Automatic alignment system testing for Vulcan

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Introduction

The Vulcan laser has many beam paths, all of which are complex systems. There are small, but important, instabilities as a result of this complexity, and the susceptibility of infrared lasers to thermal and vibrational variations. The result of this is that the laser operators must spend time each morning realigning the system, to a greater or lesser extent, before the quality of the beam is good enough to be used in experiments. In order to minimize the operator time spent re-aligning the beam paths in the laser, and thus improve its throughput, an automatic alignment system was designed. The eventual aim is to have the system implemented throughout the laser, running in the morning and throughout the day, thus removing one of the main drains on operator time.

Experimental Design

In order to align a beam automatically, one needs a sensor to identify the beam's position, a reference position for the ideal alignment, and a method of moving the beam to the reference position. Many methods exist for facilitating this procedure[1)], but the most effective for this application was identified as the use of a Quadrant Photodiode as the sensor, and New Focus Picomotor[tm] actuators to move the mirrors, with an in-house LabVIEW program to link the two.

The Quadrant diode[2)] is essentially a normal photodiode, split into four quadrants, with an output from each quadrant. Since the output from each quadrant is proportional to the amount of energy incident upon it, and the cross-section of the laser beam is known, it is easy, using a simple summing amplification circuit, to work out the beam position. The diode is placed so that it takes the leakage through a highly reflective mirror, in such a way that the leaked beam is central onto the diode when it is well aligned through the system, giving a reliable reference point to bring it back to.

The Picomotors (figure 1) are piezoelectric stack-driven screw actuators, which rotate slowly (<2RPM) but have very high resolution, making them useful for highly accurate alignment. They operate on a stick/slip principle, so that when the piezo is extended or contracted slowly, the screw turns, but when it is moved fast, the inertia of the screw keeps it where it is. Thus a sawtooth electrical current can be used to move the screw in the clockwise or anticlockwise direction.

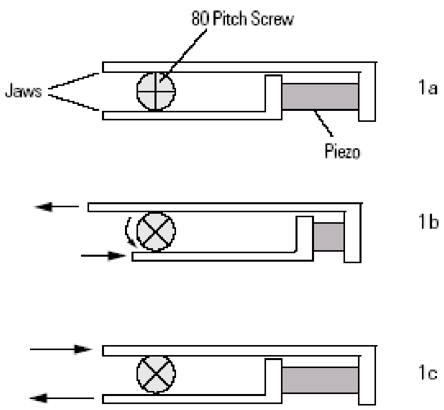

Figure 1. Picomotor operation.

The LabVIEW program tells each actuator to take a small step, checks whether the total energy on the diode has increased, indicating whether the beam has moved towards or away from the centre of the diode, then instructs the actuators to move in whichever direction takes the spot towards the centre. The speed of the movement is decreased as the beam approaches the centre, to avoid undue oscillation around the central point. When the beam is centred to a preset degree of accuracy, the program stops itself. It has a failure mode to recognize if the beam is not on the quadrant diode at all, which would indicate either a very serious misalignment somewhere, or, more likely, something obstructing the beam. If this happens the program stops itself and brings up an error message to alert the duty operators that something major is wrong. Each picomotor driver unit can drive up to three picomotors, for the operation of, for example, a gimbal mount. The drivers can be 'daisy chained' together, and the program easily adapted, so that the system can align the beam onto quadrant diodes throughout a beamline, one mirror at a time, starting at the beginning.

In order to accurately align the beam in three dimensions, two actuated mirrors and sensors must be used, to centre the beam, and then point it through the system (figure 2). A test bed was designed using a CW laser, with two ready-made picomotor-actuated one-inch mirrors and two quadrant diodes, with a long beam path, to test the system over the sort of distances likely to be encountered in Vulcan itself. The first actuated mirror was set up to centre the beam onto the second mirror, which then pointed it through the rest of the optical system to the final Quadrant Diode. Near-field and Far-field cameras were set up to monitor the beams in a similar fashion to the Vulcan diagnostics, so an indicator of the degree of misalignment that could be dealt with could be obtained.

