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Next Generation X-Ray Optics (NGXO)

Alignment and Bonding of Silicon Mirrors for High-Resolution Astronomical X-ray Optics [10699-141]

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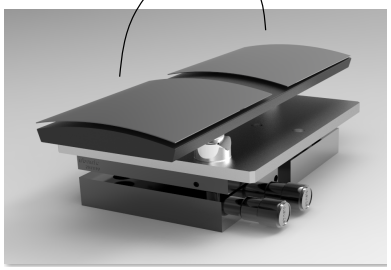
Mirror Alignment for Large X-ray Telescopes

- **Future large x-ray astronomy missions require *large area* and *high resolution***
  - Present consensus is to integrate thin, lightweight, segmented mirrors to form a compact but large telescope with high resolution (better than 1")
- **Key technologies**
  1) ***Accurate mirror substrates***: polishing high quality mono-crystalline silicon
  2) ***Stress-free reflective coating***: stress-based distortion cancellation
  3) ***Precise alignment and integration***: kinematic mounting and distortion-free bonding
- **Four-point alignment** for quasi-cylindrically symmetric mirrors (segments)
  - ***4-Point alignment:*** Pitch and yaw angles, image center (X, Y) are controlled by heights of the 4 mount points
  - ***Alignment Precision:*** better than 1"
  - ***Bonding error:*** ~ 0.1μm (~ 1")
  - ***Current single mirror pair x-ray tested***: 3" (Half–Power Diameter)
- **Integration into (meta) shell**
  - Shell structure has rotationally defined axis
  - Interlocking mirrors ⇒ lightweight, mechanically strong telescope

4-Point Alignment of Mirrors

4 DOF of mirror, pitch (θ_y), yaw (θ_x), and translation ΔX, ΔY are controlled by the heights of the 4 supports

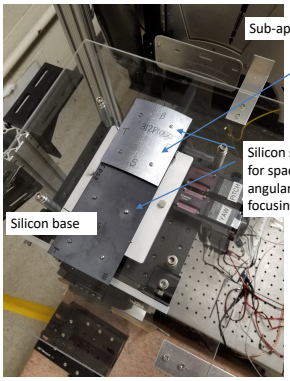
Silicon mirrors simply supported



X
Y
Z

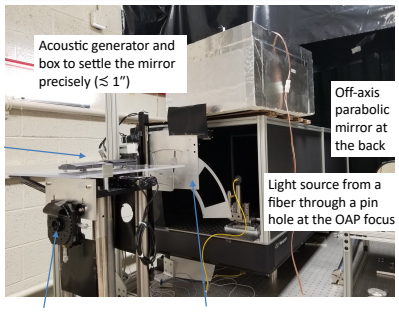
- **Pitch (θ_y) and yaw (θ_x):** compactness of focus
- ***ΔX, ΔY***: image center onto the optical axis of system
- **Rotation (θ_z)** is invariant from cylindrical symmetry
- ***ΔZ*** is nearly invariant from small grazing angle (long focal length)
- **Co-alignment** of "primary" and "secondary" mirrors, and mirrors in the next [(n+1)th] shell, are done through a common optical axis reference

Focus and Precision of Alignment and Bonding



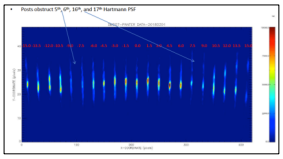
▲ ***Alignment setup***. *Sub-aperture images were taken for mirrors aligned in a collimated optical beam. Centroids the sub-aperture images at the focal plane determine the quality of focusing and de-center errors. They, in turn, determine the amount of iterative correction of spacer heights needed for a better alignment.* ▶

- Individual mirror statically determined by the 4 spacers
- Mirrors are acoustically settled
- Sub-aperture measurement of mirror images in a collimated beam qualifies the alignment
- Corrective spacer height is achieved by polishing
- Epoxy applied to round-top spacers bonds mirror in place

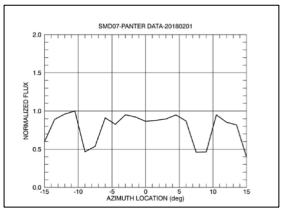


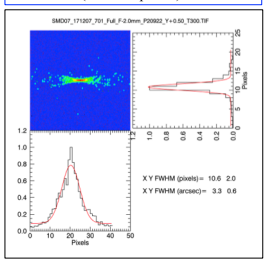
Summary: X-ray Test Result

- Aligned and Bonded mirrors were tested at GSFC and MPE Panter
- Resolution of single pair of mirror is 3 arcsecond
- Flux is uniform (except at the spacers)
- Alignment of mirror in the second shell is achieved in optical beam at 1" (not x-ray tested yet)



Planned work:
- Complete alignment, bonding, and testing of multiple pairs (in progress)
- Integration of mirrors onto meta-shell structure (in implementation)
- New precision mirror positioning structure (in development)





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