Adaptive X-ray Optics III (SPIE 9208)
2014 August 17; San Diego, CA (USA)

Toward large-area sub-arcsecond x-ray telescopes

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and co-authors

Authors represent most of US effort toward sub-arcsecond x-ray telescopes.

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[j] Oak Ridge Associated Universities, Goddard Space Flight Center (USA)
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Several co-authors are presenting at this conference.

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Outline

- Motivation and issues
- Categories of potential solutions
- Actuator technologies under development

Objective

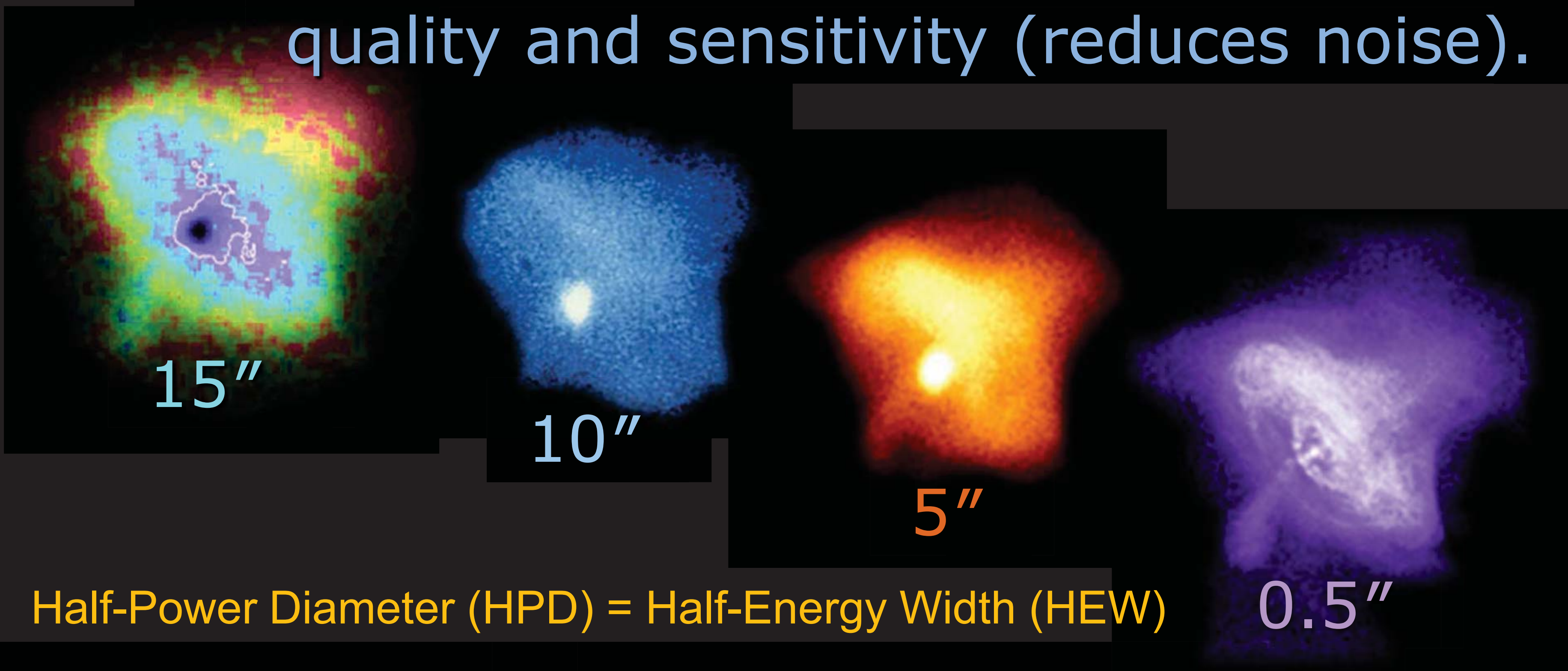
- Next major US x-ray astronomy mission will not likely start until 2020’s, after next Decadal Survey.
- *X-ray Mission Concepts Study Report* (2012.08.13)
  - “Lightweight optics [HPD < 10″] are the central technological development that provides an order of magnitude more collecting area relative to existing observatories. It is fundamental to all of the notional missions as well as advancing X-ray Explorer-class missions in the near term.”
  - “The next major goal in lightweight optics is to improve the angular resolution by an order of magnitude to the sub-arcsec level, a return to *Chandra* resolution but with much larger effective area.”

Outline

- Motivation and issues
  - Seek *Chandra* resolution with 30× area.
  - Must resolve technical and programmatic issues.
    - Achieve imaging performance within constraints of mass, geometry, cost, and schedule.
- Categories of potential solutions
- Actuator technologies under development

The key metrics of an x-ray telescope are angular resolution and aperture area.

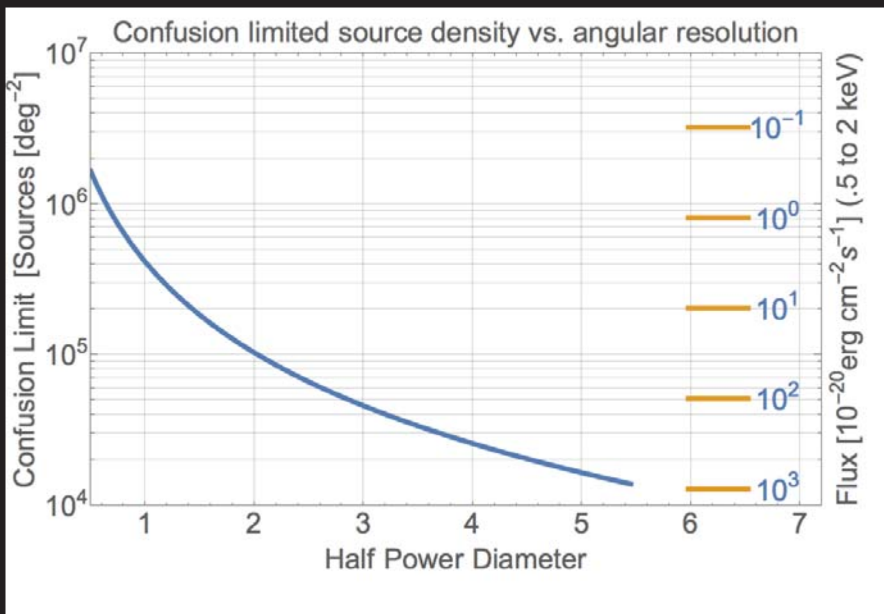
Finer angular resolution improves imaging quality and sensitivity (reduces noise).

