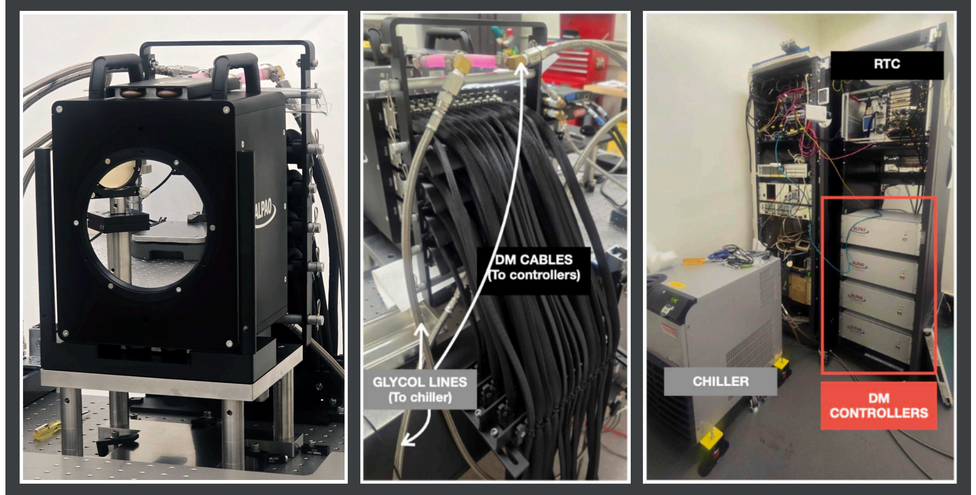
High Order Advanced Keck Adaptive Optics (HAKA): Results from lab integration and testing of the High Order Deformable Mirror

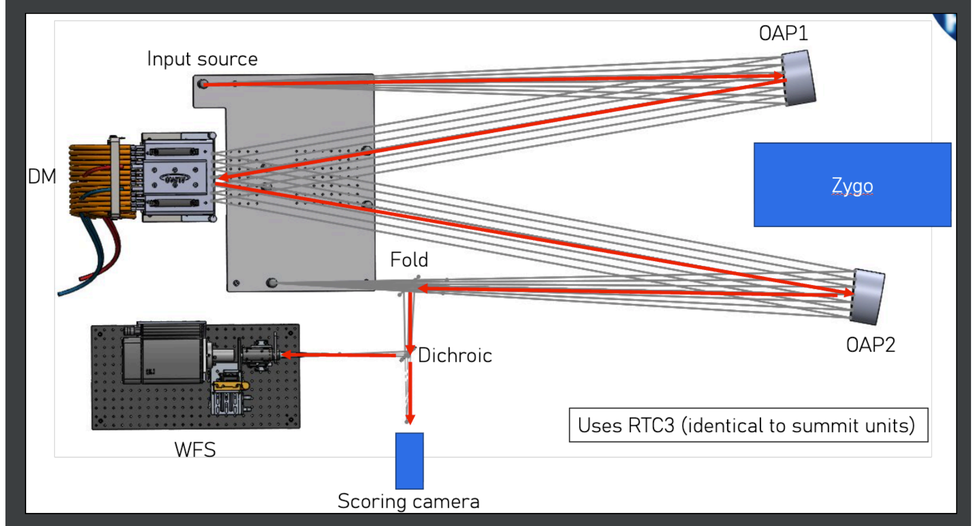
Maria Vincent, Charlotte E. Guthery, Scott Lilley, Michael Bottom, Sylvain Cetre, Mahawa Cissé, Luke Gers, Sonia Karkar, Eduardo Marin, Jonathan Steiner, Johnny Tam, Jacob Taylor, Tatum Umiamaka, Ed Wetherell, Peter Wizinowich, Antonin Bouchez

ABSTRACT: We present the test-bench design and alignment, the closed-loop WFS setup, modular lab control software, and results from site-acceptance and closed-loop tests. Our final results prior to on-sky commissioning on the Keck II AO bench include DM laboratory performance metrics and closed-loop stability.

About the DM and the Test Bench

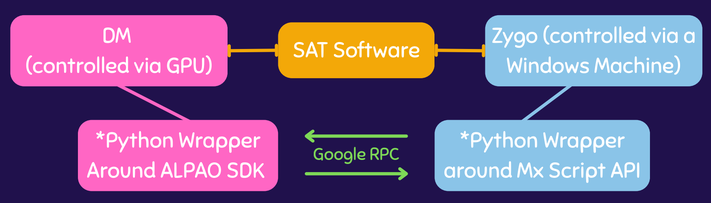


The DM is manufactured by Bertin ALPAO and has 2844 magnetic voice coil actuators and the clear aperture spans 14.5 cm. It is glycol cooled and is connected to 4 controllers (placed in the adjoining room) via a network of 52 cables.

