Adjustable X-ray Optics: Status Update

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April 12, 2013
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

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

pbr  NASA PCOS XraySAG  04/12/2013
Flat sample: multiple piezo cells

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

Left: 10 x 10 cm² 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 optical profilometer
Repeatability and gain on cylindrical test piece

Hysteresis curves.
Cylindrical segment: repeatability

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

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

• 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 effects 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

- **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

- 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