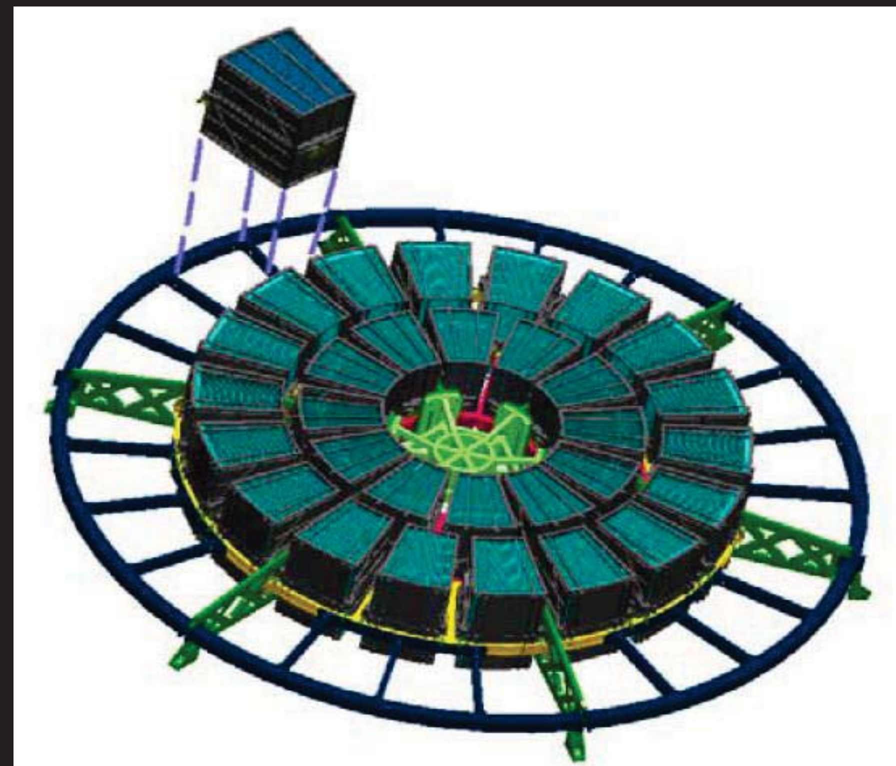


Half-Power Diameter (HPD) = Half-Energy Width (HEW)

Larger aperture area improves sensitivity (increases signal), down to the confusion limit.

SMART-X would give the sub-arcsecond resolution of *Chandra* at ≈30× the area.





Inspired by *Chandra* experience with sub-arcsecond imaging.

Leverages technology development for IXO etc. in lightweight mirrors.

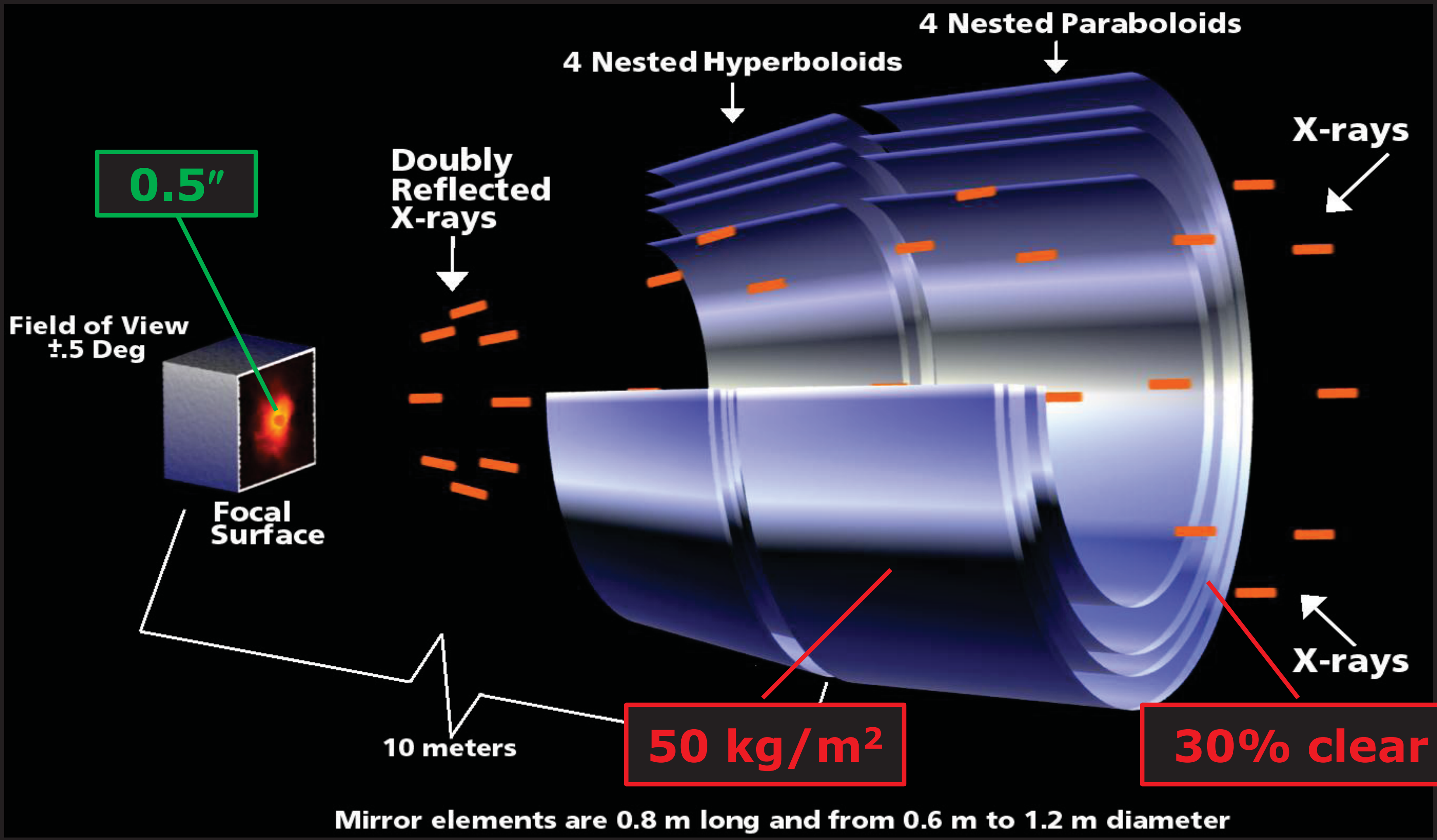
Requires initially good (5″) mirrors.

Would use electro-active layer for bimorph adjustment to <1″ HPD.

