Troubleshooting an Adaptive Optics System

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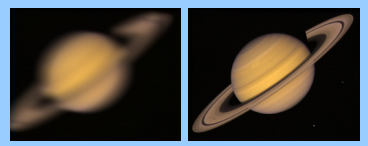
What Is Adaptive Optics?

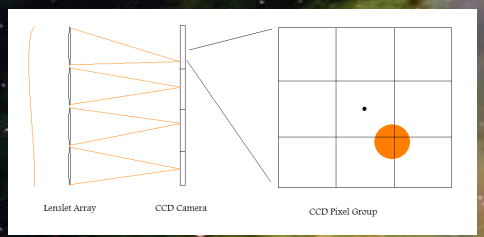


Without Adaptive Optics With Adaptive Optics

When light from Saturn reaches Earth, the wavefront of its light is flat. Once the light travels through the atmosphere, the wavefront is no longer flat. Things such as temperature differences in the atmosphere act like tiny lenses and distort the wavefront. Adaptive Optics (AO) uses hardware to improve the performance of optical systems by correcting the distortion caused by these tiny lenses.

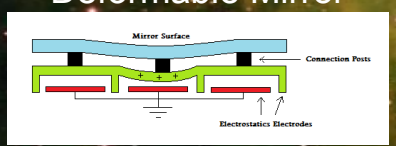
Adaptive Optics Hardware

•Shack-Hartmann Wavefront Sensor



The wavefront sensor measures the distortion of the incoming wavefront. An array of tiny lenses is placed in front of a CCD camera. Each lenslet is associated with a group of pixels. The deviation of the spot of light from the center of the group of pixels corresponds to the slope of the wavefront in that region.

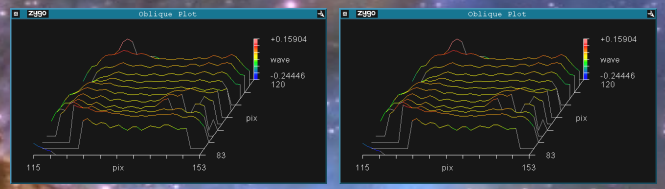
•Boston Micromachines Deformable Mirror



An array of electrostatic membranes are used to control the shape of the surface of the mirror. If the shape of the wavefront is known from the wavefront sensor, then the mirror's surface can be adjusted to correct for the distortion. The image reflected off the mirror should now be a resolved or corrected image.

Mirror Surface Test

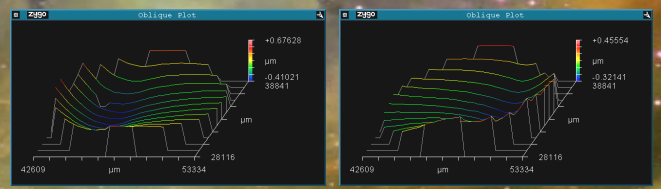
The mirror's surface was tested using an interferometer. The interferometer reflects a light beam off the mirror's surface and compares it to a reference beam. The phase difference between the beams is interpreted as the mirror's surface shape, and is shown in the isometric images seen above.



Left Image: 100 Volts is given to all the actuators on the left half of the mirror.
Right Image: 100 Volts is given to all the actuators on the right half of the mirror.
No noticeable movement or change could be detected in the images gathered from the interferometer.

Mirror Surface Test Validation

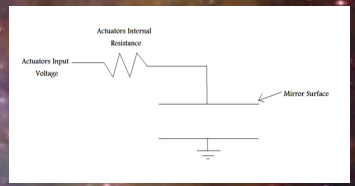
To ensure that the interferometer was set up correctly, the test was repeated with a working deformable mirror. The working mirror was loaned out by Mark Hoffman at Maui Community College.



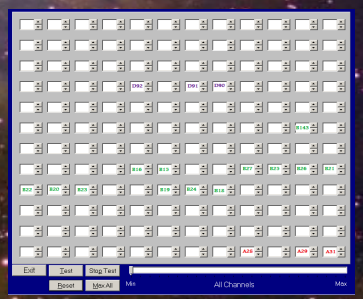
Left Image: A test where the left half of the mirror was given 100 Volts.
Right Image: A test where the right half of the mirror was given 100 Volts.

In this test, the movement of the mirror's surface was very obvious in the images from the interferometer. Clearly the interferometer setup is correct.

Operational Actuator Test



By examining the equivalent circuit, it is clear that if the actuator is operational then the measured voltage for each actuator should be equal to the applied voltage. A common failure for the actuators is a permanent latched-down condition. If the actuator is latched-down, then the voltage drop across the internal resistance will be measured.



After first verifying proper voltages without the mirror, then the mirror was inserted. Every channel was given a voltage and the output pin was measured to verify proper operation. The display above is a mapping of the only operational actuators with their corresponding output pin address.

Conclusion

•The Boston Micromachines deformable mirror was proven to be non-operational:
- **The interferometer showed that we were unable to control the mirror.**
- **A second test verified that the interferometer test setup was correct.**
- **A final test established and pinpointed the mirror's faulty actuators.**

•The deformable mirror will need to be replaced in order to create a functional adaptive optics system.

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Hubble Space Telescope Image: http://hubblesite.org/gallery