Development Roadmap for an Adjustable X−ray Optics Observatory

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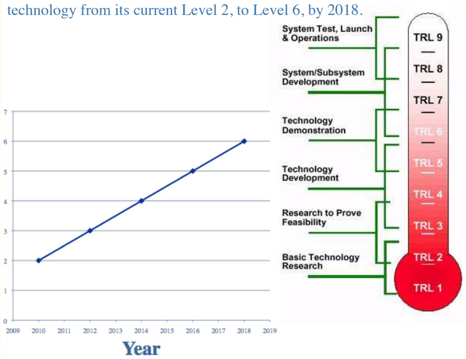
ABSTRACT

Technology Readiness Levels (TRL)

We are developing adjustable X-ray optics to use on a mission such as SMART-X (see posters 38.02, 38.03 and Presentation 30.03). To satisfy the science problems expected to be posed by the next decadal survey, we anticipate requiring effective area greater than 1 m^2 and *Chandra*-like angular resolution: ≈0.5". To achieve such precise resolution we are developing adjustable mirror technology for X-ray astronomy application. This uses a thin film of piezoelectric material deposited on the back surface of the mirror to correct for figure distortions, including manufacturing errors and deflections due to gravity and thermal effects. We present here a plan to raise this technology from its current Level 2, to Level 6, by 2018.



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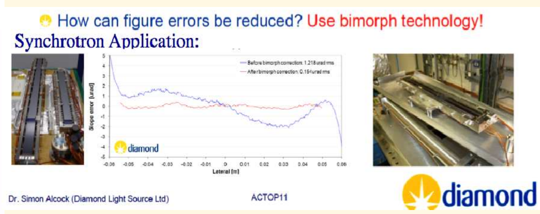
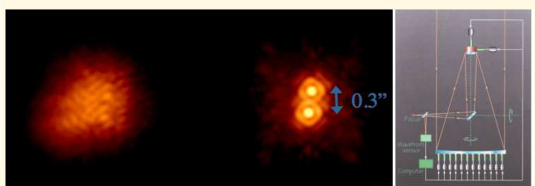
LEVEL 2

Technology concept or application formulated

Criteria (cf. two figures below)

- Adjustment of X-ray mirrors used at synchrotrons. 1-d, 10Åcontrol
- Adaptive optics, ground based telescopes





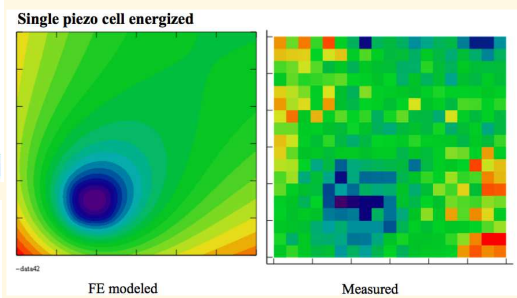
Credit: Chas Beichman and Angelle Tanner of JPL, www.astro.caltech.edu/palomar/AO/

LEVEL 3

Analytical and/or experimental proof-of-concept

Criteria

- Measure controlled deformations of a flat glass sheet produced by piezo-electric actuators
- Metric: Demonstrate control of displacements to 40 rms, over a range of +/- 4000 Å



We have successfully deposited a grid of piezoelectric cells on the back of a flat glass surface. Activation of a single piezo cell (right) is roughly consistent with the prediction (left), proving the concept of controlled figure adjustment. To exit TRL level 3 it remains to prove that the controlled displacements are within the required accuracy.

LEVEL 4

- Component or breadboard validation in a simulated environment.
- A low fidelity system/component breadboard is built and operated to demonstrate basic functionality.

Criteria

- On a conic pair of mirror elements, deposit piezos, align the secondary to primary, measure in X-rays, adjust predictably and verify by repeat measurement.
- Produce a breadboard module with connections for piezo actuators and alignment hardware, and install multiple shells aligned to a precision consistent with 0.5 arcsec imaging.

LEVEL 5

- Component or breadboard validation in a simulated environment.
- A mid-level fidelity system built and operated in a simulated operational environment.

Criteria

- Multiple shells in a full size module are adjusted to produce a half-arcsec X-ray image.
- Demonstrate alignment of modules to 0$''$.2. item Subject module to acoustic, vibrational testing

LEVEL 6

- System/subsystem model or prototype demonstration in a relevant environment
- A high-fidelity system/component prototype built and operated in a relevant operational environment.

Criteria

- Subject a module to environmental testing. Then repeat the TRL 5 demonstration, showing that the shells retain the required 0.5 arcsec imaging with no further adjustment.
- Fly a (sparse) mirror set in a rocket, and obtain an image of a bright celestial point source.

Using the MSFC calibration facility (shown above), or a similar facility, we will produce an X-ray image using a single module with a limited number of primary/secondary mirror pairs, to demonstrate Technology Level Readiness 5.

MANUFACTURING READINESS LEVELS

These must be considered for making mandrels, slumping, mirror element metrology, depositing piezo films, electrical connections, calibrating influence functions, and alignment and assembly.

MRL Issues:

Technology and Industrial Base; Design; Materials; Cost and Funding addressed prior to 2020 decadal survey.

Process Capability and Control; Quality Management; Manufacturing Personnel; Facilities; Manufacturing Management addressed in Phase A.

We are currently at Level 4: Capability to produce in a laboratory environment

In Phase B:

- Level 5: Produce components in a relevant environment.
- Level 6: Produce a prototype subsystem in production-like environment.

In Phase C/D

- Level 7: Capability to produce subsystems in a production environment. at PDR
- Level 8: Pilot line capability demonstrated. Ready to begin low rate production.
- Level 9: Capability in place to begin full Production at CDR