Dan Schwartz [9208-6]

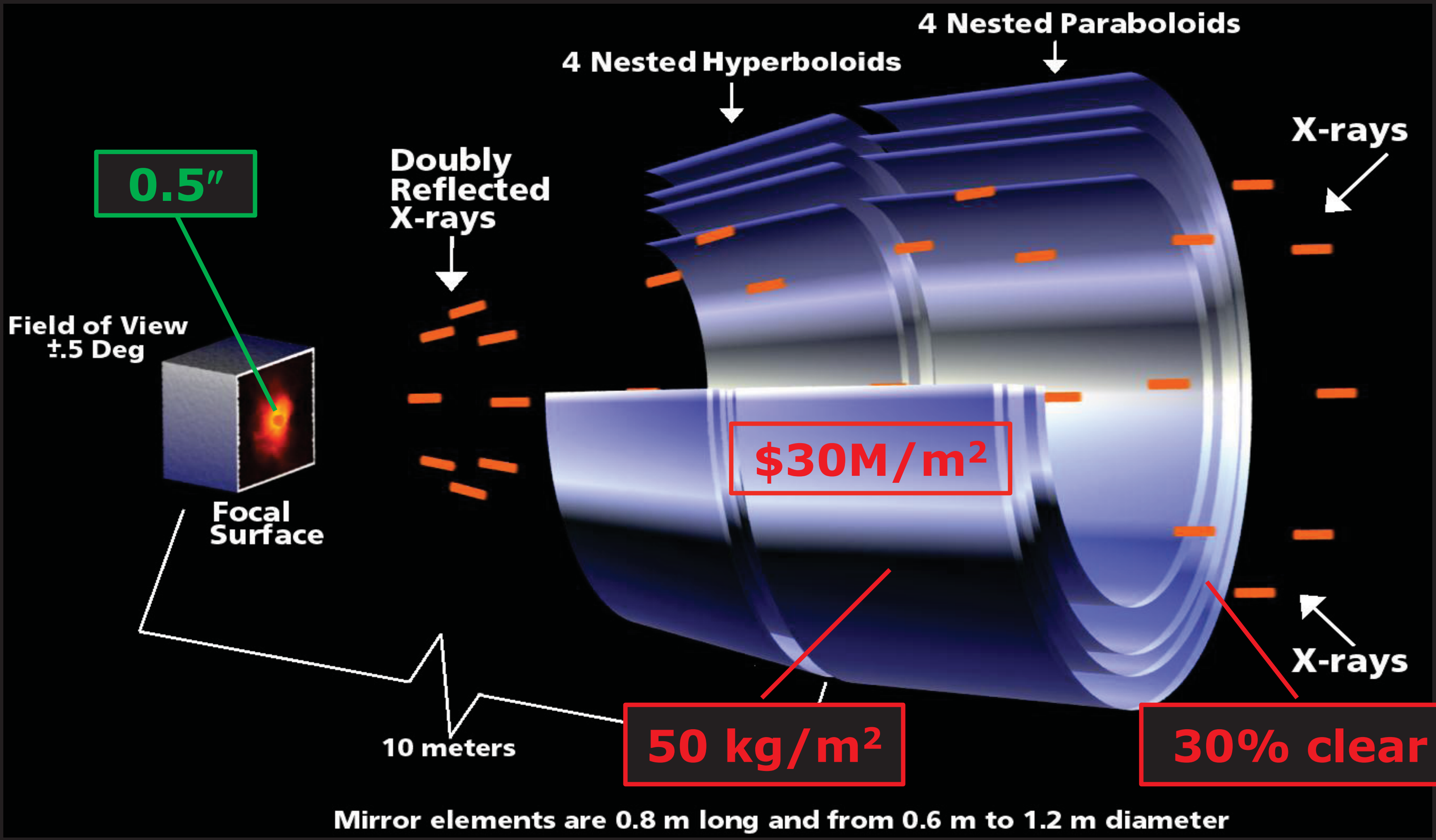
Focusing x-ray telescopes utilize nested grazing-incidence (Wolter-1 like) mirrors.

Schematic of *Chandra X-ray Observatory* x-ray telescope



A large-area <1″ x-ray telescope faces technologic and programmatic issues.

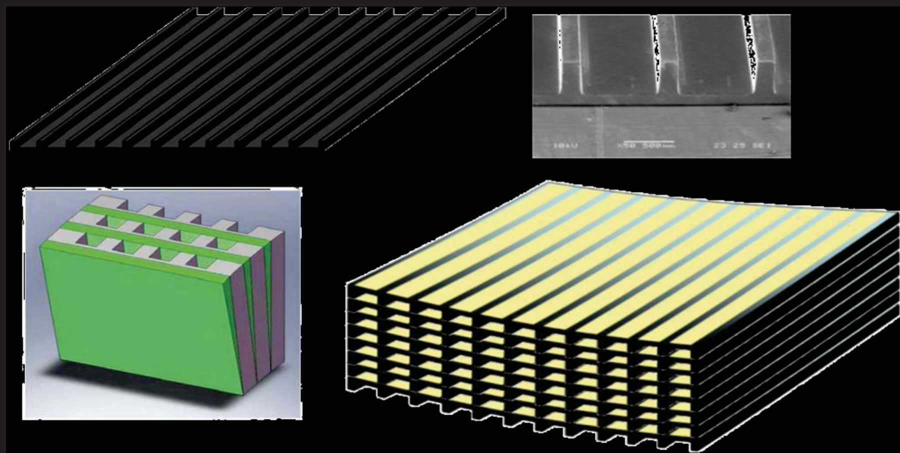
Schematic of *Chandra X-ray Observatory* x-ray telescope

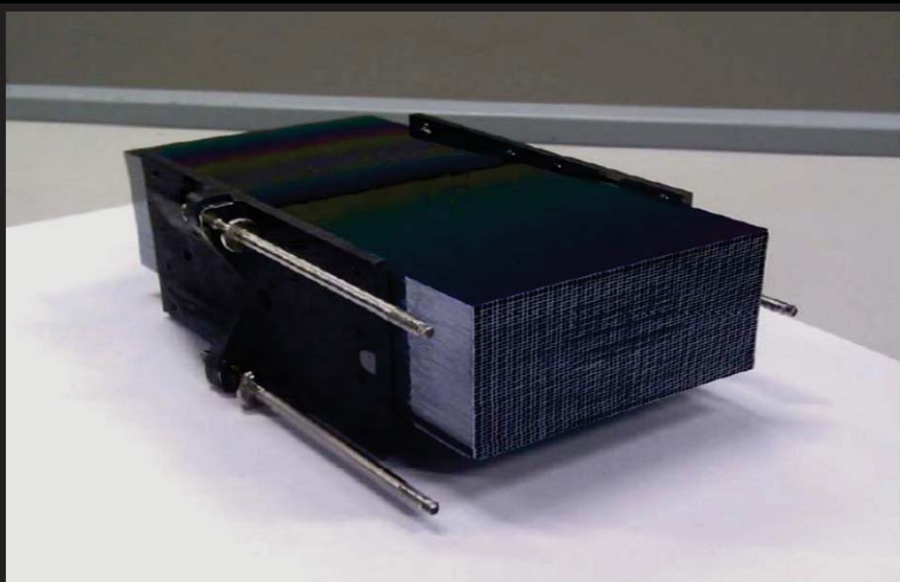


Outline

- Motivation and issues
- Categories of potential solutions
  - Stiff optics
  - Active optics
- Actuator technologies under development

