Performance Evaluation of the Iris AO Segmented MEMS Deformable Mirror

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Iris AO, Inc.

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Fabrication Facility

- Berkeley Microfabrication Laboratory

Research Collaboration

- Berkeley Sensor & Actuator Center

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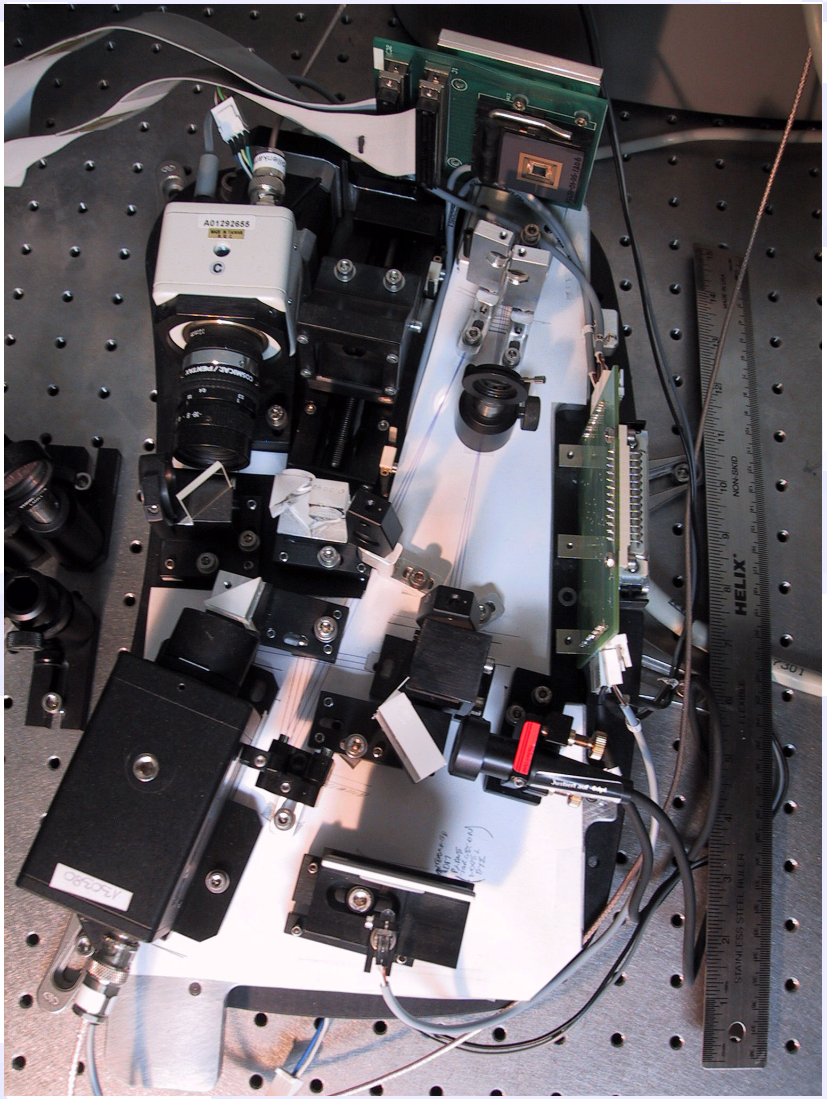
Iris AO Introduction

- Founded in 2002
- Based in Berkeley, CA
- Small high-technology firm specializing in MEMS AO
  - High-performance, robust MEMS based DMs that address a large application space
  - Multi-channel high-voltage drive electronics
  - AO imaging systems



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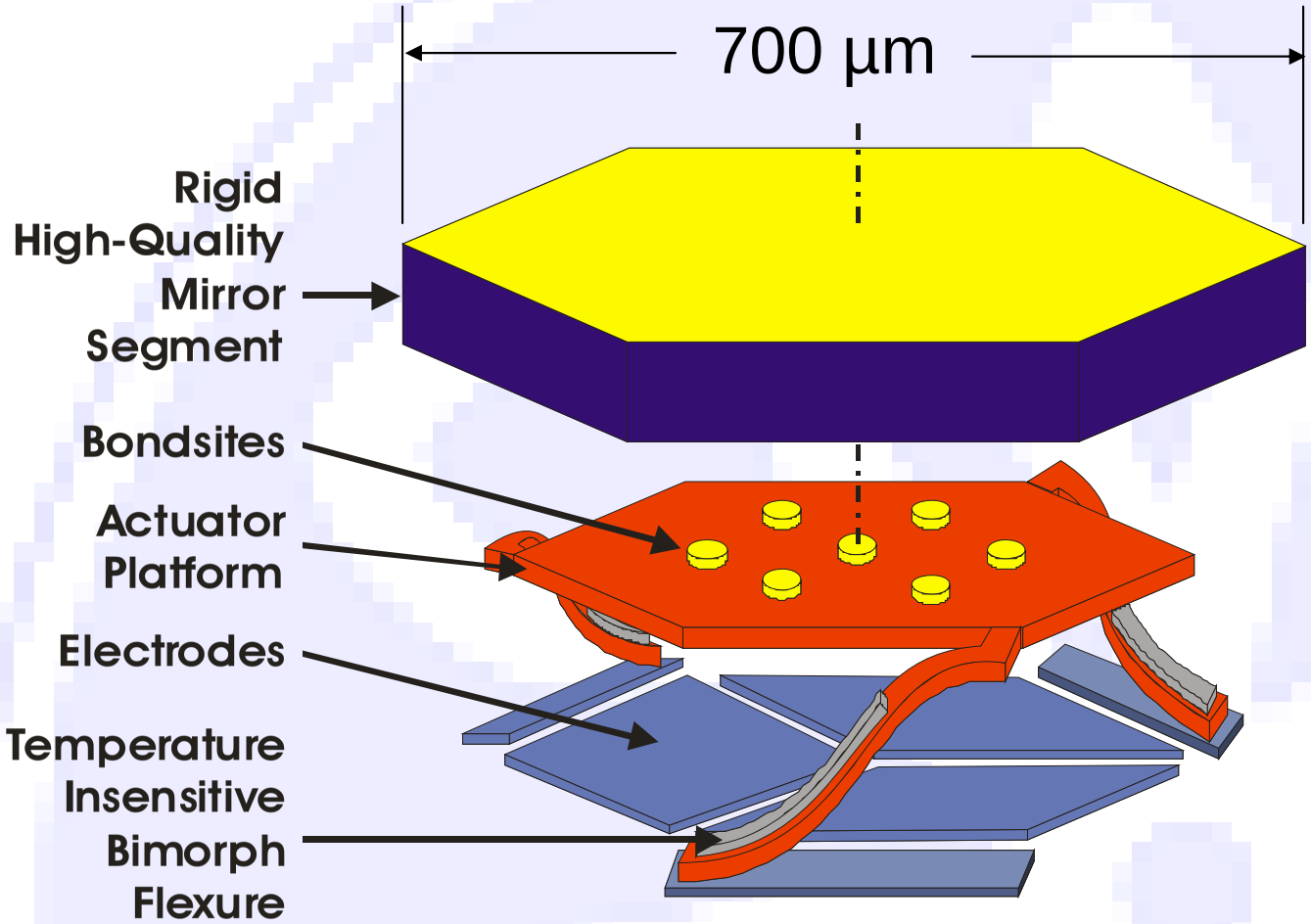
Segmented MEMS DM Schematic



