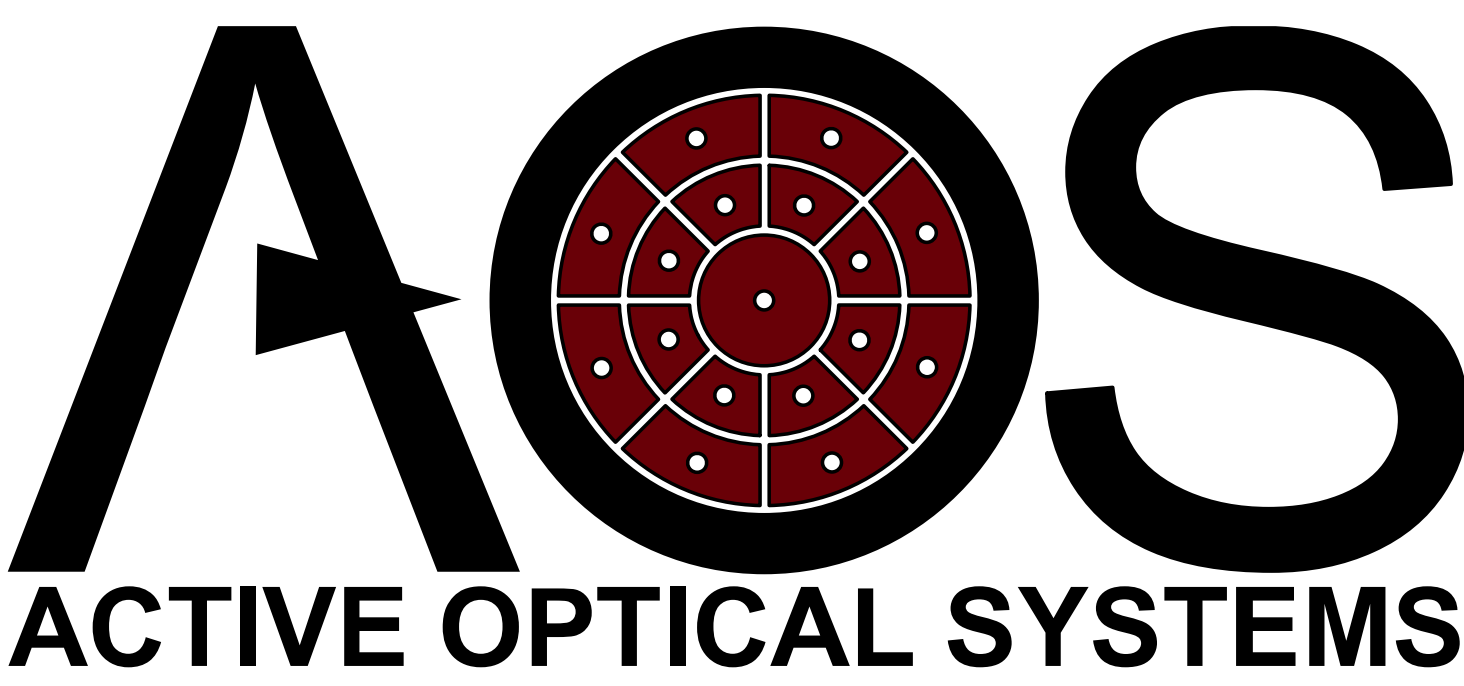




HEL Deformable Mirrors & Fast Steering Mirrors

Jesse Jameson, Justin Mansell, Brandon Taylor
Active Optical Systems, LLC



ABSTRACT

As the HEL industry transitions from the laboratory to fielded military applications, the challenges like atmospheric propagation, thermally induced aberrations, and beam pointing stabilization are increasing. AOS has designed and delivered products that can improve all beam control challenges. We present here our deformable mirrors (DM) and fast steering mirrors (FSM) that have been delivered and tested in fielded systems and recent test results qualifying them for HEL use.

