Adjustable X-ray Optics: Status Update

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Summary Status: Refresher from Aug. '12

- Demonstrated good agreement between modeled and measured influence functions on flat test optics
- Improved yield on test flats to > 95 per cent (good piezo cells)
- Modeling with representative figure errors from mounted mirrors consistent with half arc sec HPD post correction.
- Claimed TRL 2
- Just started work on curved segments
  - Uniform deposition
  - Printing electrode pattern
- Incorporating optical profilometer

Summary Status: New Since Aug. '12

- Improved yield on flat mirrors to routinely 100 per cent
  - I.e., all piezo cells good
- Incorporated new metrology
  - Lower noise than before and faster, but not meeting our expectation
- Response uniformity meets requirements (+/- 30 per cent)
- Repeatability within metrology noise (20 nm, rms)
- Fabrication and testing of cylindrical test mirrors
  - Influence functions match models to within metrology noise
  - Piezo coefficient same (within errors) to flat pieces
- Believe now at TRL3

Flat sample repeatability and uniformity

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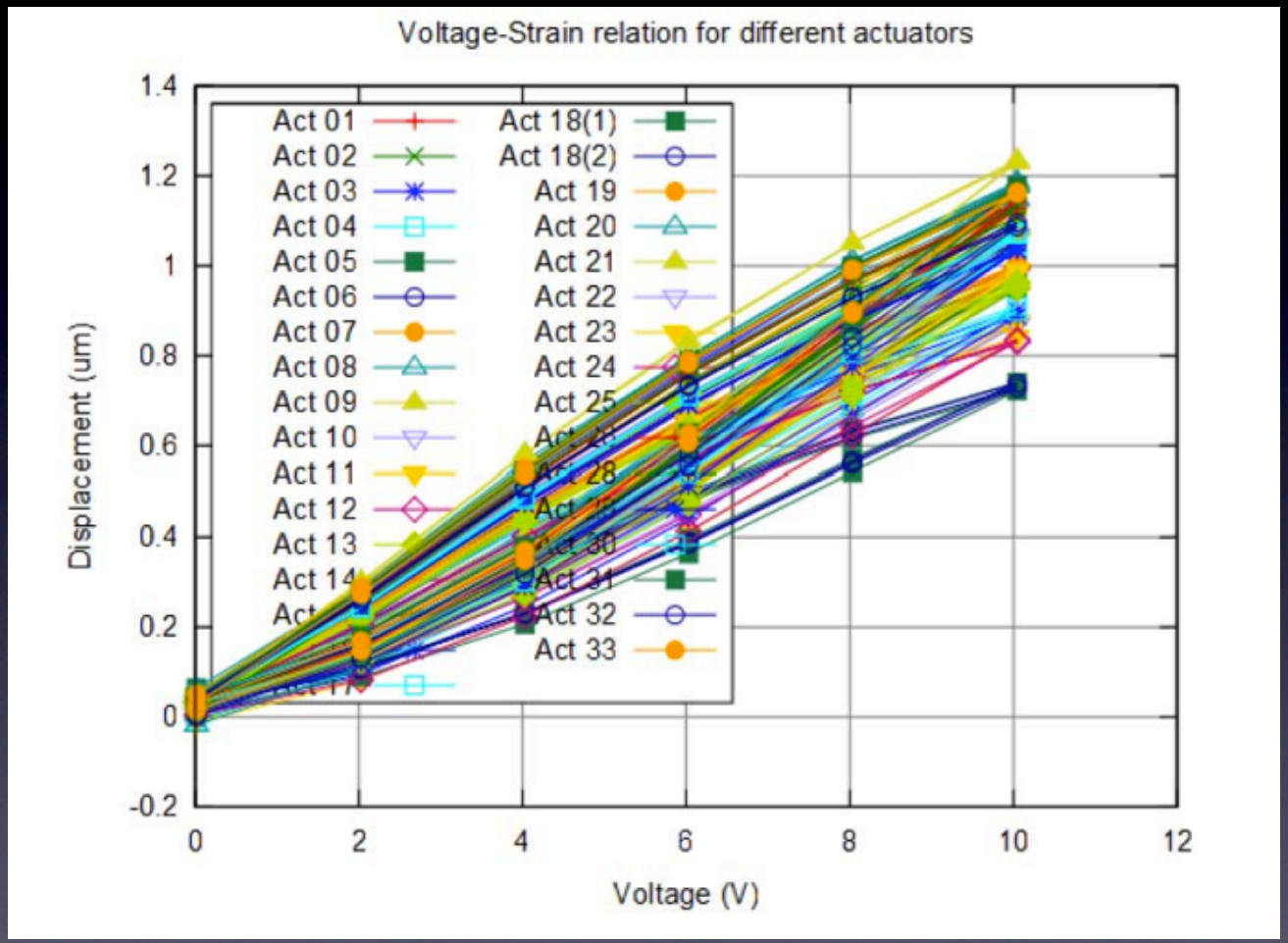