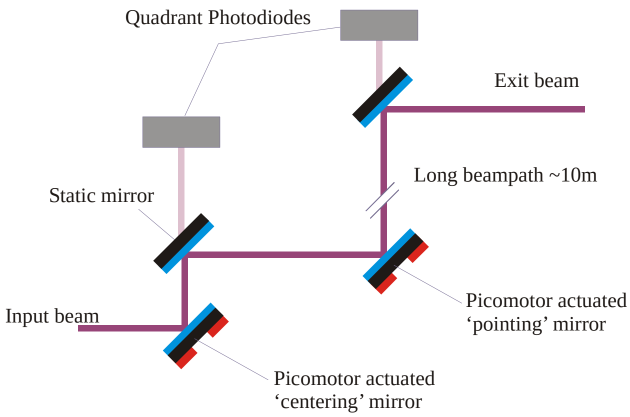

Figure 2. Alignment technique.

The system is eventually going to be widely incorporated in the laser, to control as many of the 'unstable' mirrors as possible, but, after consideration of the options, it was decided that the first place for installation would be the sliding mirror in LA4[3)]. This mirror is used for the LA4 CW alignment beam to Target Area Petawatt, and regularly loses its alignment due to vibration and shocks from the sliding mechanism, requiring operator intervention to realign it. This mirror has low damage potential to the laser system, since it is not in place during shots, and as a result only deals with the low power (200mW) beam, from the alignment laser. It is also highly monitored by near- and far-field diagnostics, making it easy to both monitor the movement of the beam, and to retrieve the alignment of the beam, should something go wrong. The combination of the regularity of its misalignment and the low damage potential of any problems, make it the ideal mirror on which to begin the system implementation. It is also at the largest size of any mirror in the Vulcan system, so if the actuators can move this mirror accurately and in a reproducible fashion, they can efficiently operate anything else in the system.

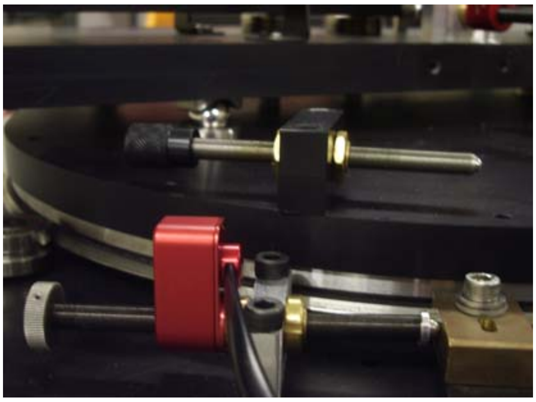

Figure 3. The manual (black) and Picomotor (red) actuators for the LA4 mirror.

A test bed (Figure 4) was designed to replicate the optical setup in LA4, due to some differences in the system to that already tested. The LA4 setup had a 6mm beam expanded up to 180mm, propagated through a short system, including the sliding mirror, then focused back down to 6mm in the Adaptive Optic sensor channel, where the quadrant diode was to be sited. The test bed used the same CW laser as the original test system, expanded, reflected off of a large mirror and focused back down to 6mm, before being pointed onto a quadrant photodiode. The Picomotors replace the manual screw actuators on the mirror mount, and the far-field of the beam is monitored with a CCD camera, to provide a visual indication of the beam position in the fashion used for the LA4 alignment.

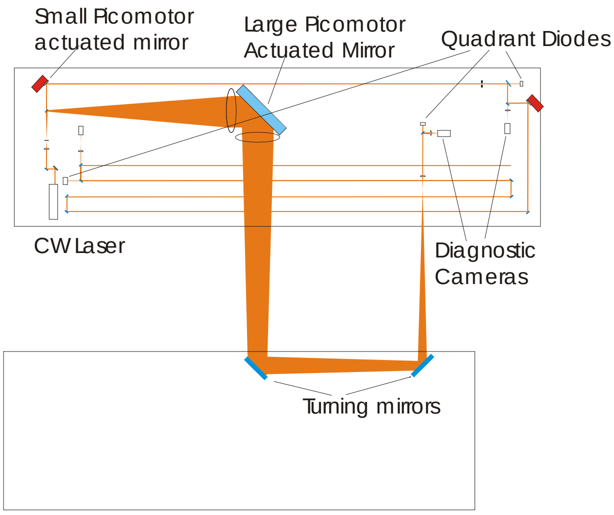

Figure 4. Test bed showing both small and large beam systems.