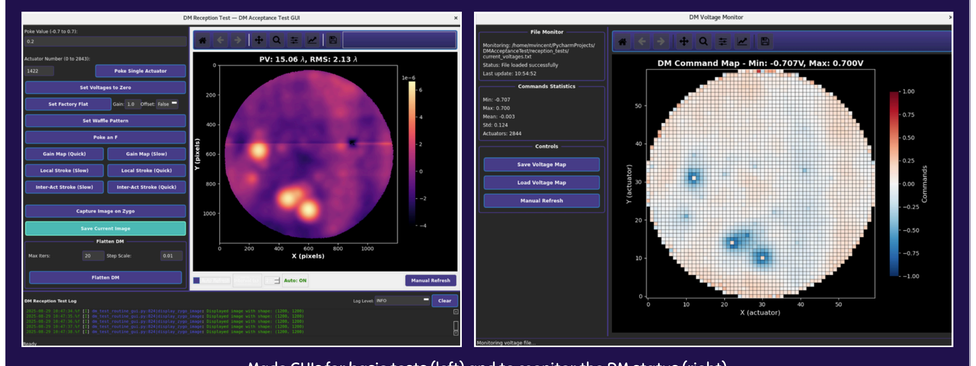


Various components of the bench were aligned using an Alignment Telescope (not pictured). We also tested other optics like the Pupil Relay Optics for the Shack Hartmann Wavefront Sensor (SHWFS). These have been designed to match the optical relay on the K2 AO bench.
The Zygo interferometer is used for Site Acceptance Testing (SAT) to verify the functionality and performance of the DM under lab conditions and recreate the results reported by ALPAO in their final factory test report

Site Acceptance Testing- Software Architecture



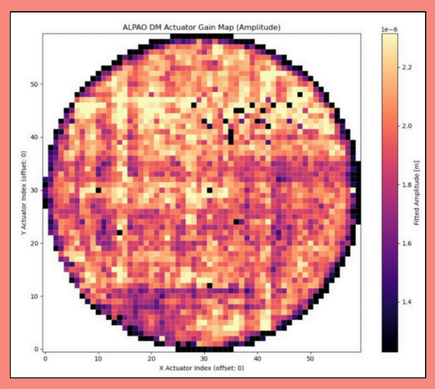
*Python Wrapper is to match the style of modular Python software architecture for K1 & K2 AO



Made GUIs for basic tests (left) and to monitor the DM status (right)

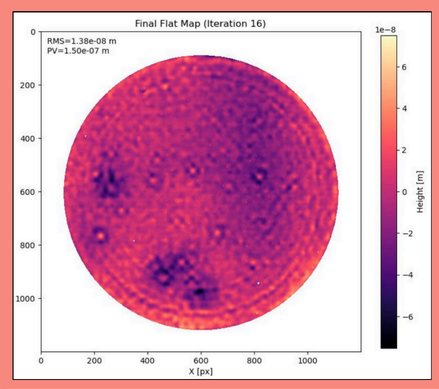
ACKNOWLEDGEMENT: Some of the data presented herein were obtained at Keck Observatory, a private 501(c)3 non-profit organization operated as a scientific partnership among the California Institute of Technology, the University of California, and the National Aeronautics and Space Administration. The Observatory was made possible by the generous financial support of the W. M. Keck Foundation. The authors wish to recognize and acknowledge the very significant cultural role and reverence that the summit of Maunakea has always had within the Native Hawaiian community. We are most fortunate to have the opportunity to conduct observations from this mountain.