Hysteresis curves for all 33 actuators on 10 cm diameter flat test sample.

Flat sample: multiple piezo cells

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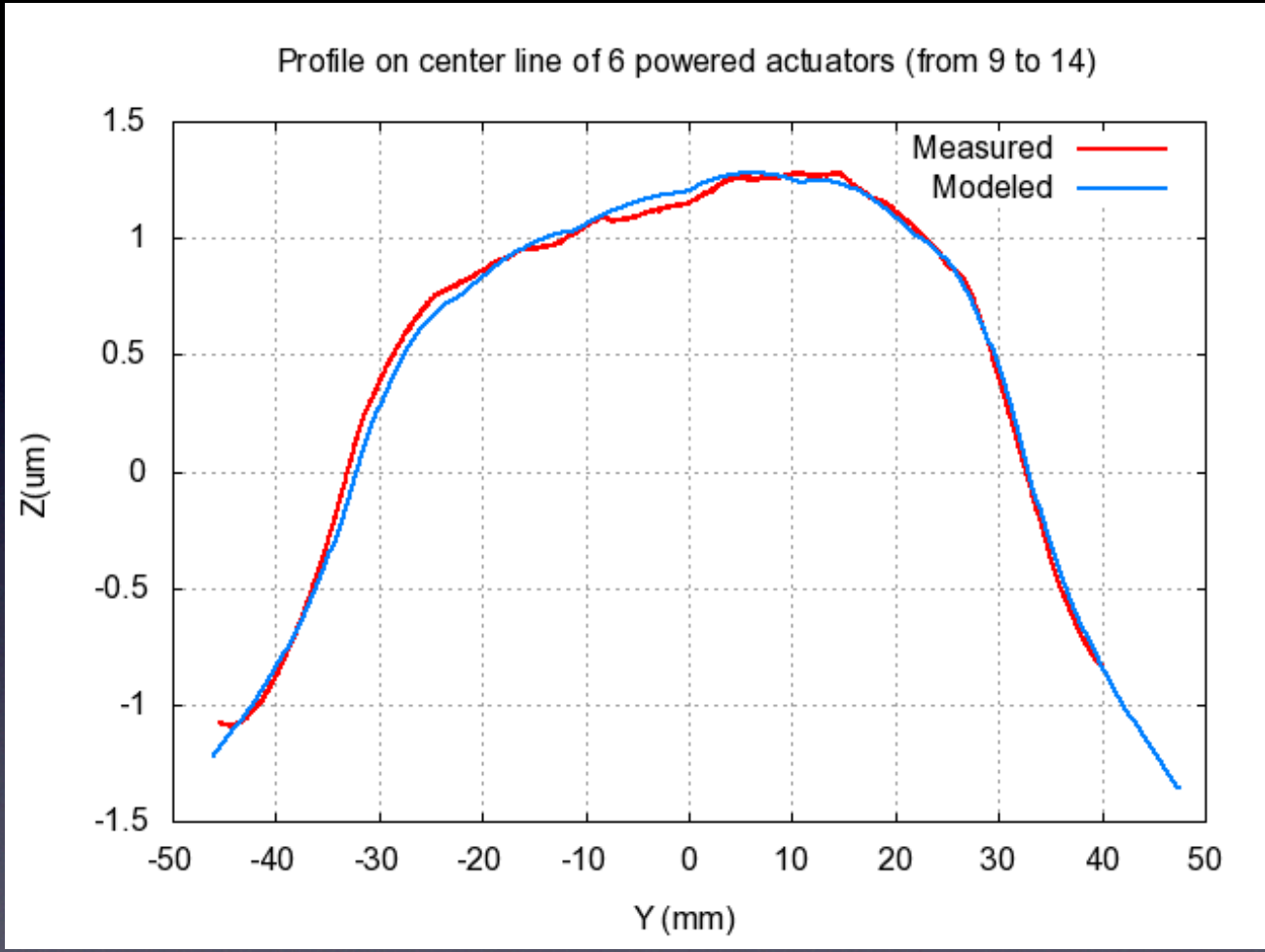

Energized 6 piezo cells in a row – all at same 10V. Measured profile matches modeled profile to within 40 nm, rms.