- Robust assembled mirror surface stays flat
- Temperature insensitive bimorphs elevate mirror above substrate
- Piston/tip/tilt electrostatic actuation

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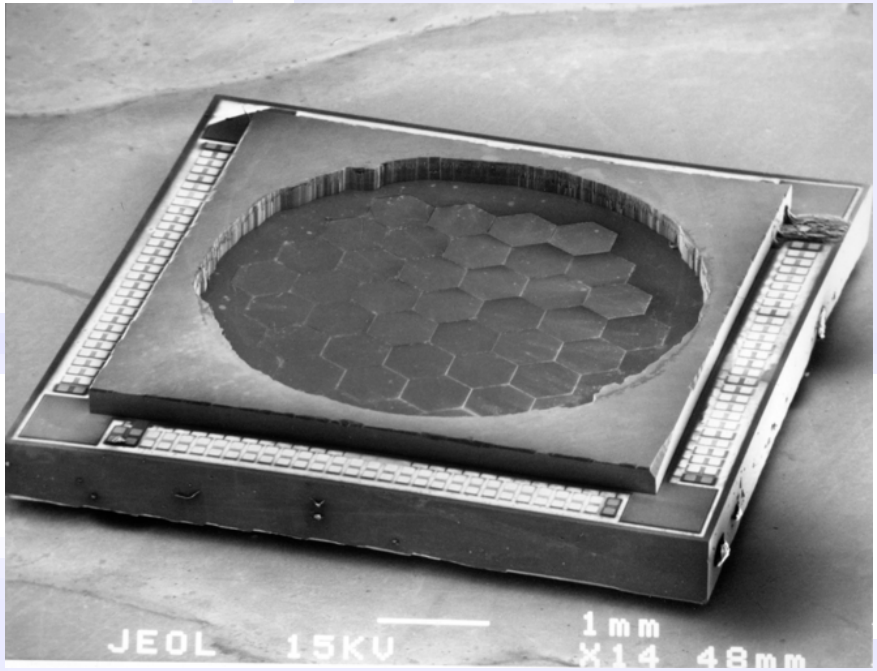
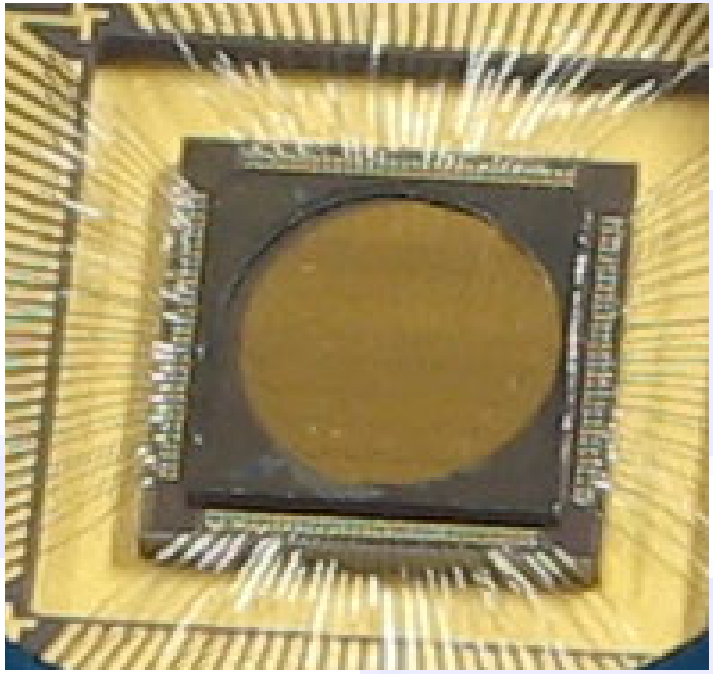
37-Segment PTT DM Images