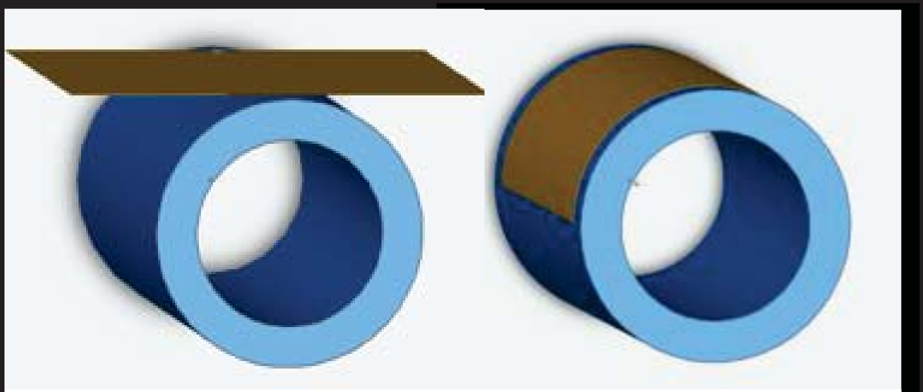
ESA’s ATHENA+

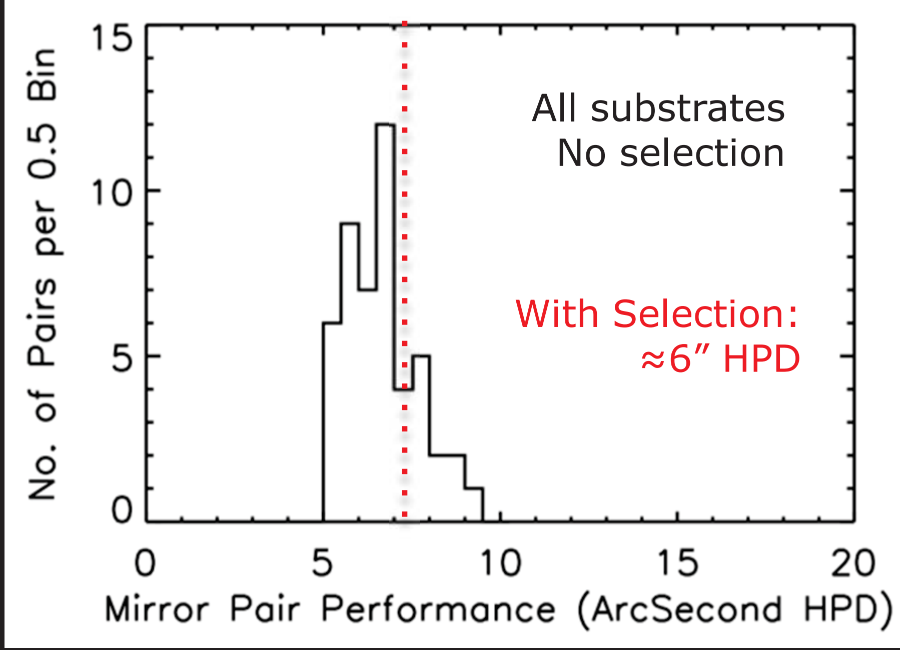




www.the-athena-x-ray-observatory.eu

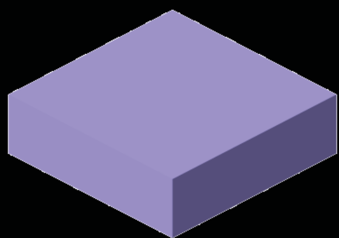
Slumped glass



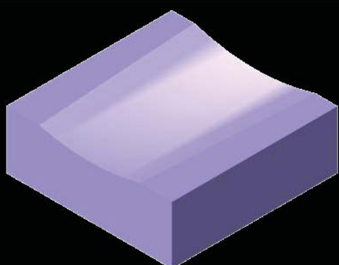


Will Zhang [9144, 15]

Mono-crystalline silicon

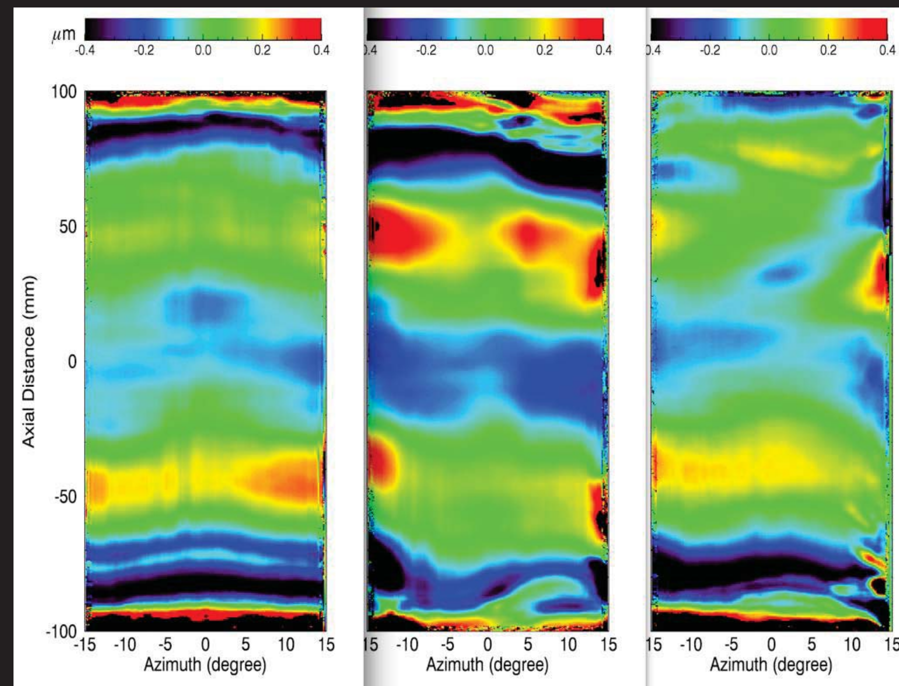


1. Procure single crystalline silicon.
2. Heat and chemically etch to remove all surface/subsurface damage.



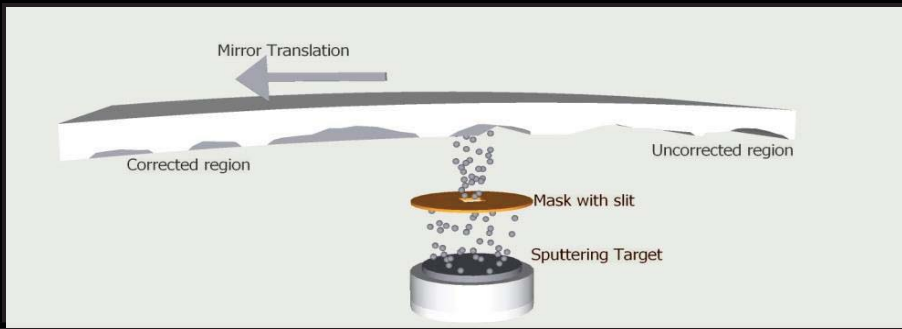
1. Wire-EDM machine conical shape.
2. Heat and chemically etch to remove damage.
3. Polish to achieve excellent figure and micro-roughness.