Cylindrical sample

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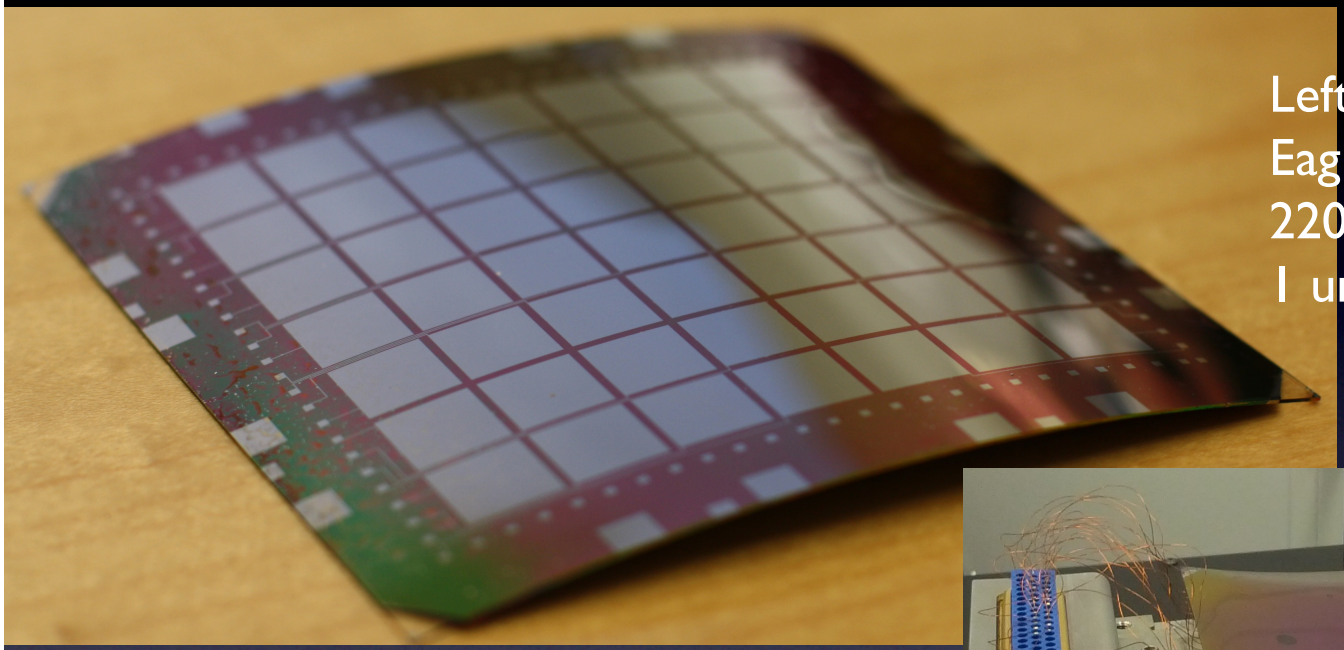
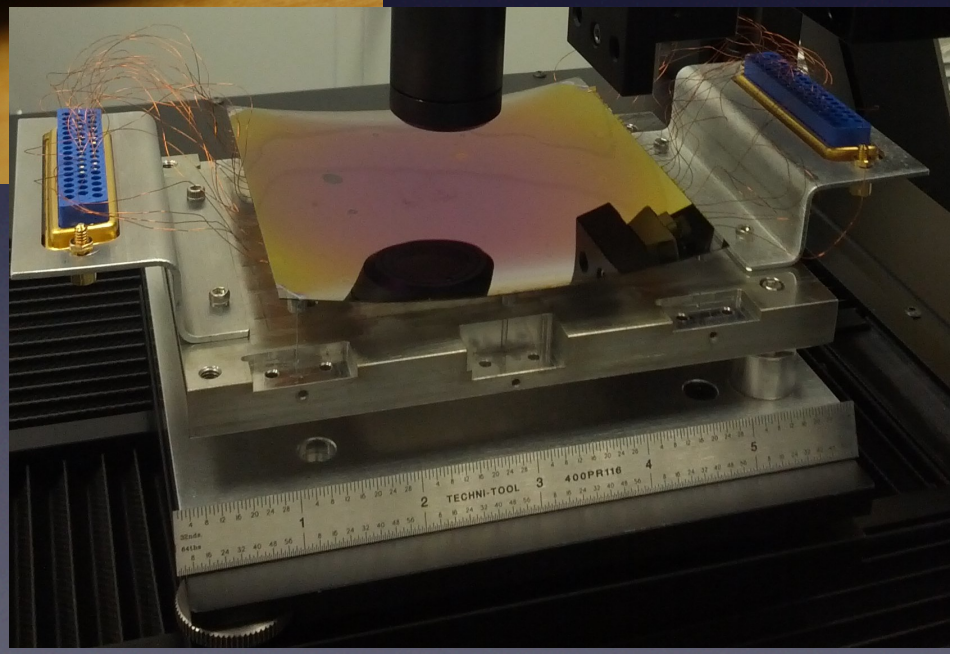


