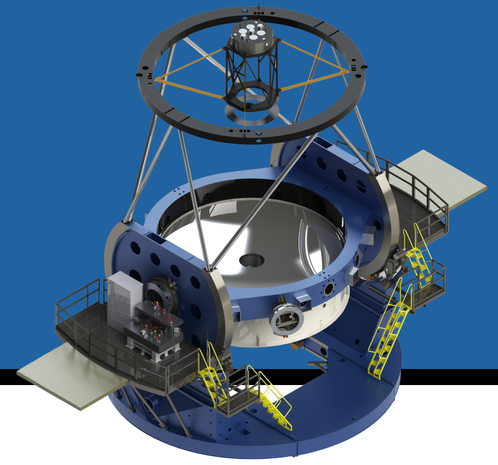
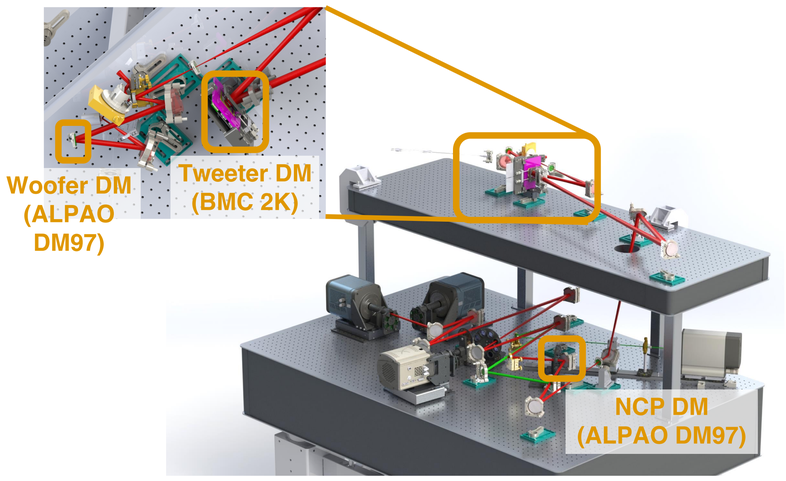
Characterization of Deformable Mirrors for the MagAO-X Project

Kyle Van Gorkom[1], Kelsey Miller[1], Jared Males[2], Olivier Guyon[1,2,3], Alexander Rodack[1], Jennifer Lumbres[1], Justin Knight[1]

[1]College of Optical Sciences, University of Arizona, [2]Steward Observatory, University of Arizona, [3]Subaru Telescope, National Astronomical Observatory of Japan



Introduction



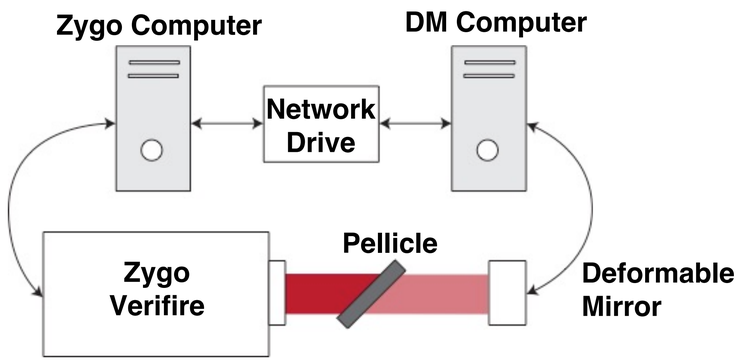
MagAO-X is an upgrade of the AO system on the Magellan Clay 6.5m telescope that will introduce extreme adaptive optics capabilities for high-contrast imaging at visible and near-infrared wavelengths.

The upgrade features 3 deformable mirrors (DMs):

- One BMC 2K: 2040-actuator, 3.5µm stroke DM for high-order wavefront control
- Two ALPAO DM97-15s: 97-actuator, high-stroke DMs for low-order correction and non-common-path (NCP) wavefront control in the coronagraph arm

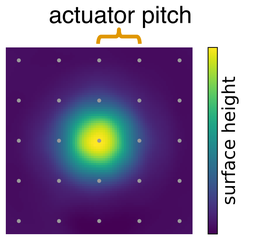
The accuracy of the wavefront correction is limited by our ability to precisely control the DMs, which requires careful characterization.

Characterization Pipeline

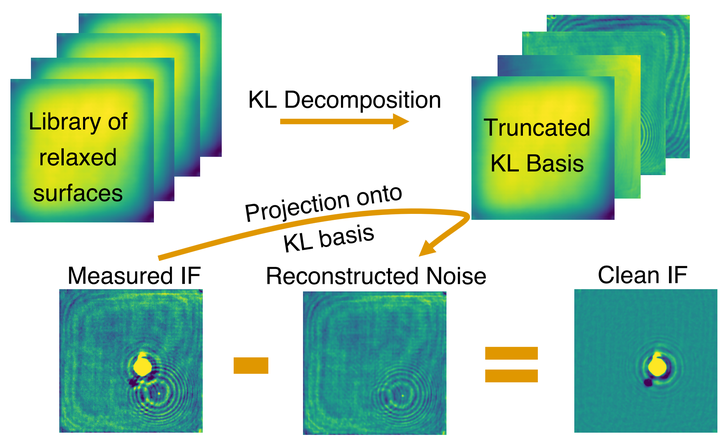


- In our testbed, we measure each DM surface with a Zygo Verifire (Fizeau) interferometer. Zygo data acquisition and DM control is automated and synchronized in Python.