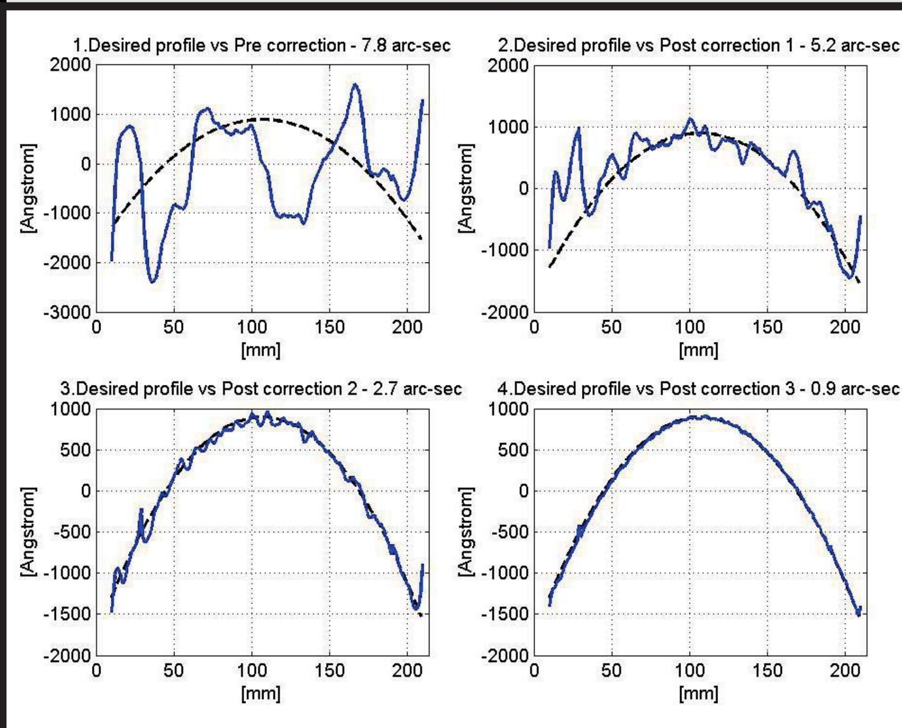
1. Use Wire-EDM to slice off the thin mirror segment.
2. Heat and chemically etch to remove all damage from back and edges.

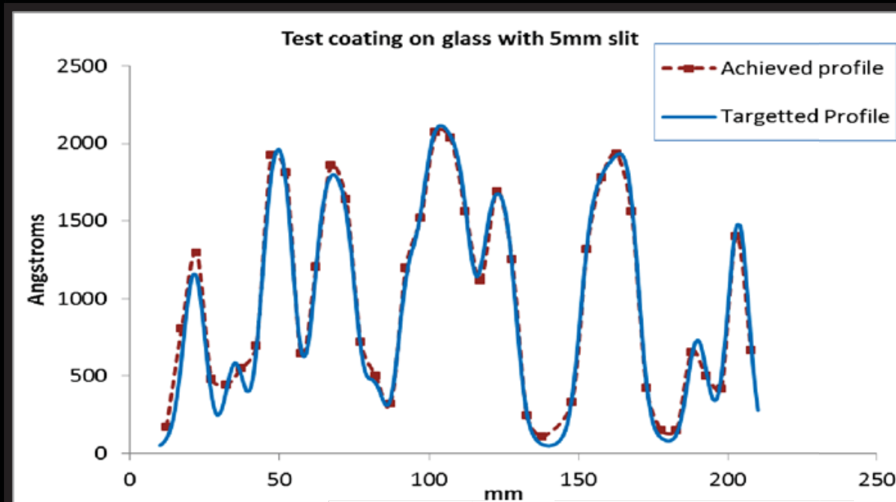


Will Zhang [9144, 15]