Left: 10 x 10 cm^2 Corning Eagle piece, 0.4 mm thick, 220 mm radius of curvature. 1 um thick PZT layer



Right: same sample as above, mounted to cylindrical optic metrology mount, on scanning pptical profilometer

Repeatability and gain on cylindrical test piece

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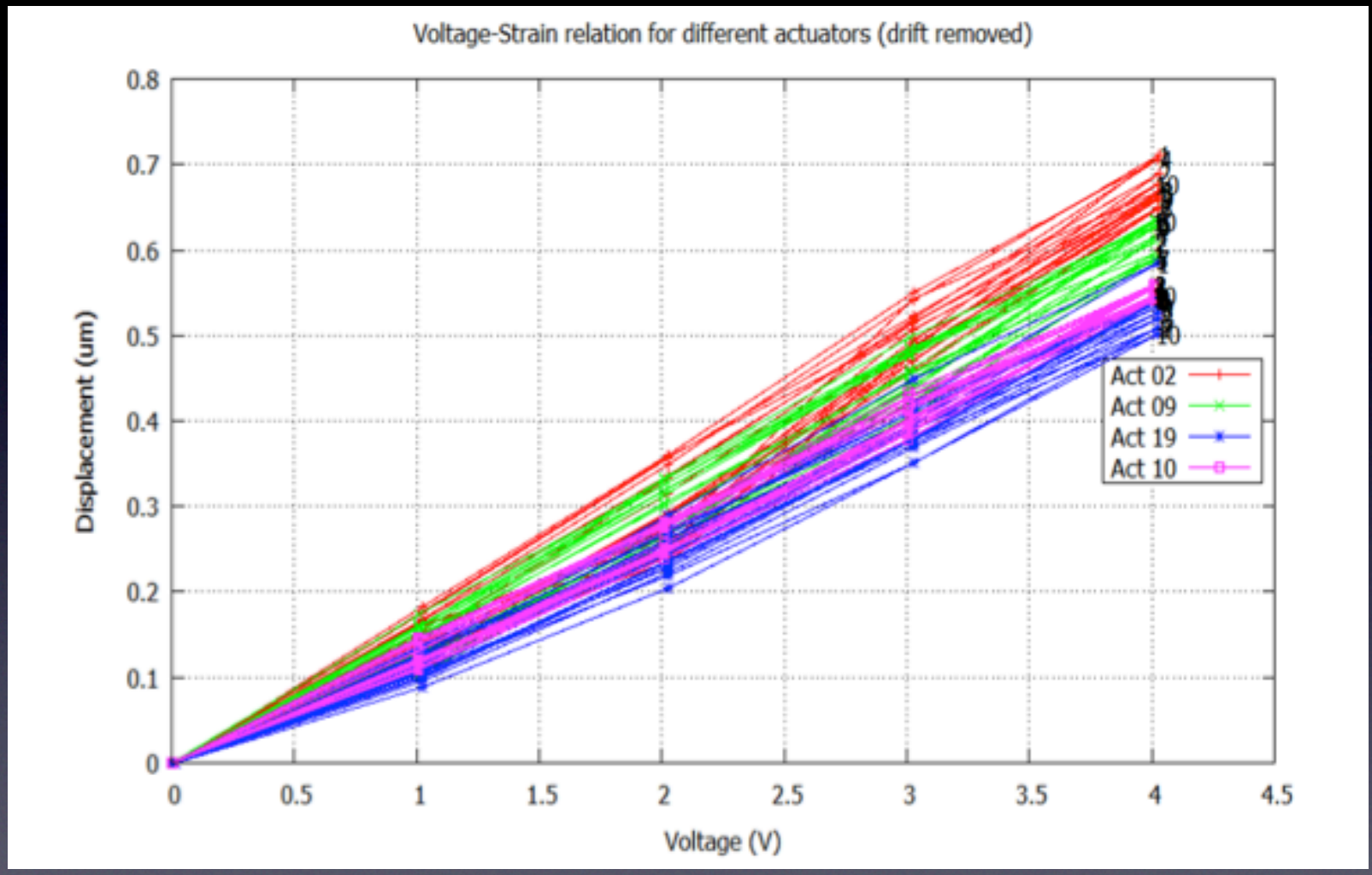