Site Acceptance Testing- Results



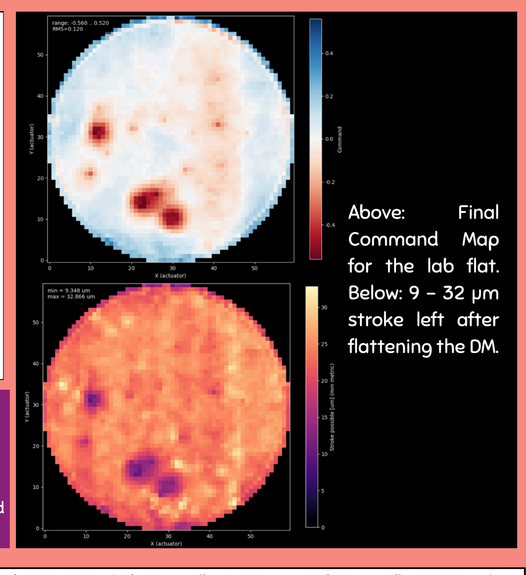
GAIN MAP

- Demonstrating the stroke of individual actuators
- Influence function measured by fitting a Moffat function to each actuator's spot on the interferogram
- Our value: mean of 1.89 µm/normalized command*

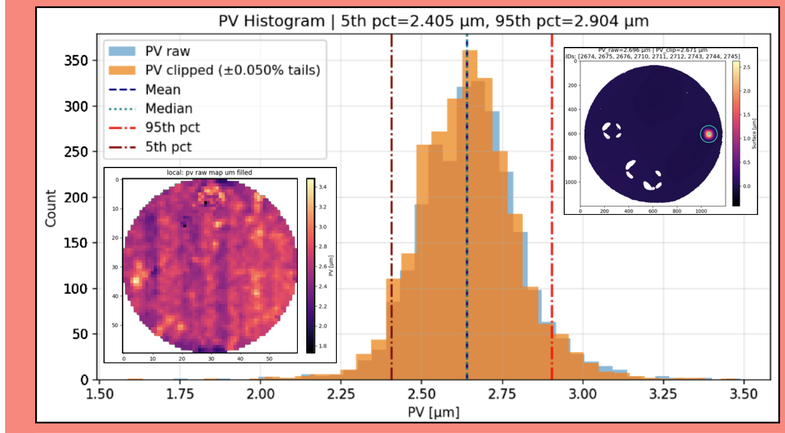


BEST ACTIVE FLAT

- Best active flat (preliminary) from a loop that applies corrections based on the surface error scaled by gain
- Target RMS of 15 nm achieved in ~15 iterations within a masked aperture that contained most of the controlled region

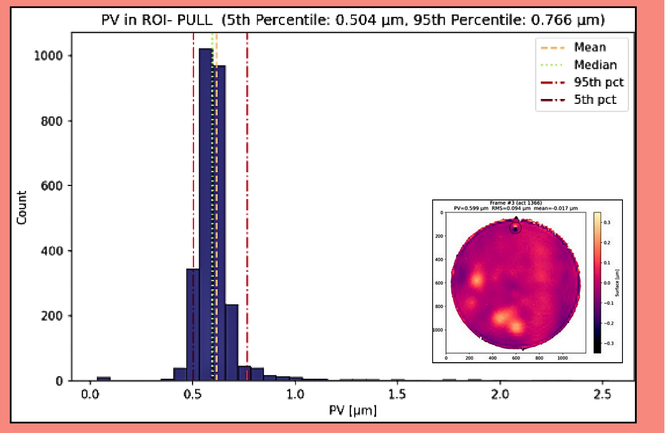


Above: Final Command Map for the lab flat. Below: 9 – 32 µm stroke left after flattening the DM.



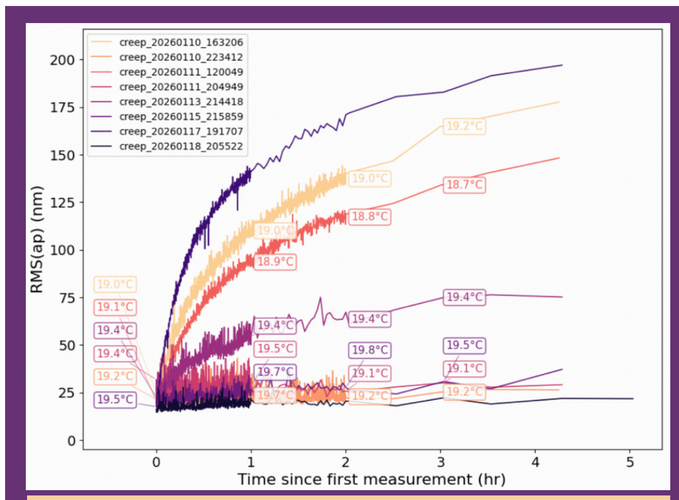
LOCAL STROKE

- Tested at 20% by poking 3x3 grid of actuators
  - Max mirror surface deformation by actuating 3x3 grid of actuators
- 90% actuators ⩾ 11.25 µm at 100% stroke.
  - Values in plots correspond to 20% stroke
  - Required spec: > 5 µm PV



