



CHARACTERIZATION OF MEMS DEFORMABLE MIRRORS FOR WAVEFRONT CONTROL IN EXTREME ADAPTIVE OPTICS

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Adaptive Optics

AO improves image resolution and contrast by compensating for turbulence in the atmosphere.



Extreme Adaptive Optics

Goals of ExAO include the **Direct imaging detection of extrasolar planets** and the study of debris disks around stars in the context of understanding planetary systems.

ExAO Testbed

Main concept is to **achieve a contrast level of 10^7** .

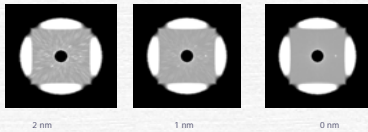
High Wavefront control and low Wavefront RMS error are needed to achieve this contrast

A **1024-actuator MEMS (Micro-Electro-Mechanical-System) deformable mirror** is used to control the wavefront.

Motivation

Low Wavefront error is important since as you decrease it planet detection becomes an easier task.

These simulated images show that the ability to detect planets depends on the wavefront error and how well we can correct for aberrations caused by the atmosphere.



5 Jupiter Mass Planet
500 Myr old (Cooling)
15 minute integration on Keck.
Bruce Macintosh

Project Goal and Method

Because it is vitally important to quantify how MEMS deformable mirrors work, the goal of the project is to characterize each of the 1024 actuators in the mirror.

The purpose of this test is to **evaluate the performance of every actuator** and see how variation in actuator response affects the overall functioning of the mirror and the ability to have a low wavefront error.

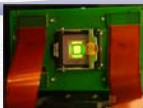
The testing process involves applying different voltages to every actuator, graphing the data and creating a fit for the data. A bias voltage was applied to the actuators not being tested since only 64 actuators were tested at a time.

The test was done three times with different bias voltages.



http://dftbms.ucsc.edu/yahfimo/View/BMC_Mirror_Elec024_Electrostatic_effects.pdf http://dftbms.ucsc.edu/yahfimo/View/BMC_Mirror_Files/13_510E.pdf

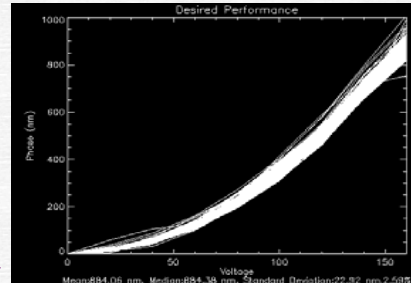
This picture illustrates the working process of the MEMS deformable mirror. A voltage is applied to the actuator and a deflection is introduced in the surface of the mirror.



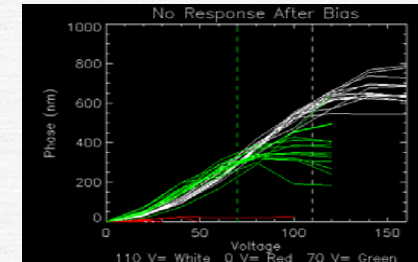
This image is of the actual MEMS deformable mirror with 1024 actuators.

Daren Dillon

Results



This is the expected quadratic response of a **good actuator**. The graph represents **96.2%** of all the tested actuators with a **deviation of only 2.59%** from the average displacement.

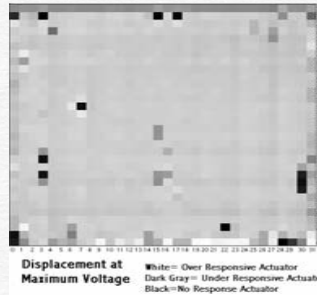


Here we have the most interesting type of bad actuator. These are actuators that have a **normal quadratic response before the bias voltage, but after the bias voltage they plateau**.

As you can see on the 110 V and 70 V bias line the displacement stops and at 0 V bias they do not show any sign of movement.

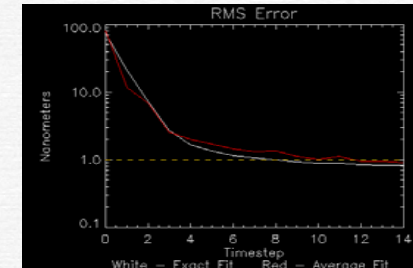
However, these are the most difficult to explain since **they do move but no below the surface**.

One of the questions is about the voltage, does the bias determine the maximum voltage you can apply to the actuator or is it a mechanical problem and the voltage is indeed getting to the actuator but it cannot move below the surface?



There are several actuators that are in the middle which corresponds to the region used to calculate the wavefront error.

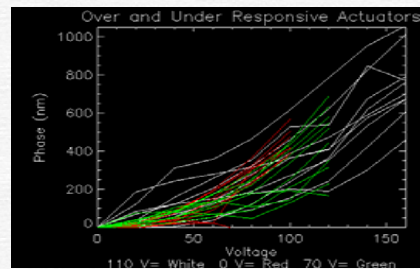
3.8% of the Actuators tested show a **poor performance**
78% of these are pairs



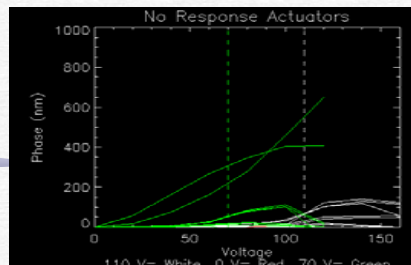
This graph shows the **process of flattening the mirror** and is done by taking a measurement, applying a correction and then taking a new measurement and applying a new correction.

The process with an average fit for all actuators created using the data from 4 good actuators (red).

The process with the exact fit for each actuator created with the new program (white).



These actuators do have a quadratic response, except that they have some jumps along the way, but in general they just exhibit a **greater variation from the average response**.



Here we have the actuators with **no response**. However, they are called **floating actuators** since they do move up to the bias level but then they show no response.

A possible explanation for the fact that they do not move is that there might be a **problem with the electronics** of the system and somehow the voltage cannot get to the actuator.

However, they do move to the bias level, which could be explained if voltage from other actuator that is at the bias is getting to it.

Another feature is that there were these two actuators that at a bias of 70 V had to an extent a good response.

Conclusion

There have been 3 different types of poor performance actuators identified.

- Over and Under Responsive**
- No Response**
- No Response after Bias Voltage**

Using the exact fit for every actuator makes the flattening of the mirror a faster process.

The next step is to find how every type affects wavefront control and why the different types of bad actuators occur and why they do it in pairs.

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