Differential deposition

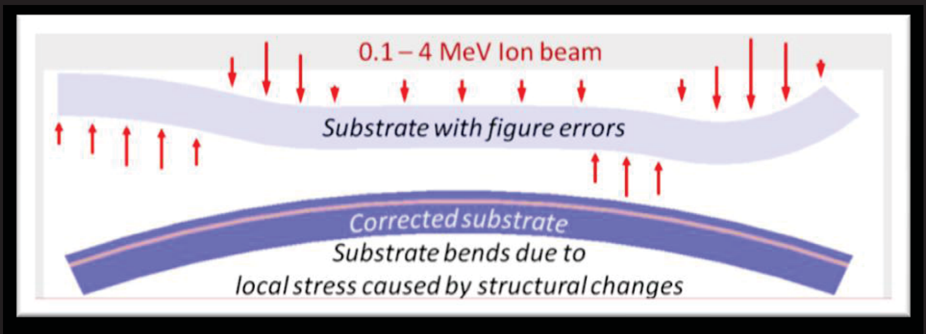


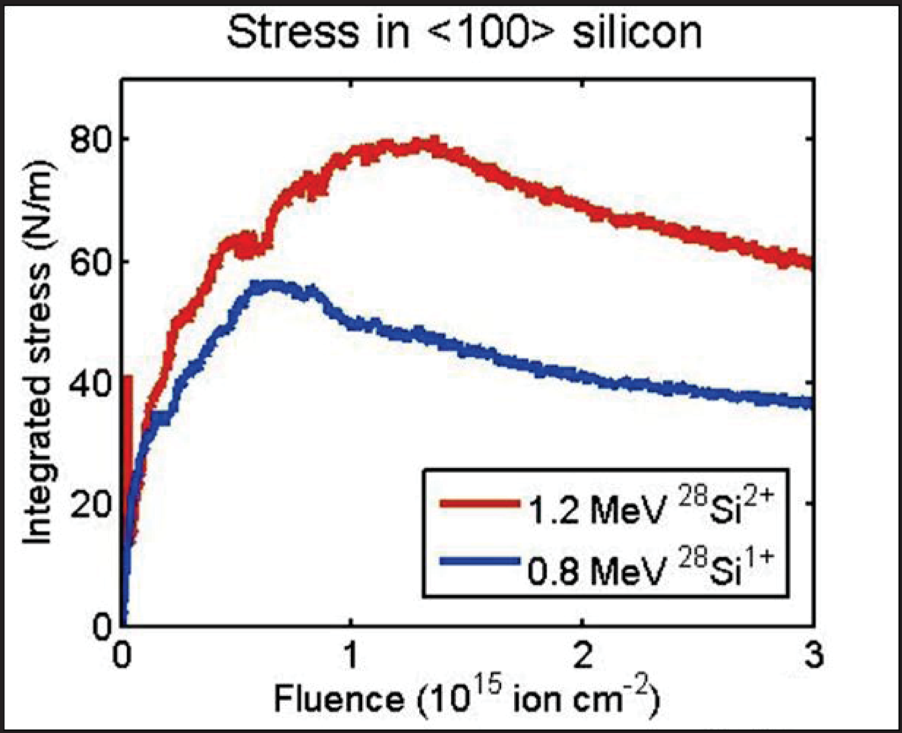


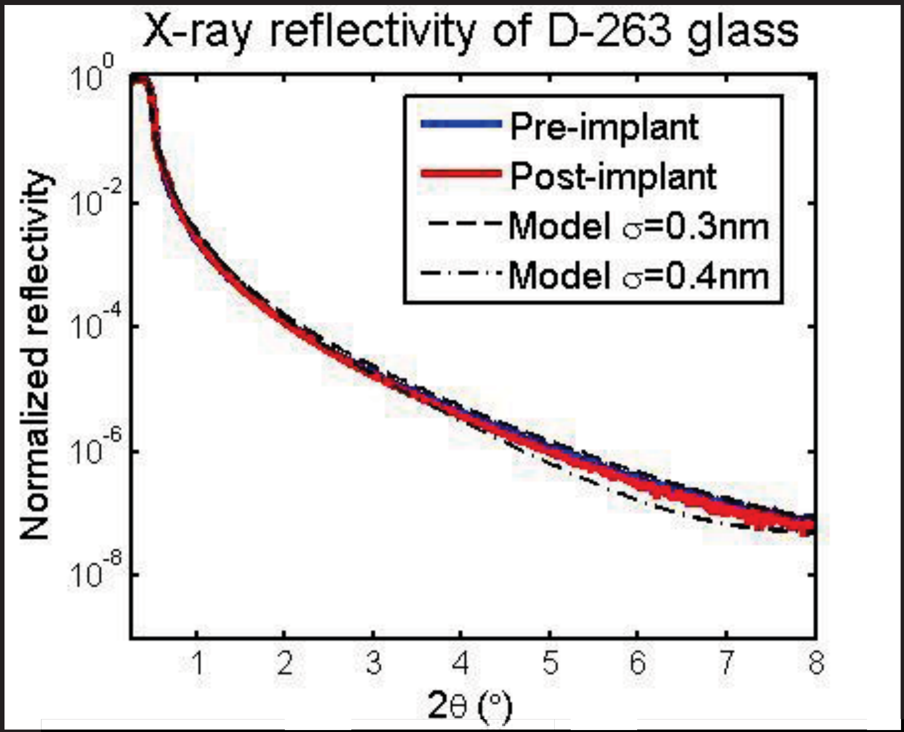


Kiran Kilaru (2014)

Differential ion implantation







Brandon Challifoux [9144, 4D]

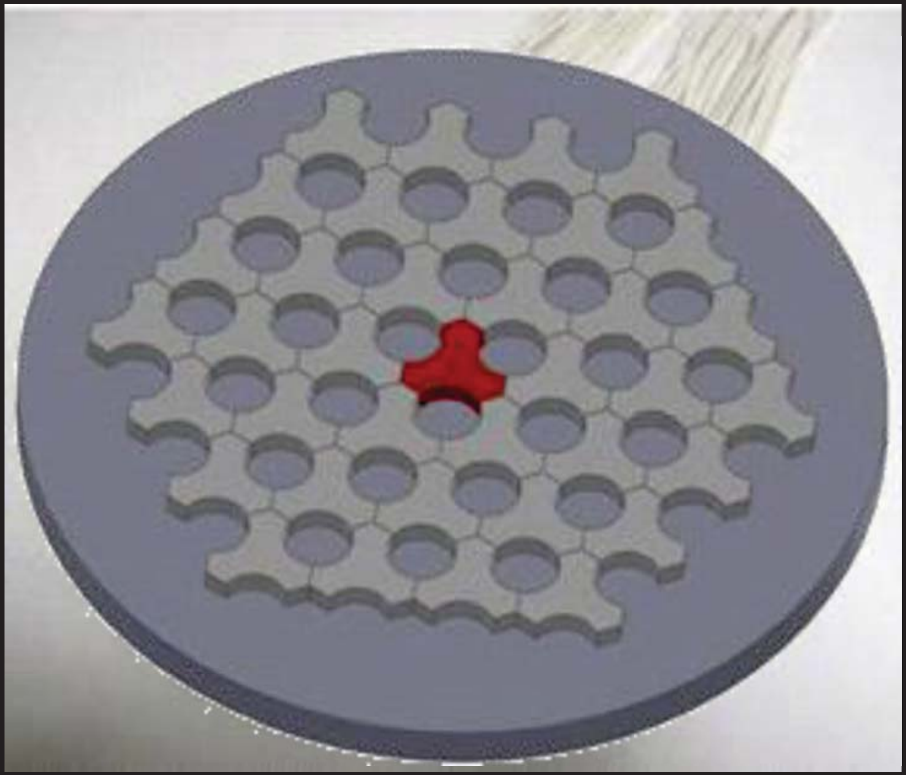
Approach toward a sub-arcsecond active x-ray telescope is multifaceted.