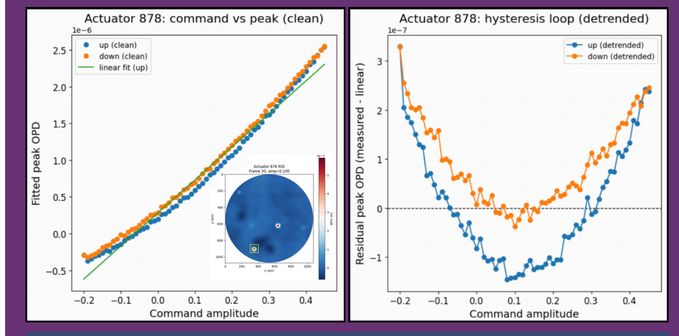
INTER-ACTUATOR STROKE

- Tested at 10% by poking pairs of actuators in opposite directions
  - PV surface deformation when pushing one actuator at the maximum command, while one of its neighbors is simultaneously pulled
- 90% actuators ⩾ 5 µm at 100% stroke.
  - Values in plots correspond to 10% stroke
  - Required spec: > 2 µm PV



CREEP

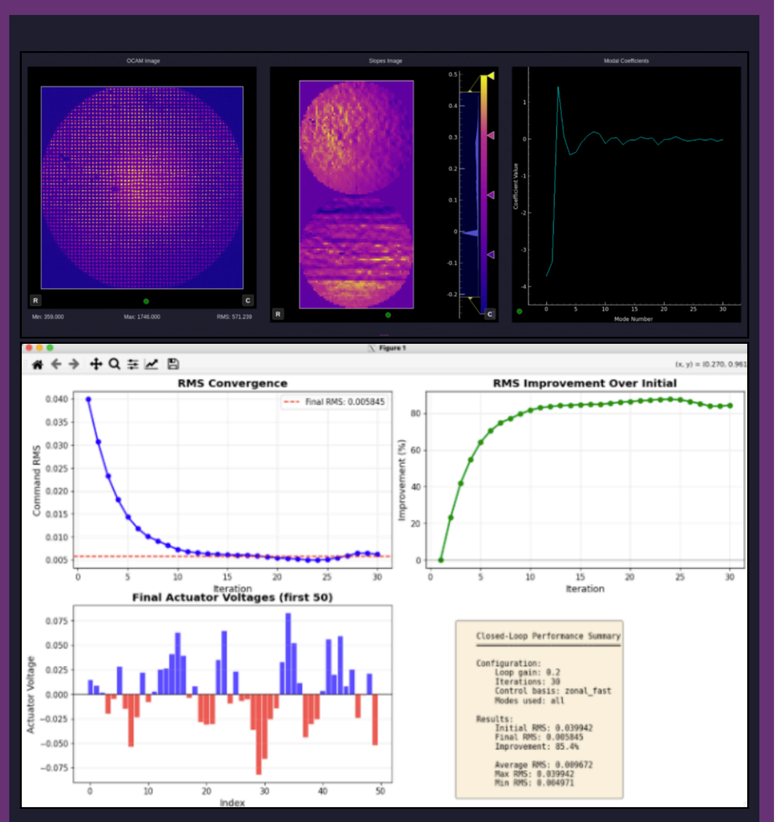
- Flattened the DM using the Zygo and monitored the change in the DM shape over a course of 4–7 hours.
- Surface error increased with elapsed time,
- RMS starts below 20 nm at early times and rises to 35–100 µm in an hour, consistent with known creep
  - This rise depends the on lab temperature at the time of measurement
- This creep is expected and will not affect closed-loop performance



LINEARITY & HYSTERESIS

- Command–response is highly linear; fit within a few tenths of µm peak surface error.
- A small hysteresis loop after detrending: residuals ~0 at small stroke; at larger stroke the down branch sits slightly above the up branch (classical hysteresis).
- Peak–to–peak hysteresis is only a few to 10% of the total actuator response over the tested range.
- This amount of hysteresis is acceptable and will not affect performance.

HQ Lab Test Results



RTC CLOSED LOOP

- Modal and Zonal Control
  - Fast mode for Zonal interaction matrix takes ~30 minutes tocomplete
  - Slow mode for zonal interaction matrix takes ~6 hours to complete
- Loop has been consistently stable when well aligned, successfully centering the spot array images

Timeline

- Installation begins: Feb 2
- First Engineering Night: Mar 11
- First Science Night: May 23