Hysteresis curves.

Cylindrical segment: repeatability

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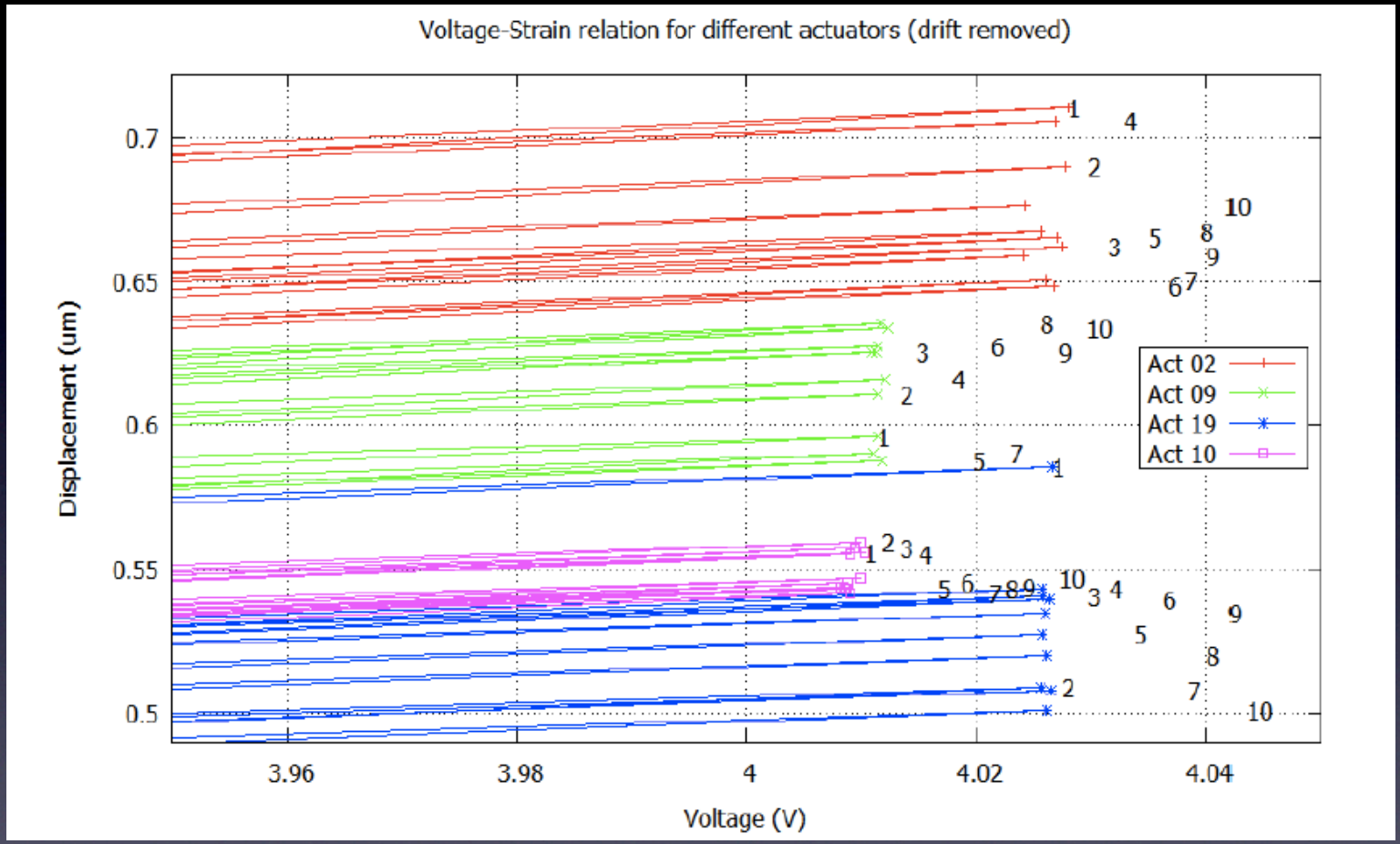