3.5 mm inscribed aperture

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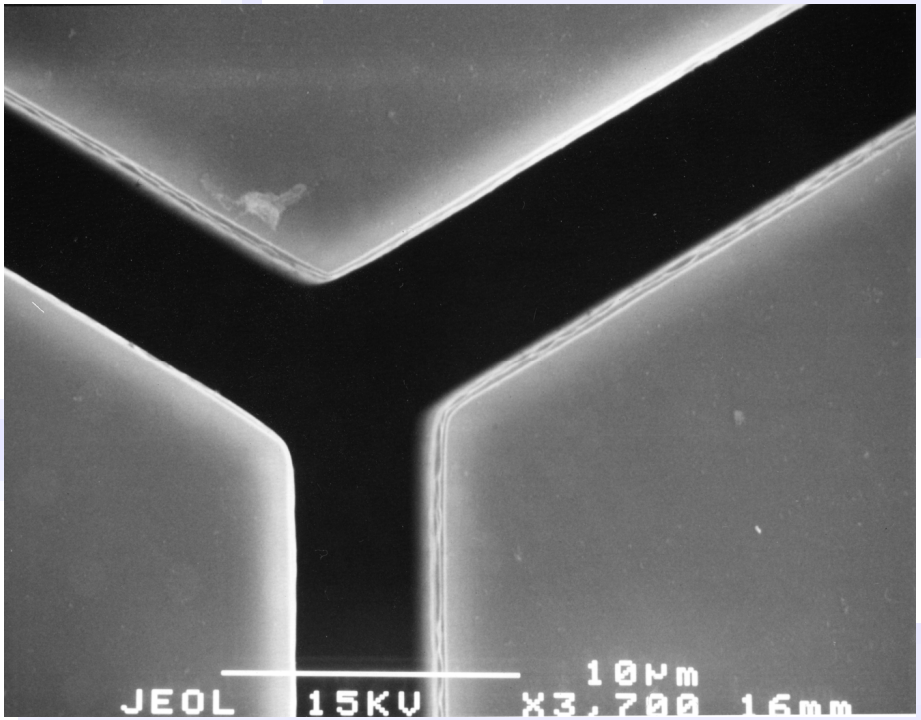
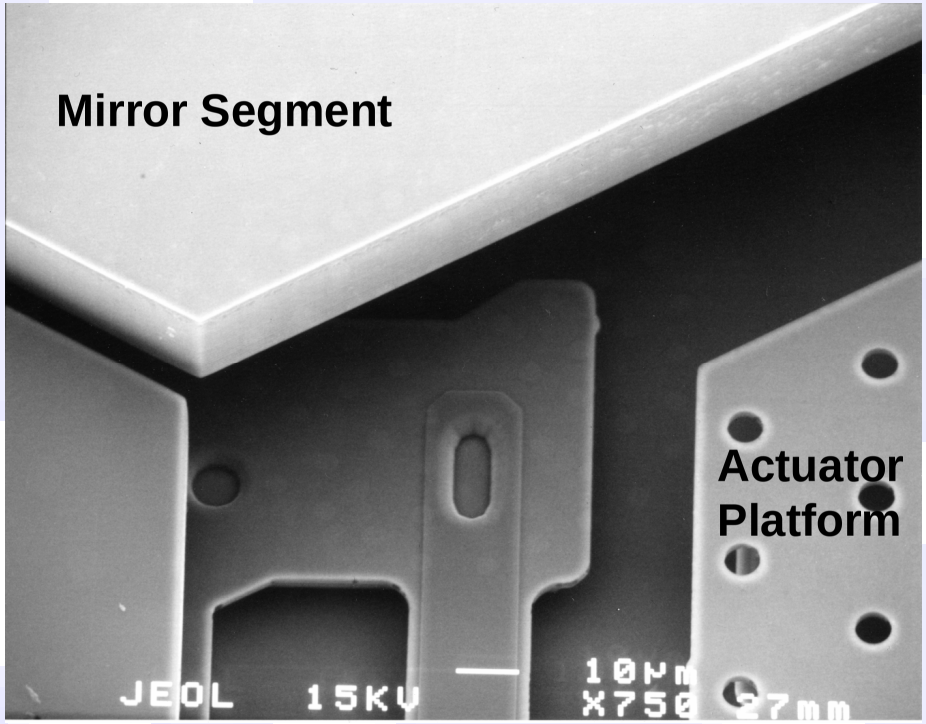
37-Segment DM SEM Images Cont'd



Mirror Segments



Bimorph Flexure

98.6% Fill Factor

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Segment Flatness Post-Packaging

Veeco

Mag: 1.4 X

Mode: VSI

Surface Data

Date: 07/26/2006

Time: 18:19:55

Surface Statistics:

Ra: 6.25 nm

Rq: 7.80 nm

Rz: 39.83 nm

Rt: 48.26 nm

Set-up Parameters:

Size: 111 X 102

Sampling: 6.06 um

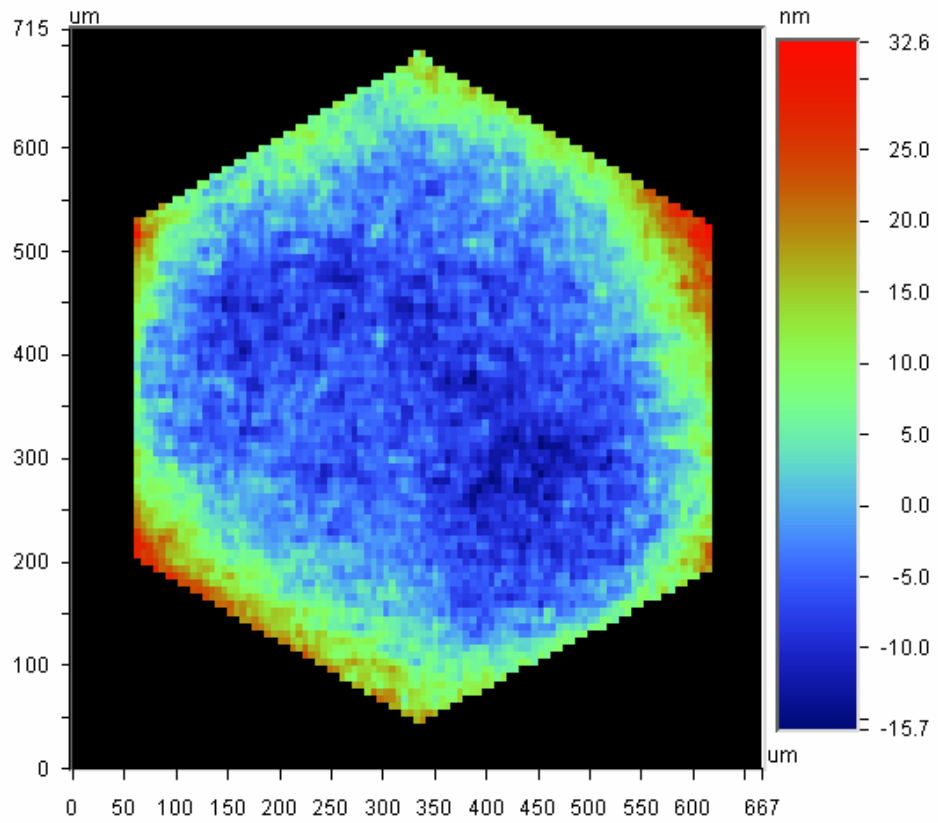
Processed Options:

Terms Removed:

Tilt

Filtering:

None



Title: FSC37-01-05-0317

Ti/Au Optical Coating, 100/1000 Å, Die Attach Cure: 120°C, 10 minutes

No optimization to date: room for improvement

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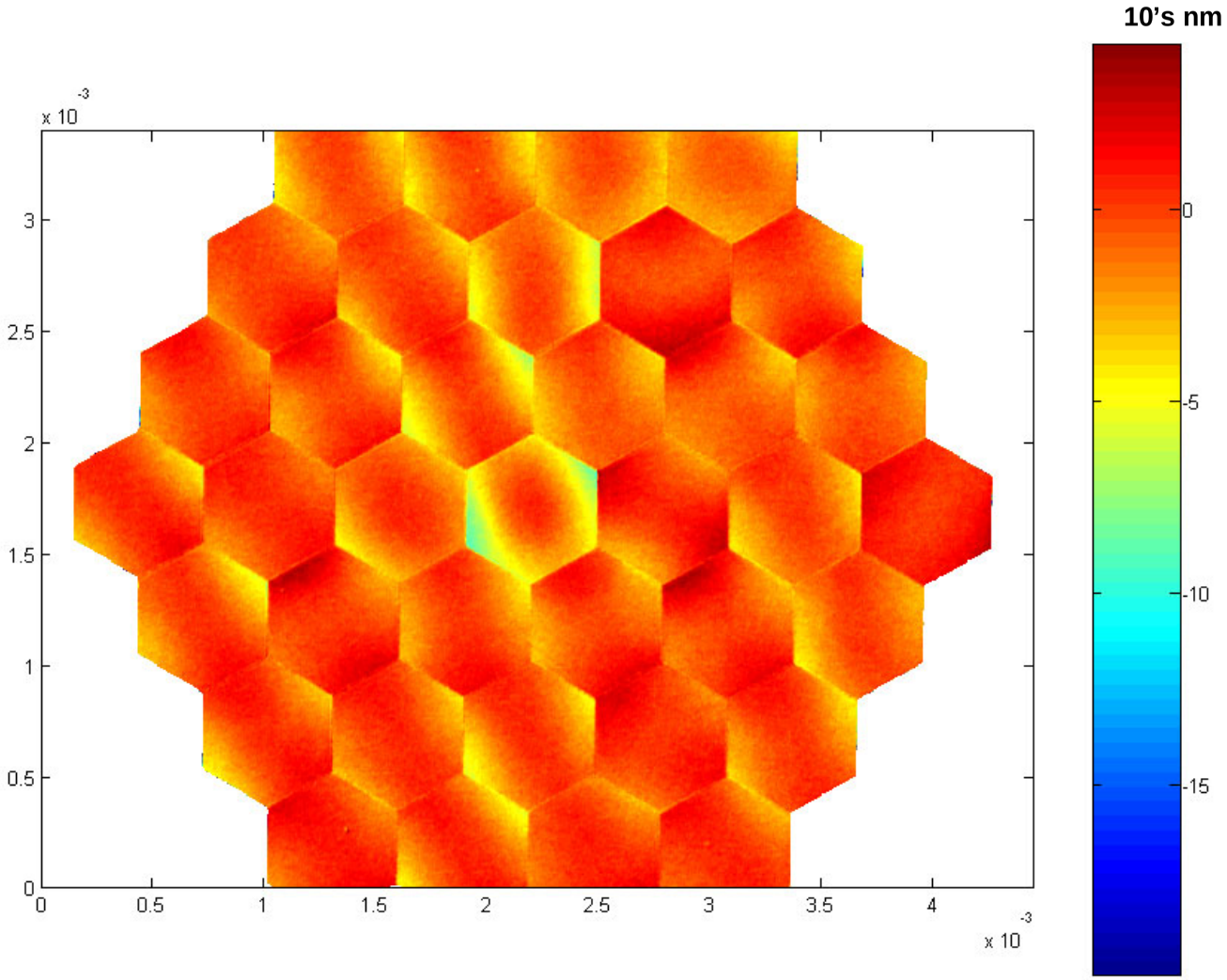
Closed-Loop Flattened Array



18 nm *rms* residual surface figure errors

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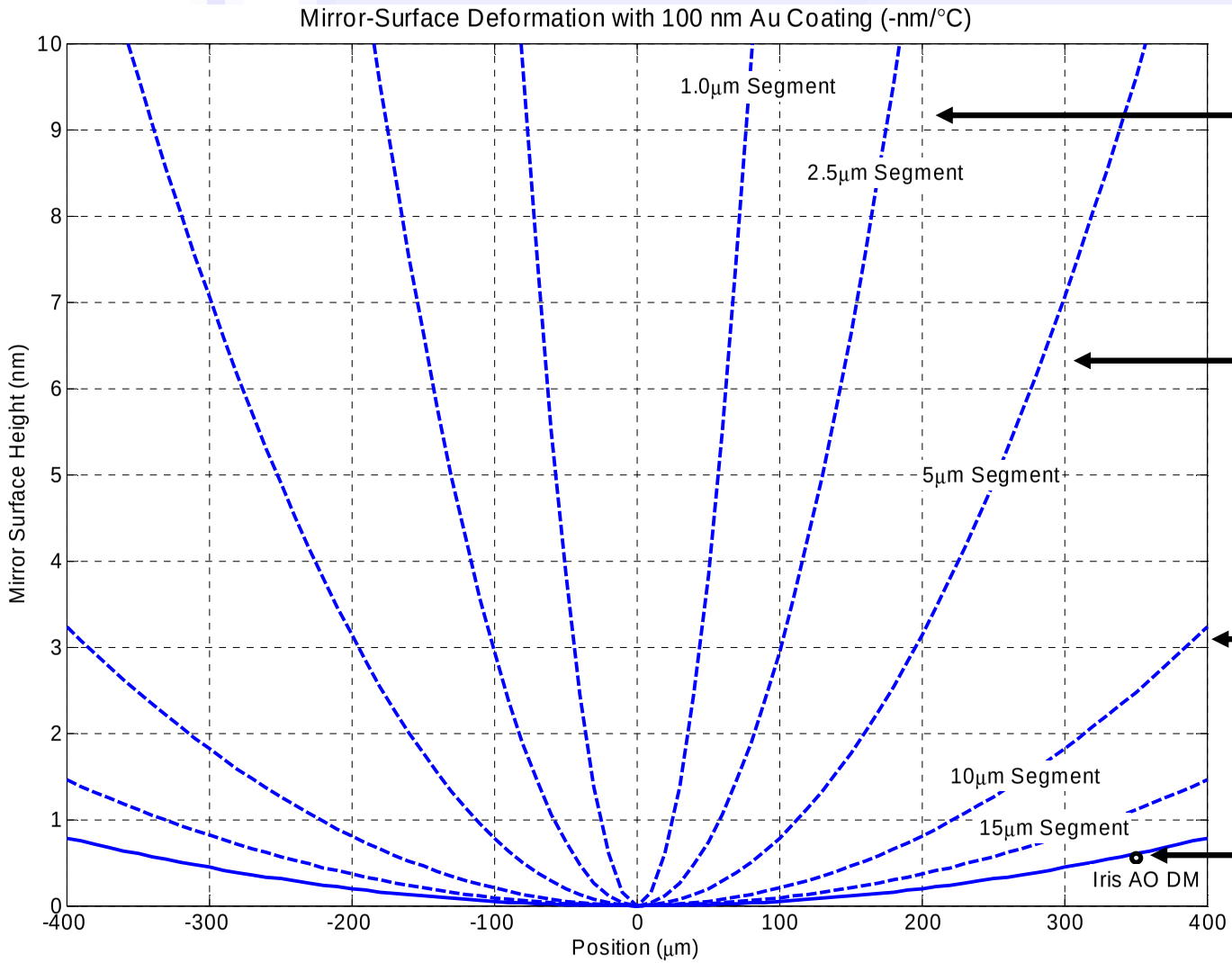
Surface Figure for ΔT vs. Thickness