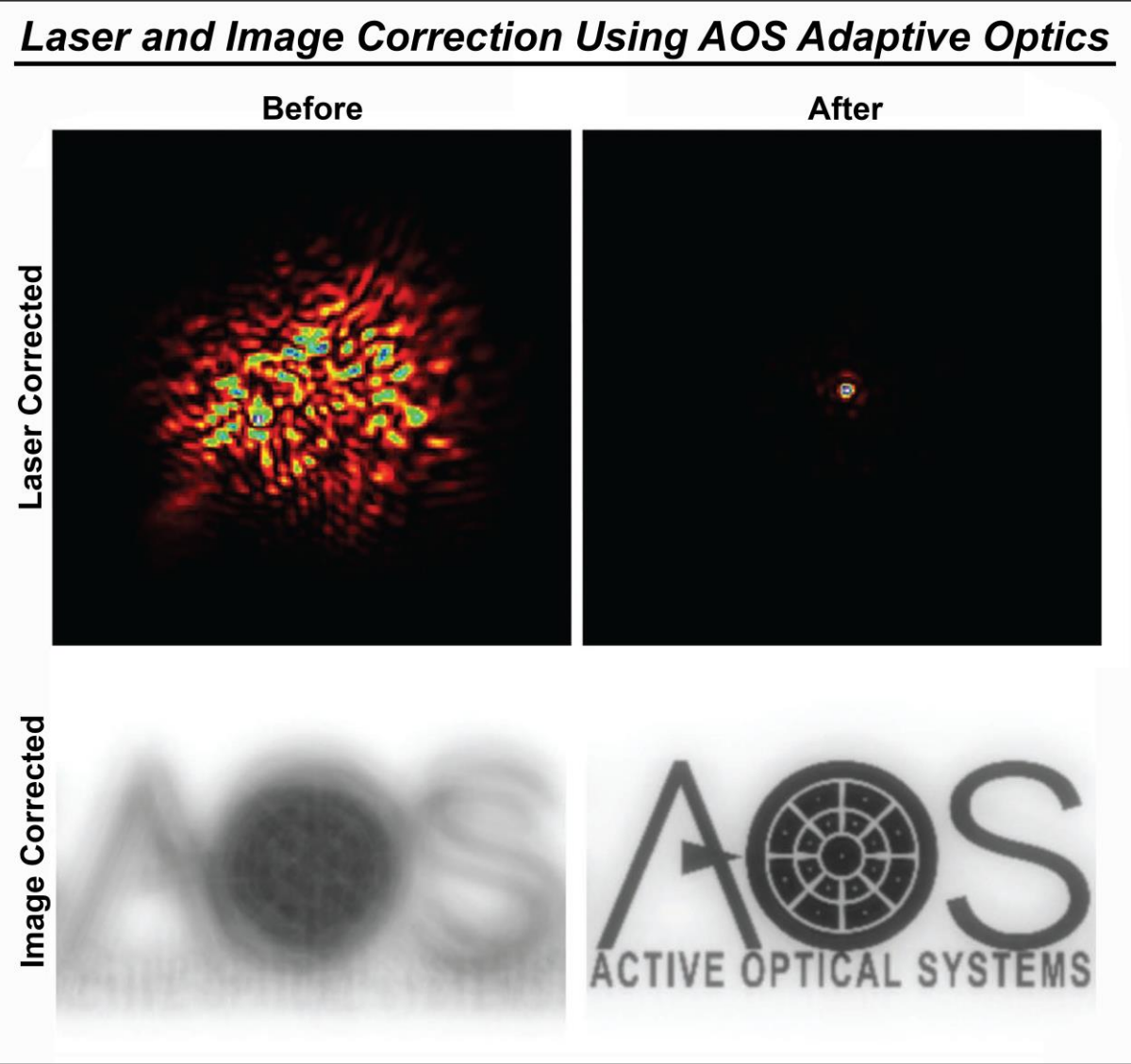
INTRODUCTION

Adaptive optics are the key to improving a HEL system's overall performance. We have continually improved our adaptive optics products by improving capabilities and producibility. Our DMs and FSMs have been successfully tested to handle high-power. AOS also focused on ruggedization and SWAP to fit our systems into fielded applications. Here we will present information on testing and capabilities of these products.