In order to test the capability of the system to function reliably in Vulcan, an electrically and magnetically hostile environment, a small setup was created using a leakage from the actual LA4 local alignment laser, reflecting the beam off of a small actuated mirror, into a quadrant diode, with all the outputs monitored, and a CCD camera monitoring the beam's position in real time, to give a comparison between the position as indicated by the Quadrant Diode and the actual position of the beam. The camera's output was recorded while the 208mm disc amplifiers were fired, to see if the mirror or quad cell were adversely affected. No area of Vulcan is more hostile than this, since the set up was in close proximity to the largest amplifiers in the laser, so it was a harsh test. The next stage of testing will be to modify the test bed still further, to existing plans that will simulate all of the major parts and layouts in the Vulcan laser, to test exactly where it will be feasible to implement the alignment system, and make sure that none of the more unusual components, such as the Vacuum Spatial Filters, cause unforeseen problems for the program. Based on current performance, no errors are expected, but it needs to be tested.

In the future, the aim is to implement the system as widely as possible in the laser. Once the LA4 system is installed, the next target will be the main laser area CW alignment system, and then the injection mirrors for the other oscillators. It should be possible to use the system for alignment using the retro reflectors on the double-passed disc amplifiers as well, another area of the laser that often needs alignment, although less regularly than the various injection mirrors. This has not yet been tested. The other big target for automation would be the mirrors on the 'down periscope' sending the laser from LA3 to LA4 to go to TAP, but the mirror mounts currently in use there are not of a sort that can be fitted with picomotors.

Conclusions

The system has demonstrated fast, accurate automatic alignment of both large and small aperture laser beams. The program was designed to be as adaptable as possible so that it could be tuned to give the best results in any given optical arrangement. Both systems were shown to be capable of aligning the beam more accurately than an operator could, in a similar time, and from a larger displacement of beam than is usually encountered in Vulcan. The system is capable of operation by remote desktop, so that the control computer can be left inside the Laser Area, and the program can be initiated from the Main Control Room, removing the need for operators to enter the Laser area themselves to perform alignment duties, and speeding up the set up and operation of the laser. Ideally the program will eventually be triggered automatically by the control system of Vulcan as soon as the mirror slides in, so no human intervention is needed.

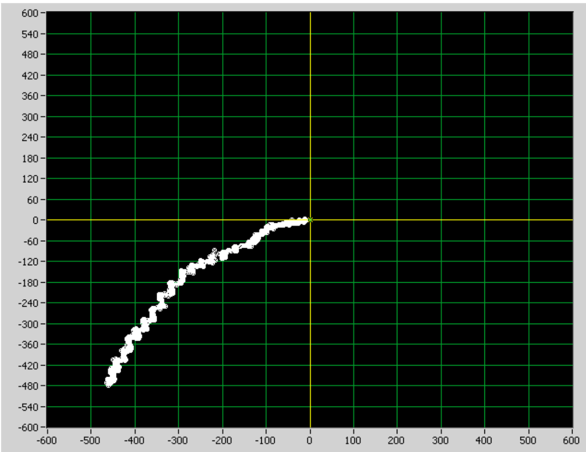

Figure 5. Program output showing alignment from bottom left to centre. Scale is in microns.

References

1. S. Grafstrom *et al.*,
Opt. Comm. 65(2), 121 (1998)

2. Paul Sharman
'Position sensing with photodiodes' Advanced Photonix, Inc. Online article for *Laser Focus World*

3. S. Hawkes *et al.*,
Laser Area 4 Beam delivery and Diagnostics commissioning, CLF Annual Report 2001-2002