Surface Machining

Surface Machining *Stacked Layers*

Surface Machining *Thick Film (Epipoly)*

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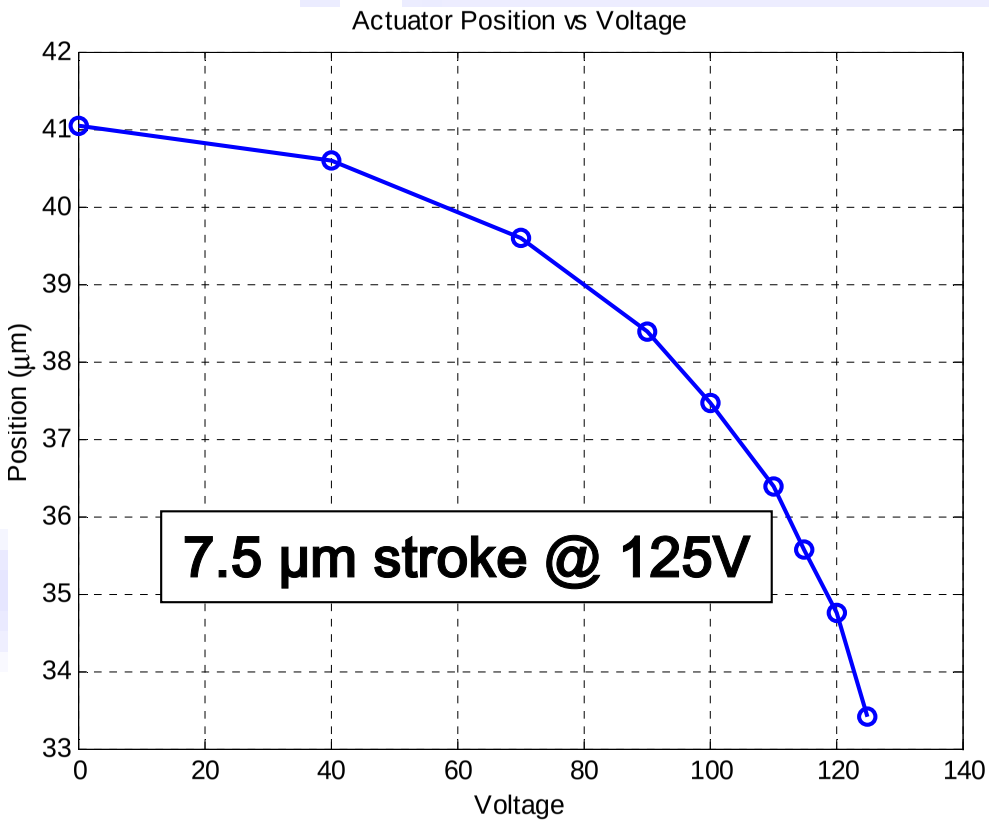
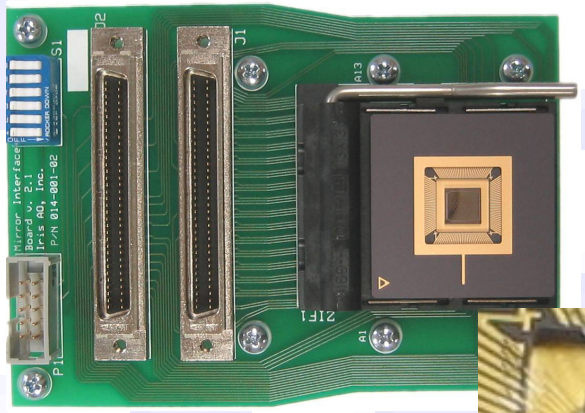
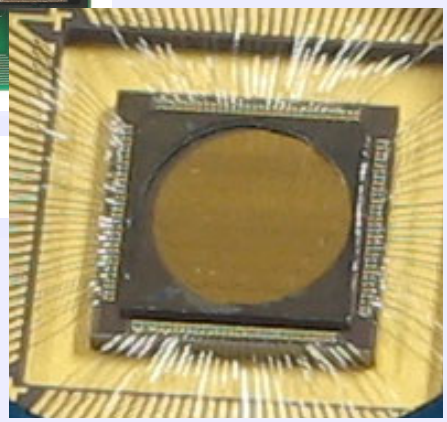
High-Stroke Actuation







- **Nonlinear response but very repeatable**
- **No hysteresis**

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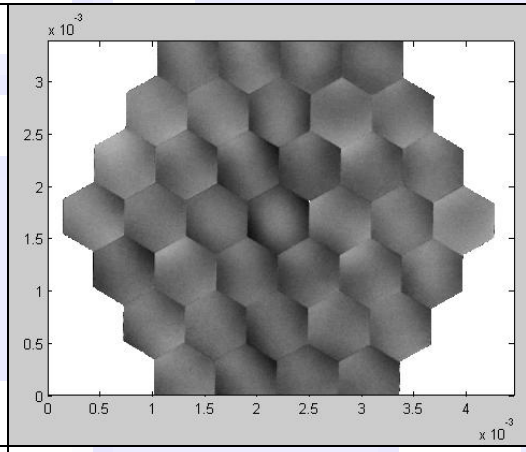
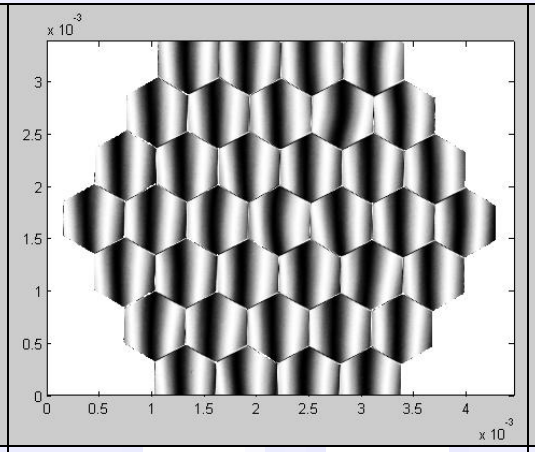
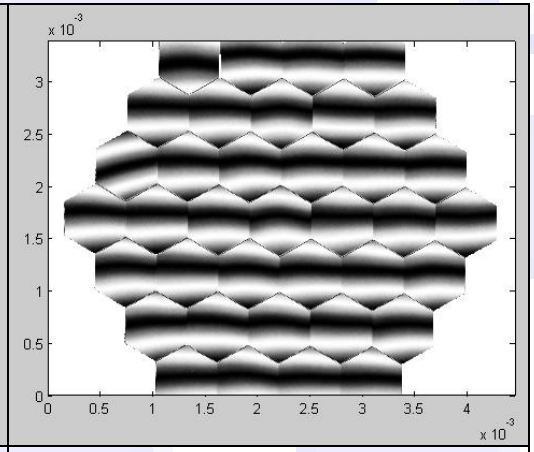
Open-Loop PTT Controller Results