DEFORMABLE MIRROR (DM)

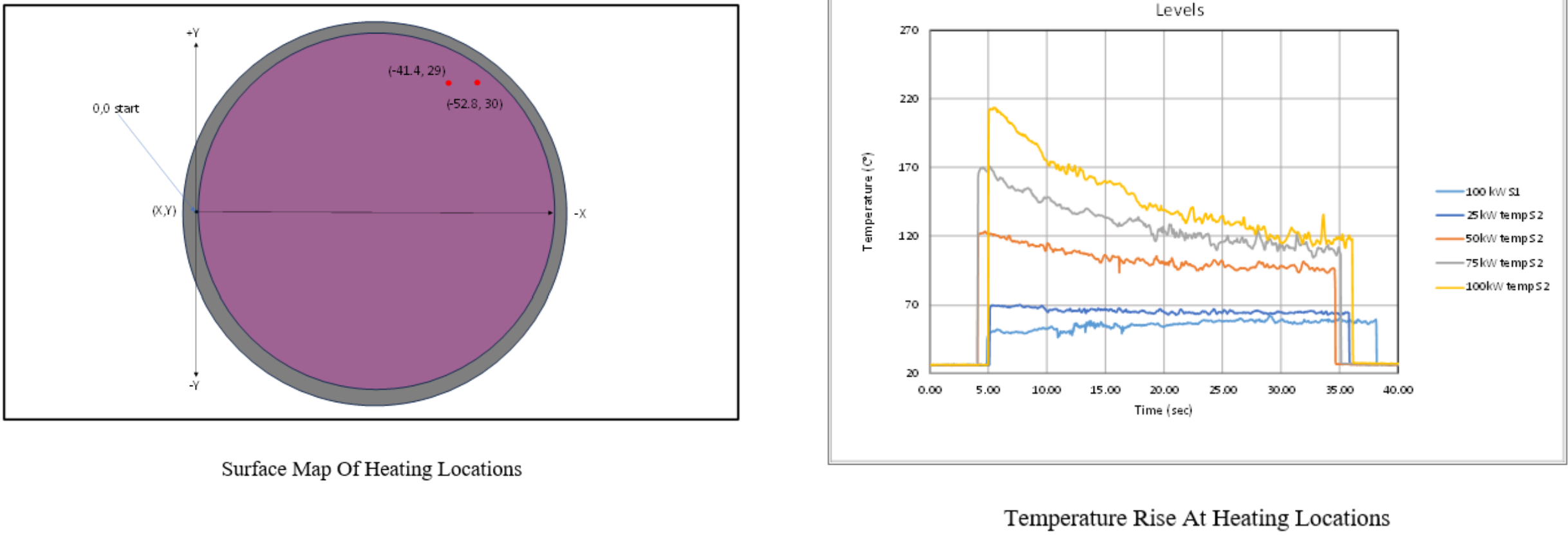
AOS PZT-actuated plate-type deformable mirrors are available in a variety of actuator patterns and coatings. We have designs for both rugged environments and laboratories.

Parameter	Value	Notes
Diameter (mm)	25 to 230	1" to 9"
Actuator Count	6 to 1004	
Actuator Stroke (µm)	2 to 36	
-3dB Bandwidth (kHz)	1 to 20	
Actuator Pitch (mm)	3 to 12	
Actuator Pattern	Any	Hexagonal, Rectangular, Annular, etc.
Angle of Incidence (degrees)	Any (0 to 45 typical)	Typically 10-degrees for High Power Coatings
Laser Power Handling	Tested up to 240kW and 1MW/cm²	120kW (20kW/cm²) for 5s resulted in <1°C heating
Actuator Lifetime	10 ¹⁰ cycles	10 years (8 hours per day every day at 100Hz operation)
Tested Temperature Ranges	-40 to 71C	Tested temperature ranges in an environmental chamber
DM Switching Time (µs)	10 to 1000	Electronics Dependent
Vacuum Bake	10 µtorr	Low Outgassing Materials
Technology Readiness Level	9	The DMs have operated on fielded military aircraft
Manufacturing Readiness Level	5	Thanks to the Army ManTech effort we will be at a 6 by the end of FY24