Expanded plot of hysteresis curves for cylindrical test mirror. Numbers on right represent order in which the hysteresis curves were measured.

Repeatability = 20 nm, rms, equal to metrology noise for test,

Cylindrical test mirror: influence functions

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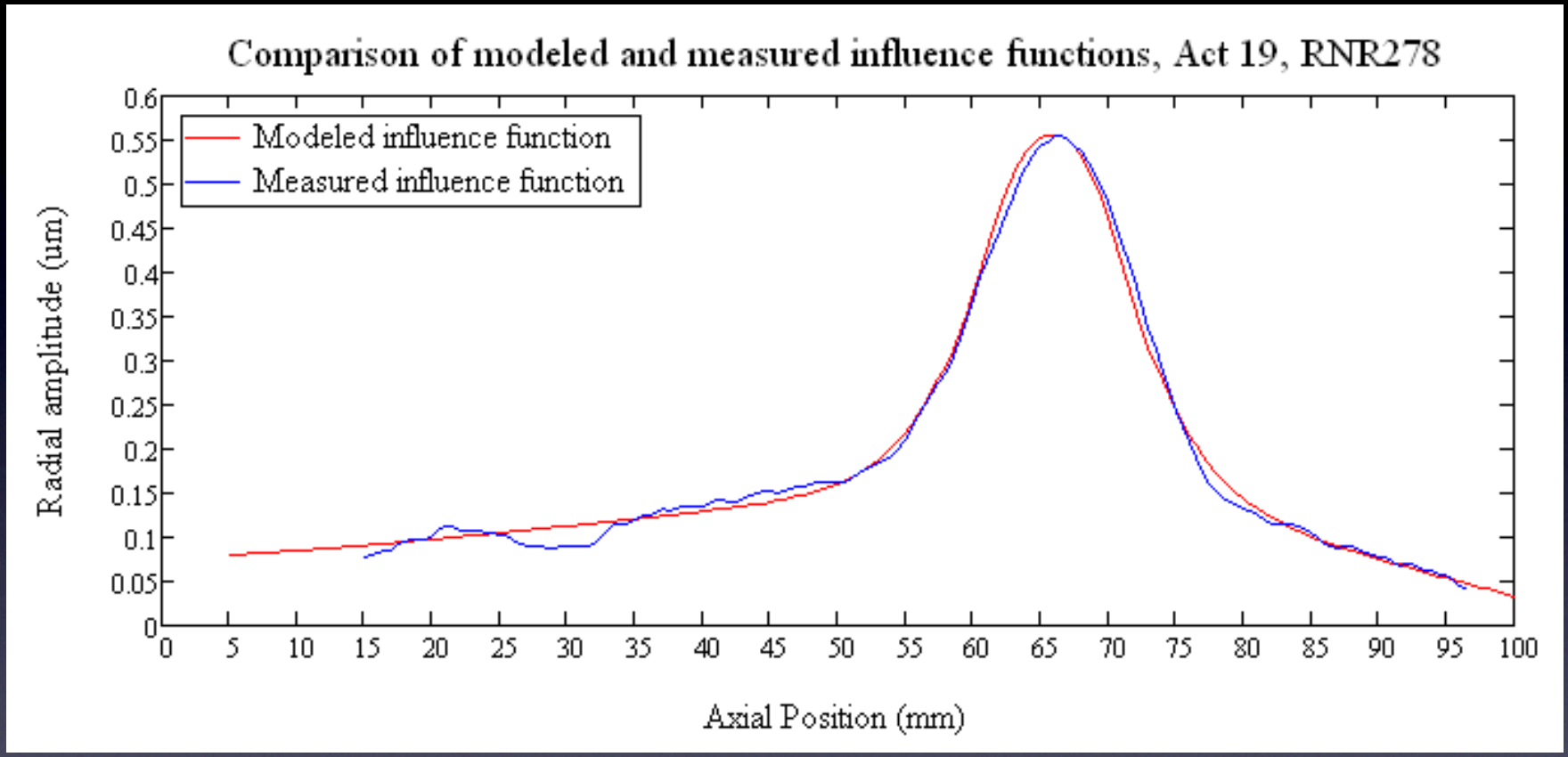