			
Set Point	Z=-2 µm	θ_x=1.5 mrad	θ_y=1.5 mrad
rms Surface-Figure Error (nm)	19	NA	NA
Piston Std Dev Error (nm)	8	22	28
X Tilt Std Dev Error (µrad)	18	57	71
Y Tilt Std Dev Error (µrad)	31	48	72

- **Measurement noise floor is 11 nm rms for piston, 40 µrad for tip/tilt**
- **Flattening demonstrated within noise floor of measurement system (same system used to calibrate the DM)**
- **Good open-loop positioning improves closed-loop bandwidth**

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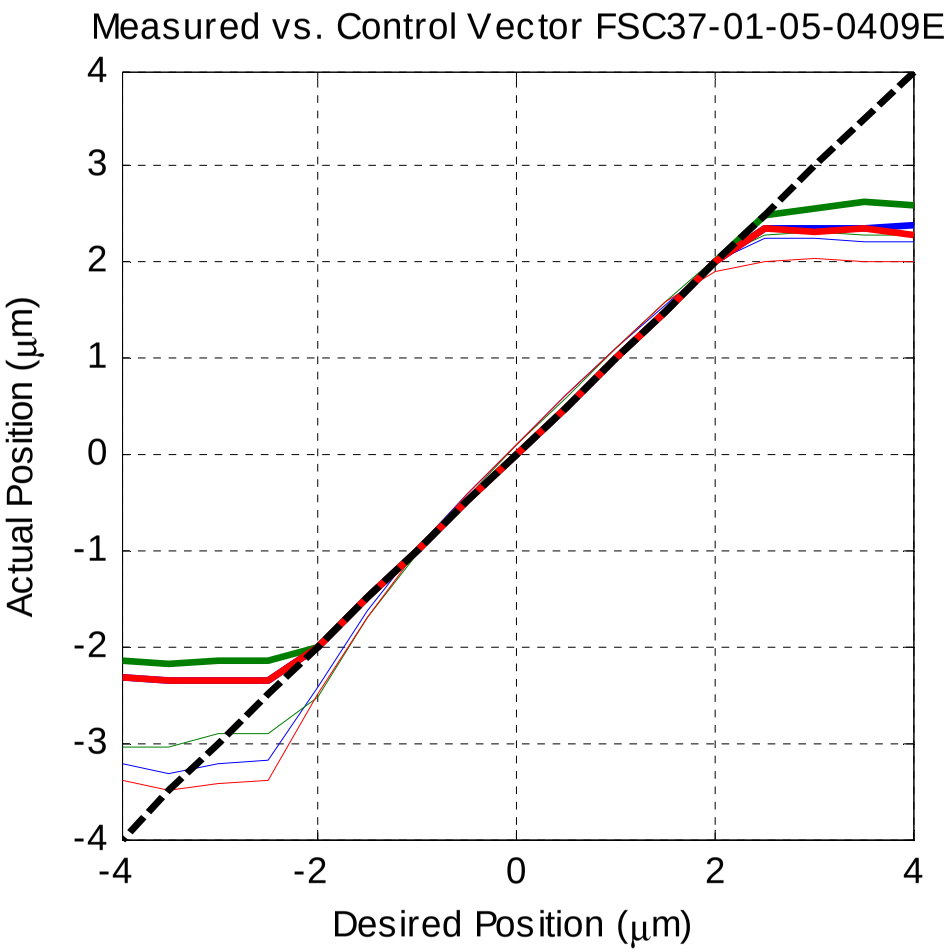
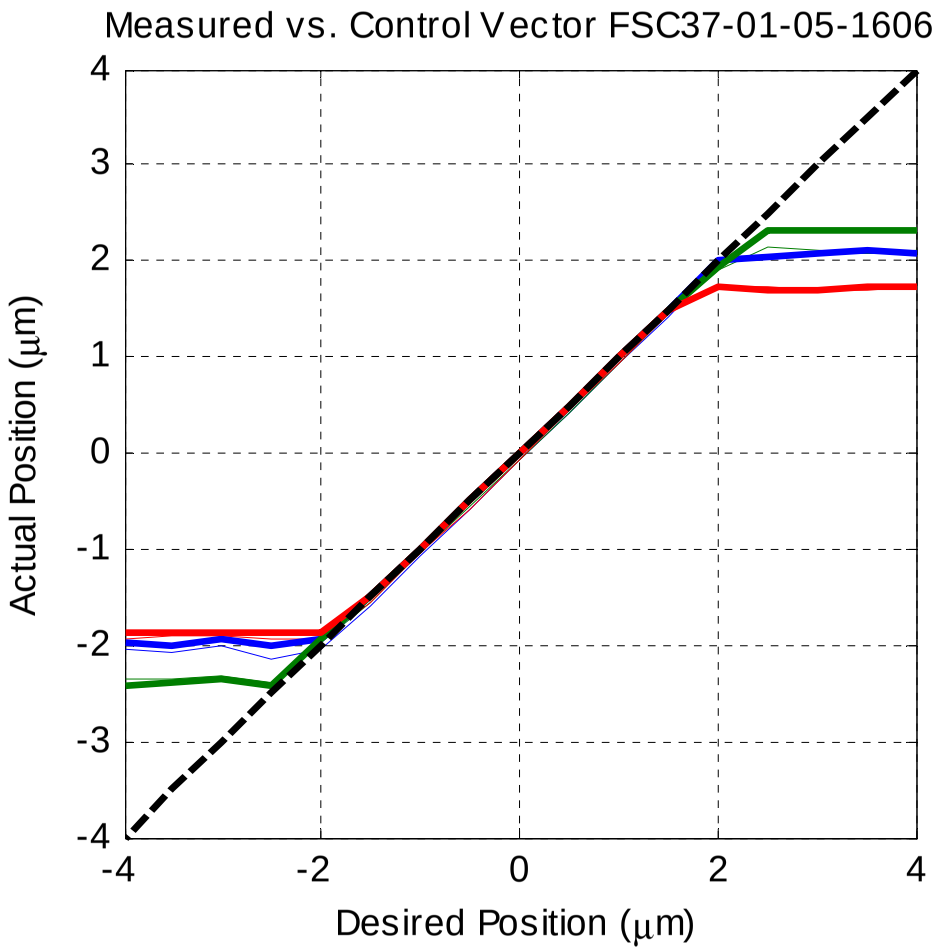
Controller Improvements