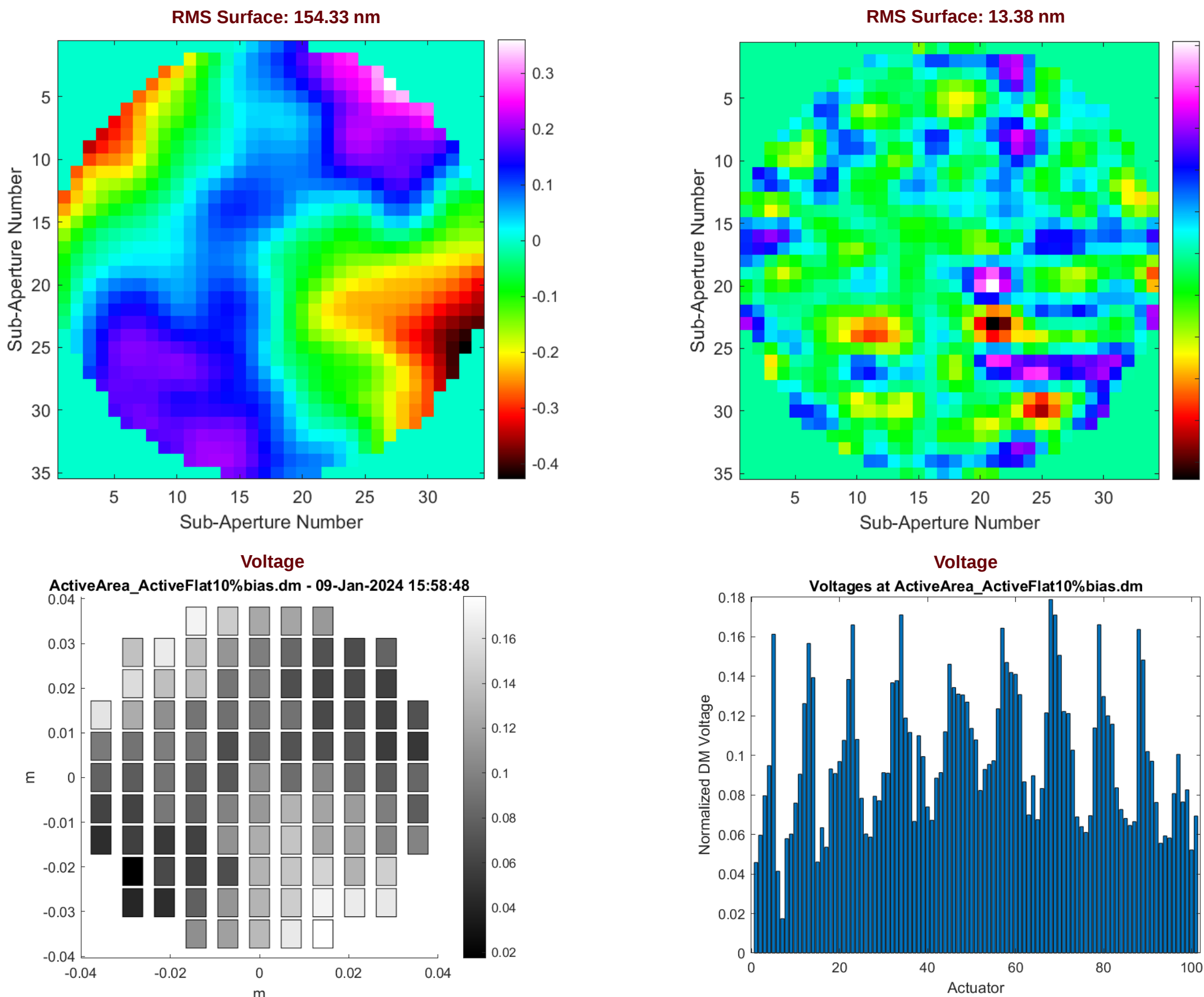


DEFORMABLE MIRROR TESTING

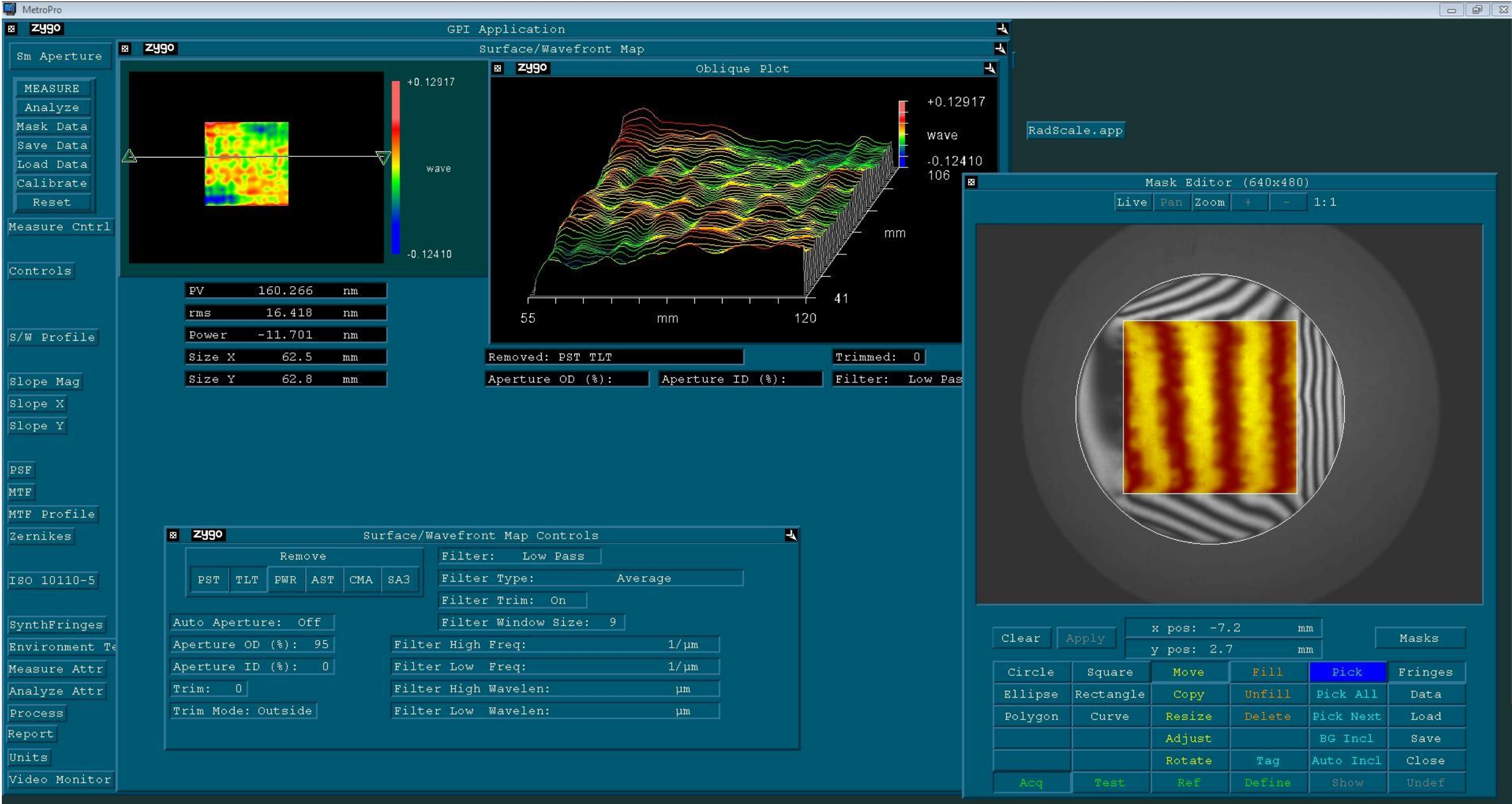
AOS conducted laser damage testing directly on a completed DM. The DM was 100% raster scanned over the full aperture at 100kW/cm². The successful results below show only two edge hot spots that reduced in temperature over the dwell time.



The same DM was then tested for damage after the laser damage testing. The images below show the DM suffered zero damage. The top left image shows the surface figure with 0V. The top right image shows actively flattened and the bottom two images show the actuator voltages needed to flatten the DM.



To demonstrate the surface figure of a DM using a Zygo Interferometer, we actively flattened an AOS DM and moved it in front of the Zygo while active to make a measurement. Below you can see over the active area measured 16nm RMS.