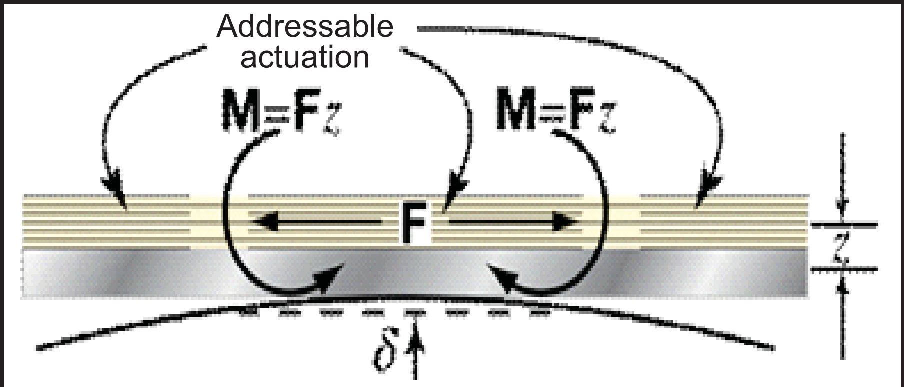
- Leverage existing x-ray technology development to start with good (HPD <5″) lightweight mirrors.
  - Minimize mid- and high-frequency surface errors.
  - Minimize or correct mount-induced distortions.
- Use surface-normal actuators to adjust alignment.
- Use surface-tangential actuator arrays to adjust low-frequency figure errors (intrinsic & mount induced).
  - Develop and test technologies for feasible STA arrays.
- Formulate strategy for on-ground and in-space image diagnostics of alignment and figure.
- Devise control algorithms and hardware for (infrequent) in-space adjustment (if needed).

Outline

- Motivation and issues
- Categories of potential solutions
- Actuator technologies under development
  - Surface-normal actuators (SNA)
  - Surface-tangential actuators (STA)
    - Electrostrictive lattice with addressable nodes
    - Patterned-electrode thin-film piezoelectric array
    - Magnetically writable magnetostrictive film

A lattice of electroactive pistons provides surface-tangential actuation (STA).





An electroactive lattice is bonded to the back of a thin mirror.

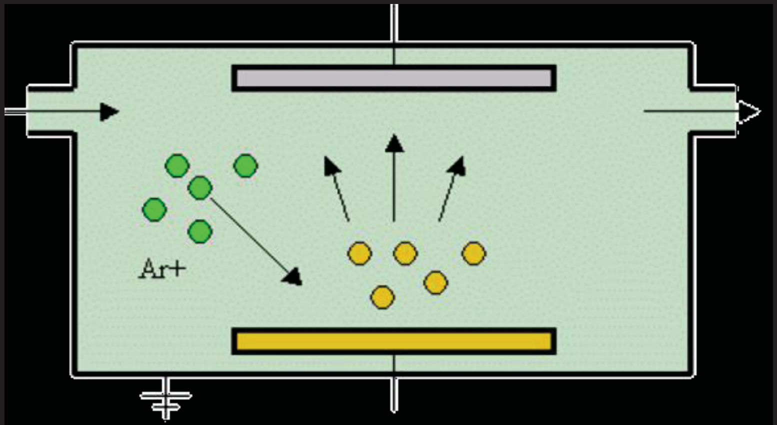
Each electrically isolated node of lattice is an addressable actuator.

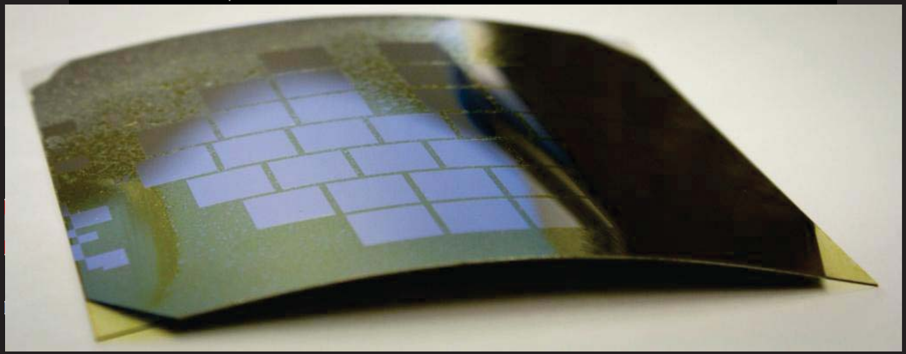
Actuation gives bimorph response.

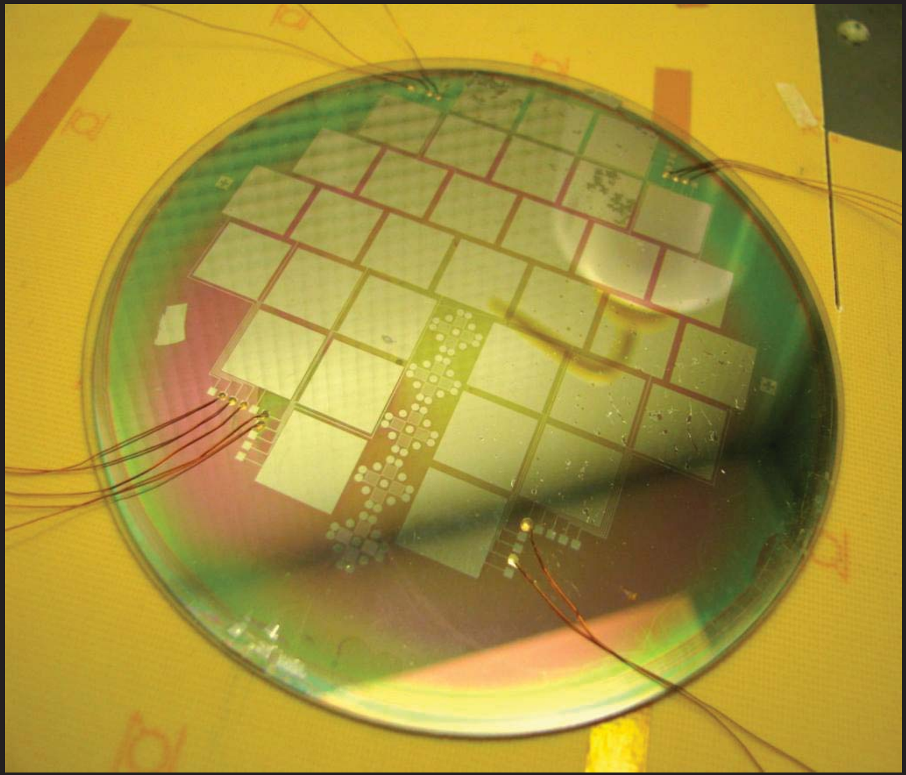
Xinetics implementation uses an electrostrictive material — PMN.

Chuck Lillie [9208-11]

An electroactive thin film with patterned electrodes provides (bimorph) STA array.







Use slumped-glass substrate.