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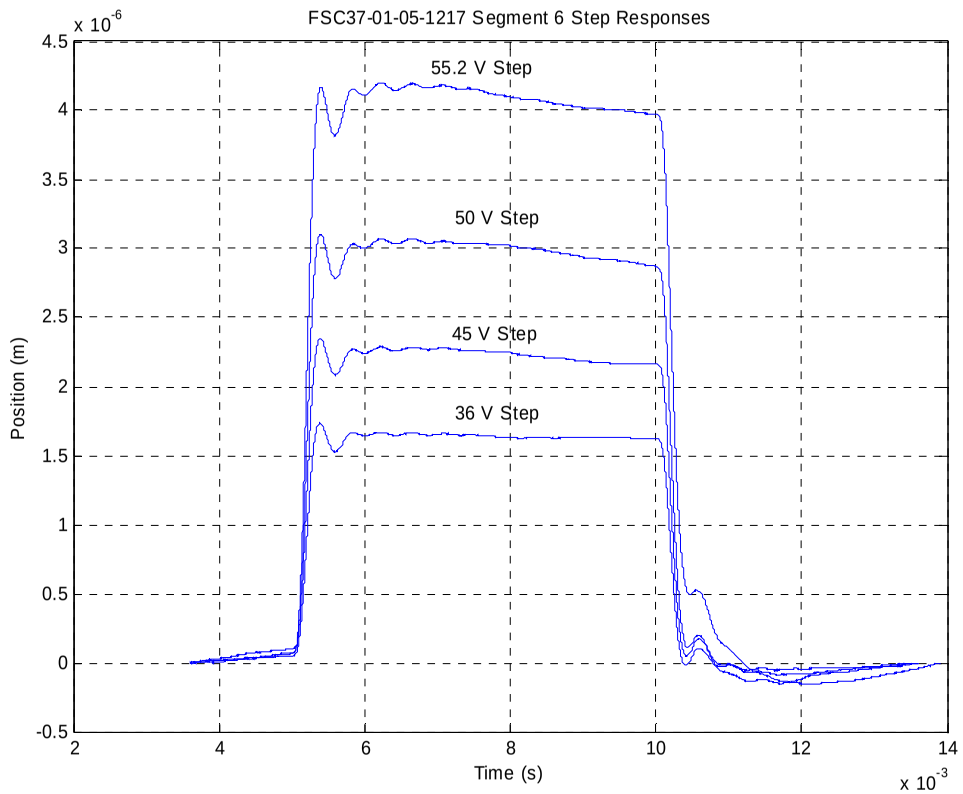
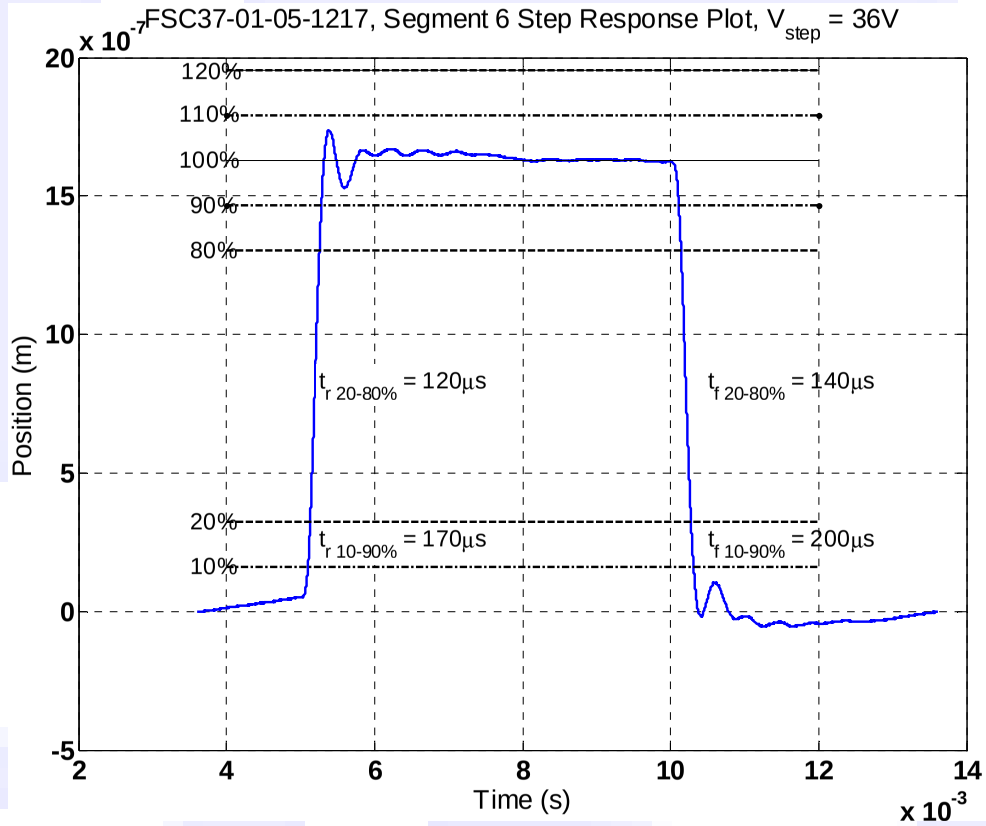
Step Response