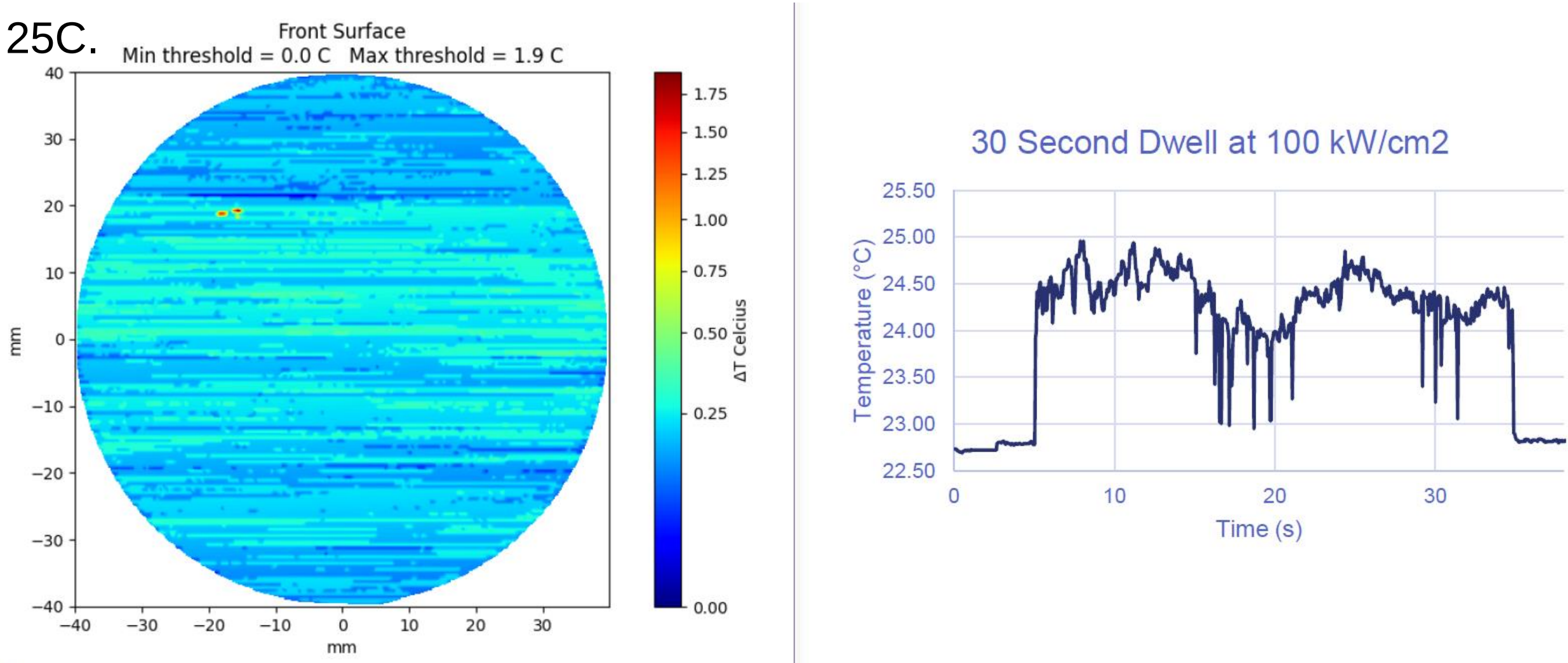
FAST STEERING MIRROR (FSM)

AOS FSMs address a wide variety of tilt needs from beam steering to mechanical jitter rejection. The FSM is scalable from 1"-class sizes to over 7" diameters.

Parameter	Value	Notes
Diameter (mm)	25 – 177.8	1" to 7"
Angular Stroke (µrad)*	5000	
Angular Accuracy (µrad)*	<5	
Bandwidth (Hz)*	50-300	Adjustable through digital Ethernet interface
Angle of Incidence (degrees)	Any (0 to 45 typical)	Typically 10-degrees for High Power Coatings
Laser Power Handling	Coatings tested up to 240kW and 1MW/cm²	FSM tested at 100kW/cm²
Actuator Resistance (Ω)	4-20	
Vacuum Bake	10 µtorr	Low Outgassing Materials
Mirror Substrate Materials	Silicon, Glass (Fused Silica), etc.	
Technology Readiness Level	6	
Manufacturing Readiness Level	5	

FSM HEL TESTING

AOS performed laser damage testing directly on a completed FSM. The FSM was 100% raster scanned over the full aperture at 100kW/cm². The successful results below show only two hot spots with a temperature rise that peaked at 25C.



CONTROLLERS & CSS/HWAS

AOS controllers are designed to reduce SWAP by combing the DM control and FSM control into a single ruggedized 3U chassis.



AOS developed an off-the-shelf laser safety system called the consolidated sensor suite (CSS). This system monitors critical optics using FLIR, visible, thermal couple, and HWAS.

