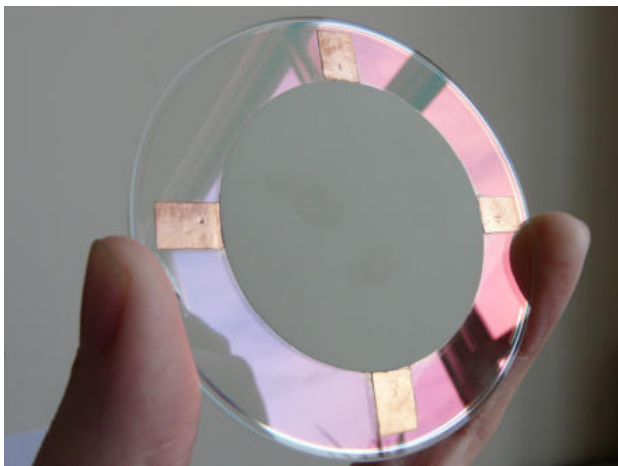


Figure 3: A prototype of the 3" diameter, double sided dielectric coated adaptive mirror.

Conclusions

A dedicated lab has been established for adaptive optics development and testing. Features include: up to 150 mm beam diameter for testing large AO mirrors, long path length and optional spatial filter to simulate conditions in the CLF's high power lasers, a diagnostics suite with wavefront sensor, near and far-field cameras.

Initial tests on existing 150 mm gold coated deformable mirrors with new commercial software were successfully completed. New hardware, software and system spares can now be tested offline before integration into Vulcan.

A new design of double sided dielectric coated mirror has been devised, allowing the use of high damage threshold, high reflectivity coatings. If successful this will allow the operation of adaptive optics at significantly increased fluences. It would also permit their use on high repetition rate lasers such as Astra-Gemini.

References

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2. C Hooker *et al* – Adaptive optics development in the EU OTTER programme – CLF Annual Report 2005-06, p202
3. C Hernandez-Gomez *et al* – An overview of the Target Area West short pulse upgrade – CLF Annual Report 2007-08, p260
4. S Hawkes *et al* – Characterization and correction of the Gemini wavefront – CLF Annual Report 2010-11
5. K Ertel *et al* – Current status of the DiPOLE project – CLF Annual Report 2010-11