

Adjustable Grazing-Incidence X-ray Optics

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Sponsoring Program(s)

Space Technology Mission Directorate
Game Changing Development

Project Description

With its unique subarcsecond imaging performance, NASA's Chandra X-ray Observatory¹ illustrates the importance of fine angular resolution for x-ray astronomy. Indeed, the future of x-ray astronomy relies upon x-ray telescopes with comparable angular resolution but larger aperture areas. Combined with the special requirements of nested grazing-incidence optics, mass, and envelope constraints of space-borne telescopes render such advances technologically and programmatically challenging.²

The goal of this technology research is to enable the cost-effective fabrication of large-area, lightweight grazing-incidence x-ray optics with subarcsecond resolution. Toward this end, the project is developing active x-ray optics^{3,4} using slumped-glass mirrors with thin-film piezoelectric arrays (fig. 1) for correction of intrinsic or mount-induced distortions (fig. 2).⁵

Partnering institutions for this project are the Smithsonian Astrophysical Observatory (SAO), the Pennsylvania State University (PSU), and NASA Marshall Space Flight Center (MSFC). SAO is responsible for overall direction, mirror substrates, metrology,⁶ and analyses; PSU, for development of thin-film piezoelectric arrays;⁷⁻⁹ and MSFC, for coating studies, additional metrology, and x-ray testing (fig. 3).

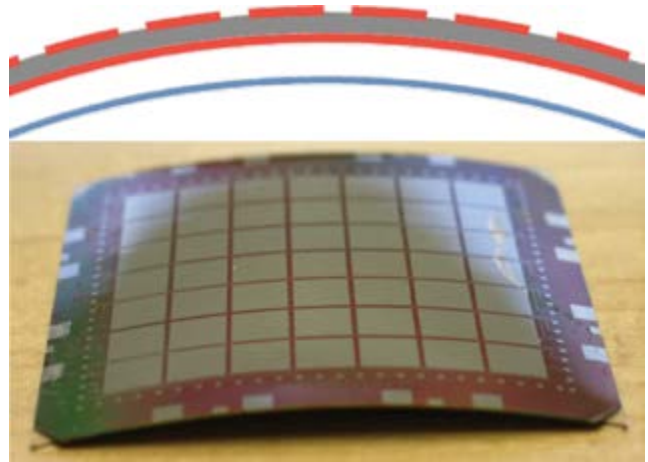


Figure 1: Grazing-incidence conical mirror segment with a backside piezoelectric array for active figure correction through voltage-controlled bimorph deformation. The drawing (top) shows—in cross section from inner concave surface outward—a thin-film optical coating (blue), the slumped-glass substrate (clear), a thin-film ground electrode (red), a thin-film piezoelectric layer (gray), and a thin-film pixilated electrode (red). The photo (bottom) displays a fabricated active mirror segment, with a 7x7 array of 1 cm square electrodes.

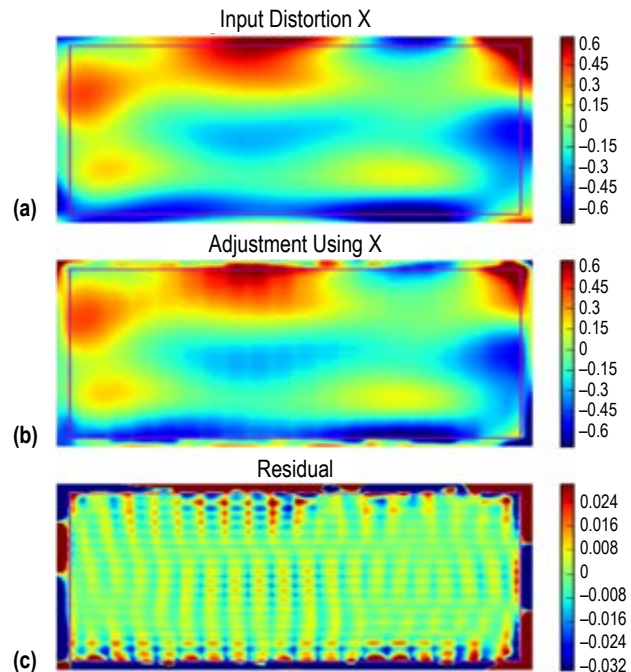


Figure 2: Simulated figure error maps for a segmented mirror, showing (a) initial error with respect to the prescribed mirror figure, (b) applied corrective adjustment, and (c) residual figure error after applied correction.

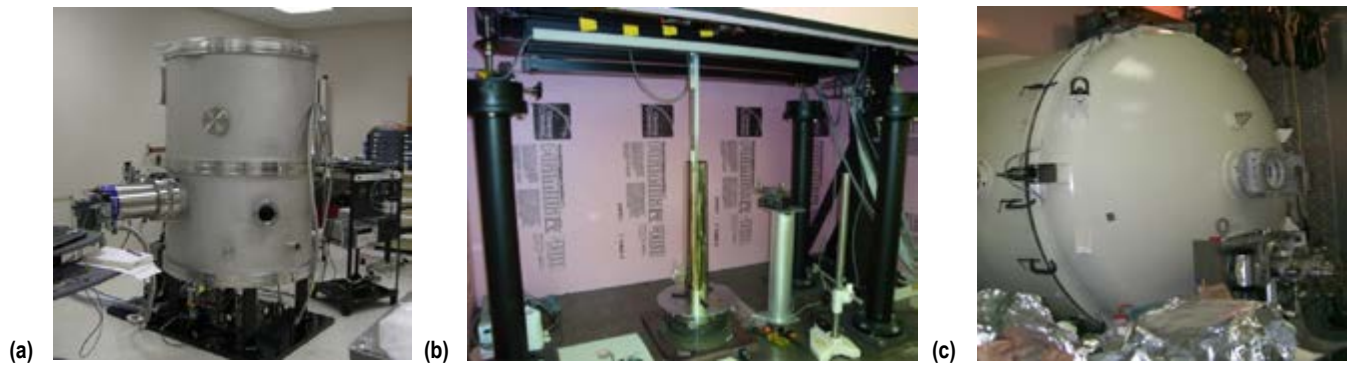


Figure 3: MSFC capabilities supporting the development of adjustable grazing-incidence optics: (a) Coating chamber, used for developing controlled-stress sputtered deposits; (b) a vertical long-trace profilometer, one of multiple metrology instruments for characterizing x-ray mirror surfaces; and (c) the 3-m-diameter (vacuum) instrument chamber at MSFC's 100-m-long X-ray Test Facility.

Anticipated Benefits

The primary anticipated benefit is the active correction of grazing-incidence x-ray optics for space applications. This technology is equally applicable to normal-incidence optics, although existing adaptive-optics technologies are adequate in situations where mass or envelope is not an issue.

Potential Applications

The potential applications of active x-ray optics are large-area, lightweight x-ray telescopes and beam-focusing x-ray mirrors for synchrotron light sources and for x-ray free-electron lasers, although alternative technologies are suitable for ground-based applications. In addition, there are potential spinoff applications for underlying thin-film technologies being developed to enable adjustable lightweight mirrors.

Notable Accomplishments

PSU has made significant progress in developing thin-film pixilated piezoelectric devices—over 90% yield⁹ in active pixels, on-device thin-film transistors⁷ (for row-column addressing) and strain gauges (to monitor deformations), and use of anisotropic conductive films⁷ (to simplify electrical connections). MSFC has developed an in situ stress monitor to help accurately control coating stress during deposition.

References

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