Comparison of modeled and measured influence functions for cylindrical test mirror (4V). Difference between model and measurement is 11.4 nm, rms – metrology repeatability ~ 20 nm rms

Other activities

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- Modeling/optimization
  - First cut test of different piezo cell layouts
    - Interleaved layout yields best result
    - Ellipsoidal shaped cells and 5 mm electrodes on 10 mm spacing give poorer result than nominal square array
  - Developing piezo voltage optimization with bounds and constraints
    - Previously, used 'canned' Python SVD least square
    - Internal 'debate' over iterative simplex or global simulated annealing
- Accelerated lifetime testing
  - Examining efects of Mn and Si dopants
  - Refining parameters for accelerated lifetime testing scaling with voltage and temperature
  - Current estimates, not including area scaling, ridiculously long (thousands of years)

Other activities

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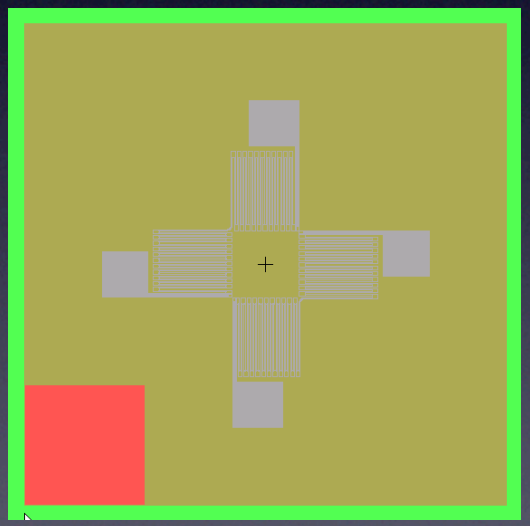
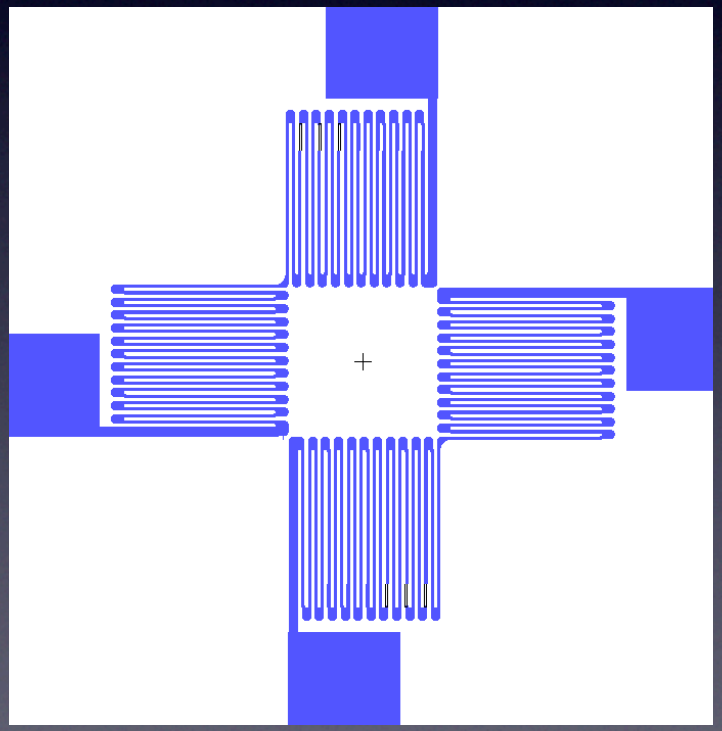
- Real time lifetime testing
  - mask and fixturing designed, being fabricated
  - Incorporate strain gauges directly on piezo cell
    - Need to test/calibrate, but estimated strain accuracy is +/- 1 part per million (ppm), compared to nominal strains of ~ 500 ppm