120/140 µs rise/fall times, 20-80%; 1.63 µm, 36 V

DMs can survive ~350 G shock/vibration unpowered

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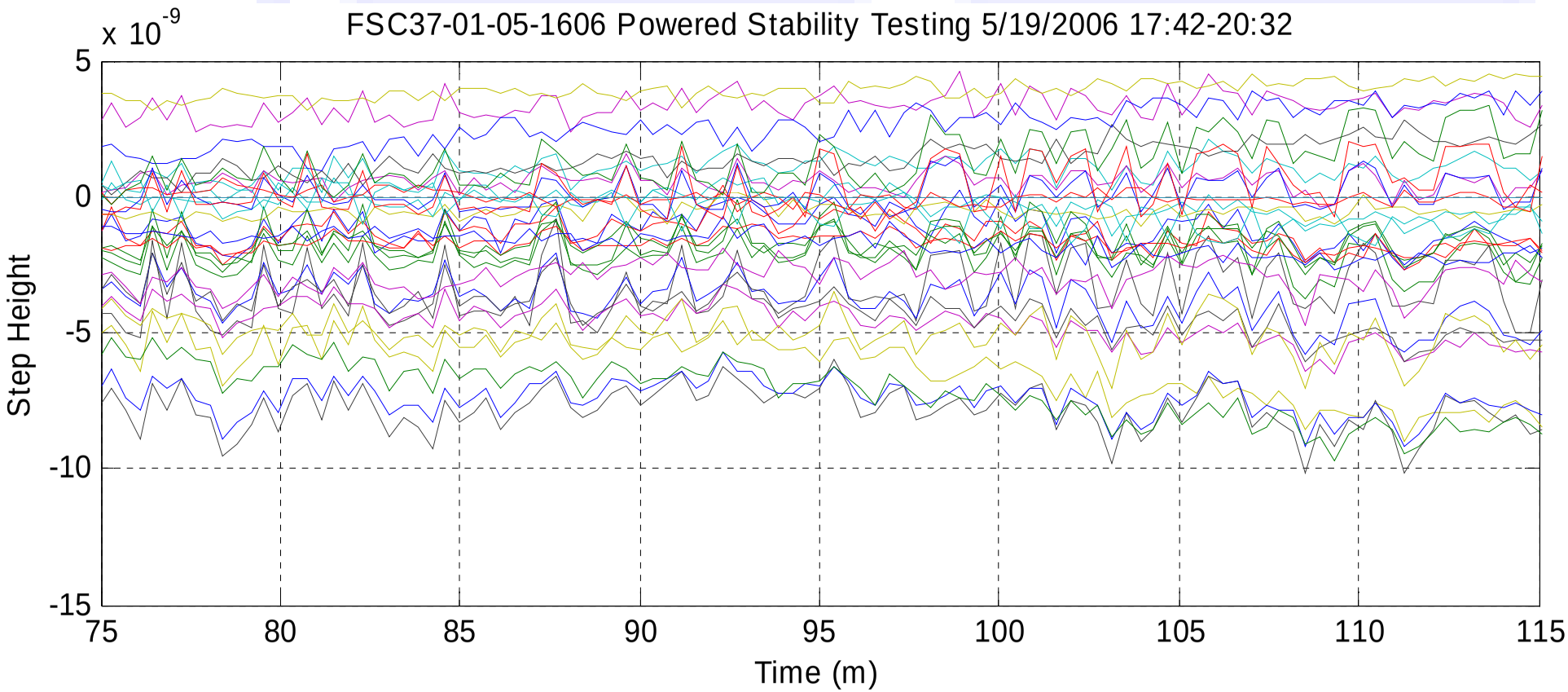
nm-Level Positioning Stability



Stability to 0.21-1.17 nm rms over 15 minutes (75-90)

Next Steps

- Flatter segments for high-contrast applications
  - 1-3 nm *rms*
- Faster segments for atmospheric corrections
- Larger arrays
  - 127, 367, …
- 2nd generation, low-noise drive electronics
- Improved shock resistance

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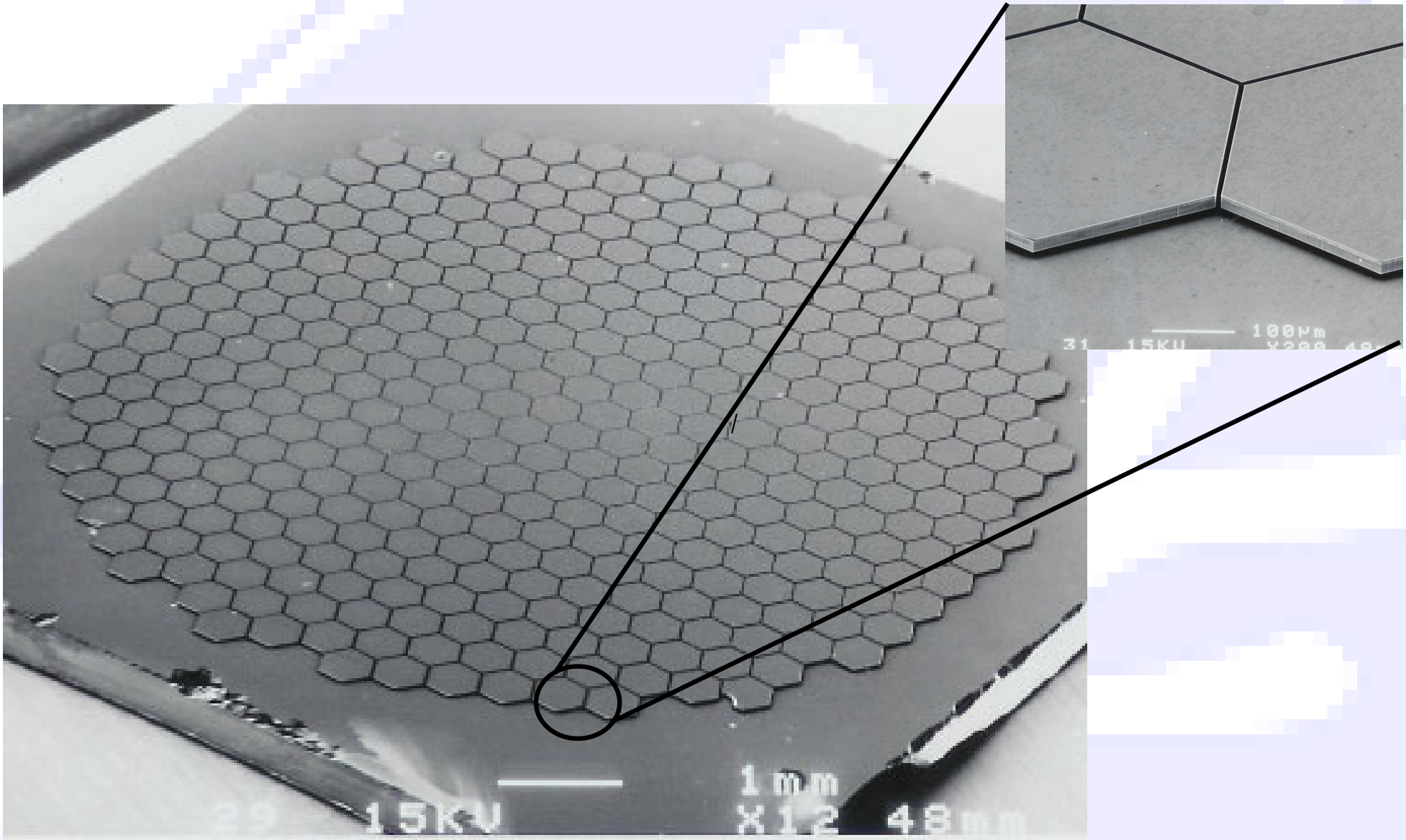
Scalable Assembly: 367 Segment Demo



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Conclusions

- Demonstrated a 37-segment PTT DM
  - 7.5µm stroke
    - Currently shipping ~5 µm-stroke DMs
  - 3.5 mm inscribed aperture
  - ~ 2.3 kHz response; 120/140 µs rise/fall times
  - Rigid mirror segment stays flat over temperature
    - < 20 nm *rms* surface-figure errors after packaging step at 120°C
  - Open-loop controller flattens array to < 20 nm *rms* surface figure errors