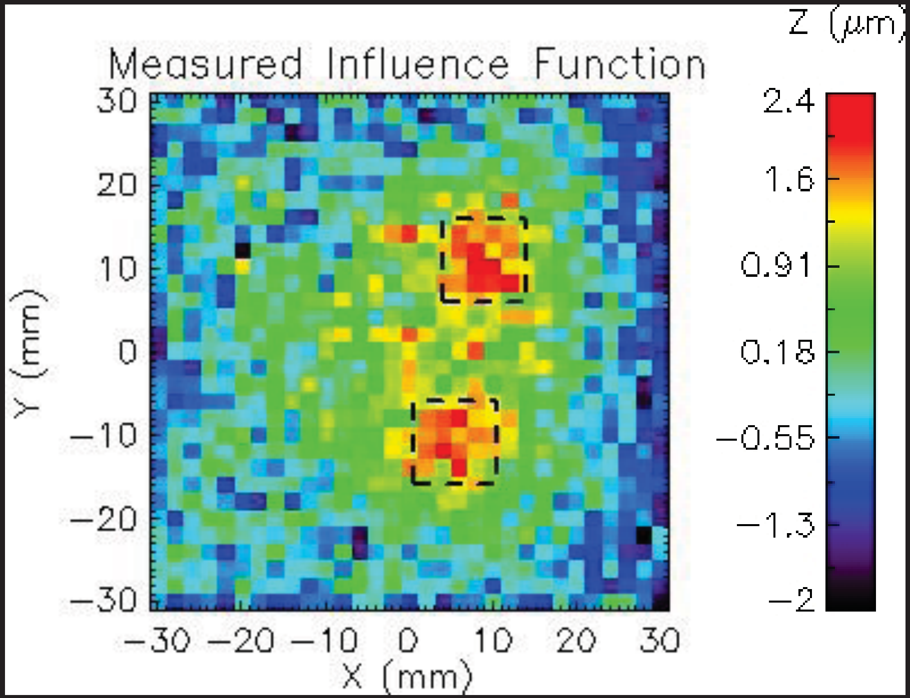
Deposit piezoelectric (PZT) on back; crystallize, anneal at high T.

Deposit electrode array and traces.

Produced flat coupons for process development and to measure the influence function.

Raegan Johnson-Wilke [9208-9]

Measurement of influence function shows semi-quantitative agreement with FEA.



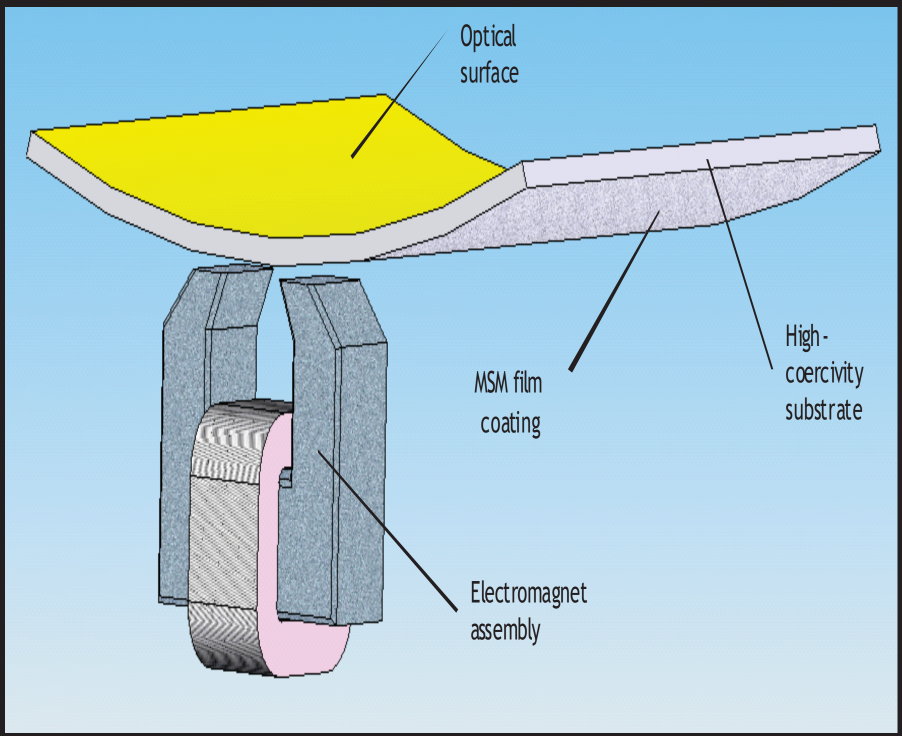
Mount mirror with thin-film STA array on back, into holder.

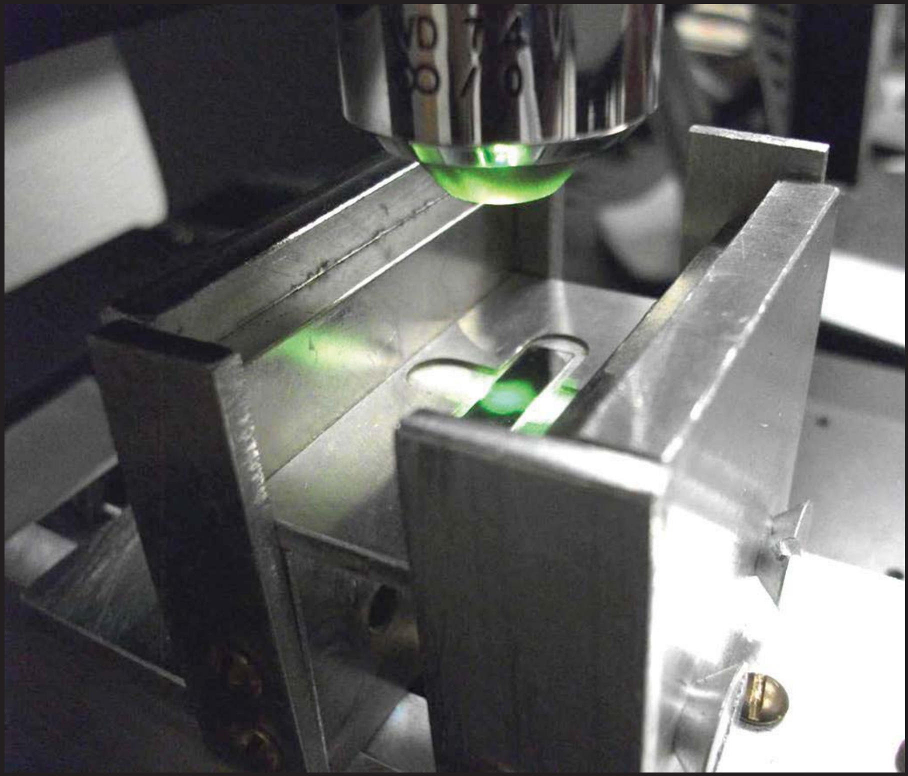
Perform metrology of active mirror in null and various actuated states.

Compare the FEA prediction with the measured influence function.

Vincenzo Cotroneo [9208-7]

A magnetic smart material MSM provides magnetically writable (bimorph) STA.





Form substrate with 10″ resolution.

Use a magnetically hard substrate or coated layer on substrate.

Deposit MSM thin film on back.

Measure magnetically written deformation with interferometer.

Mel Ulmer [9208-8]