On-cell control and feedback

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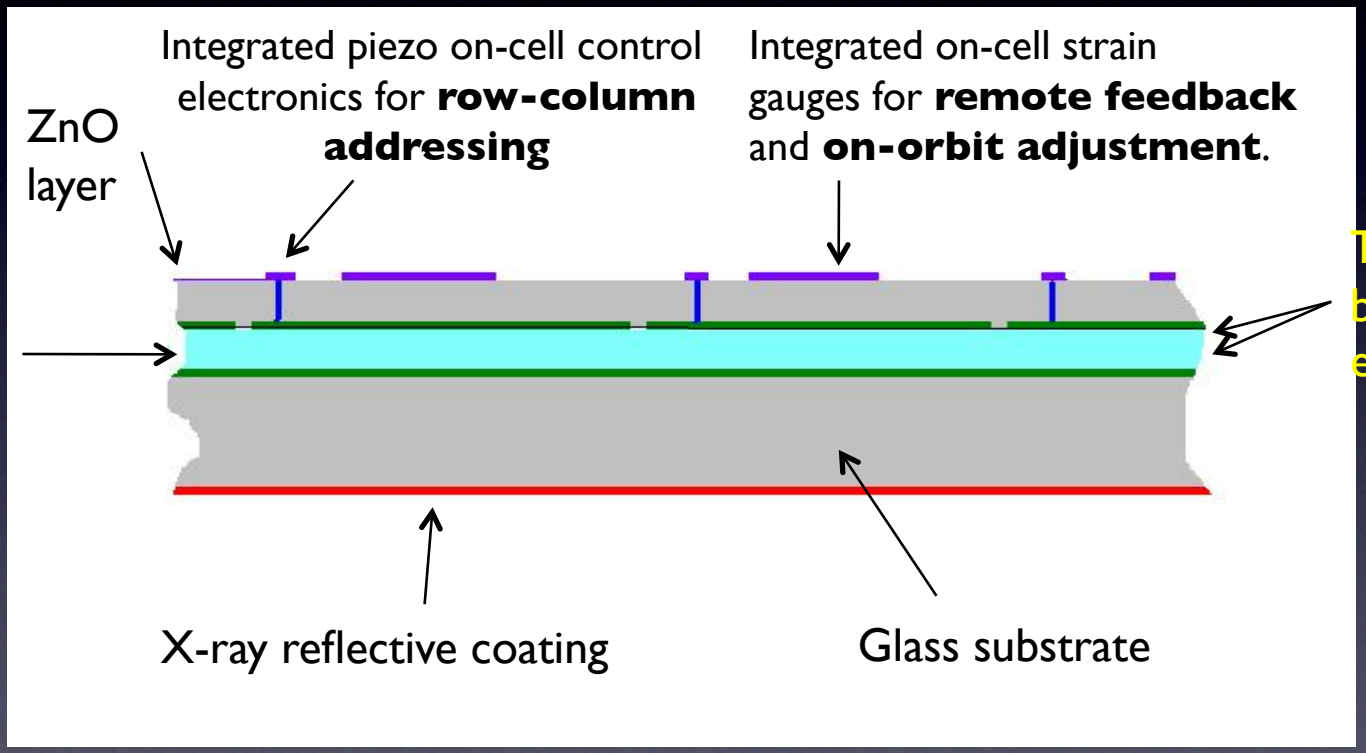
- Incorporate ZnO insulating layer above piezo electrodes and then print ZnO electronics on cell for command/control.



- Use calibrated on-cell strain gauges for on-orbit adjustment metrology/feedback. (Testing with realtime lifetime test samples).

Alignment/mounting

- SAO internally funded work on alignment
- Divergence between AXSIO/SMART-X requirements
  - AXSIO – several arc sec alignment, small (~ 3 arc sec HPD) allowable change in figure due to mounting
  - SMART-X – 0.35 arc sec (RMSD) alignment, larger (~ 5 arc sec HPD) allowable change in figure due to mounting
- Developing technology/techniques for higher accuracy segment alignment
  - Build upon SAO IXO experience
  - Build upon GSFC (Ryan McClelland) IXO/AXSIO experience

Summary

- We continue to make progress.
- Claim current TRL = 3
  - Measurements match models on curved mirror segments
  - Measurements repeatable to metrology noise levels
  - Models suggest correction of 7 – 10 arc sec mounted mirrors to sub-arc sec level
- Plan for full aperture X-ray test of mounted, aligned, corrected conical pair in late FY15
  - TRL 4
- Separate development contract (PSU PI, SAO Co-I) for ZnO integrated electronics