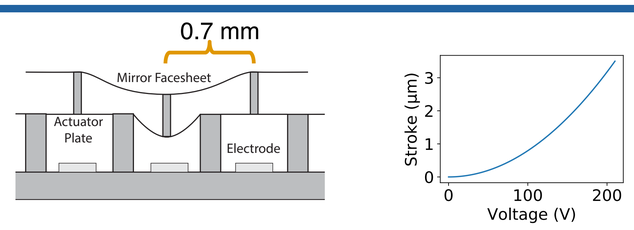
- The influence function (IF) is the response of the DM surface to a single-actuator stroke. We construct a general shape on the DM through a linear combination of all actuator influence functions.



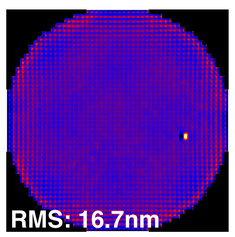
- To mitigate the effects of mechanical disturbances and other environmental effects in the lab, we remove rigid body, the static surface, and dynamic effects from each measured IF with Karhunen-Loève Image Projection (KLIP).

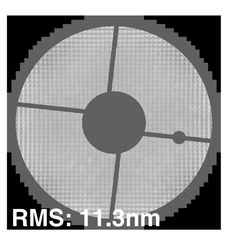


BMC 2K



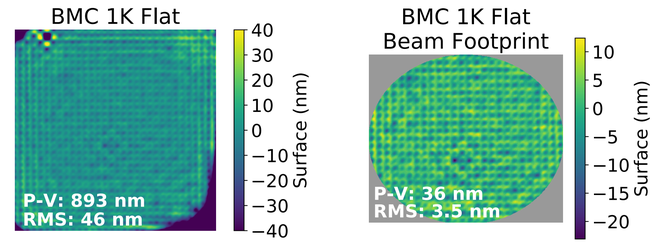
- The 50x50 2K DM from Boston Micromachines Corporation (BMC) deforms a continuous facesheet via an electrostatic force between an electrode and actuator plate, resulting in an approximately quadratic voltage-stroke relationship.



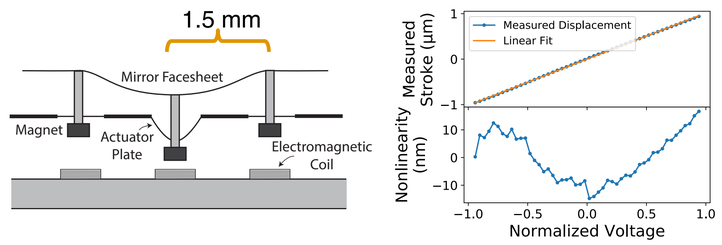


- BMC's characterization of the 2K DM found one significant defect and a 16.7nm RMS flat over the 19.6mm diameter. Over the MagAO-X coronagraph pupil with the defect masked, the surface RMS reduces to 11.3nm.
- We expect to take delivery of the 2K during summer 2018.

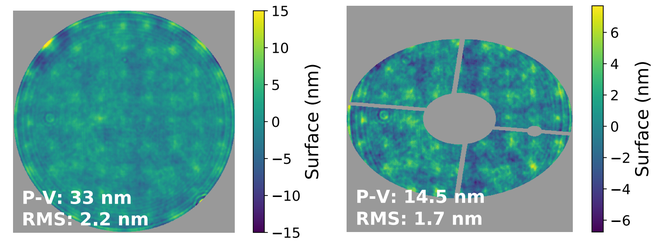
- With a BMC 1K (32x32) currently in use in the UA lab, we have demonstrated the ability to drive a BMC DM to a powered flat of 3.5nm RMS over our beam footprint in closed loop with the Zygo.



ALPAO DM97



- The ALPAO DM97 actuates via an electromagnetic coil and permanent magnet mounted by post to a reflective facesheet, resulting in a linear voltage-stroke relationship over a wide range of strokes.



- Following our characterization process, we achieved a flat of 2.2nm RMS over the full 13.5mm diameter and 1.7nm RMS over the MagAO-X pupil projected onto the NCP DM in the coronagraph arm.

Future Work

- Inter-actuator coupling introduces a nonlinear stroke response, which leads to errors in the conventional control scheme. Modeling efforts are underway to develop an approach that accounts for this effect.
- Surface metrology will be improved by use of a high-reflectance Zygo reference flat and removal of the pellicle from the optical path.
- We will perform in-house characterization of the BMC 2K and a 2nd ALPAO DM97 upon delivery.

Acknowledgements

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THE UNIVERSITY OF ARIZONA College of Optical Sciences

References

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