

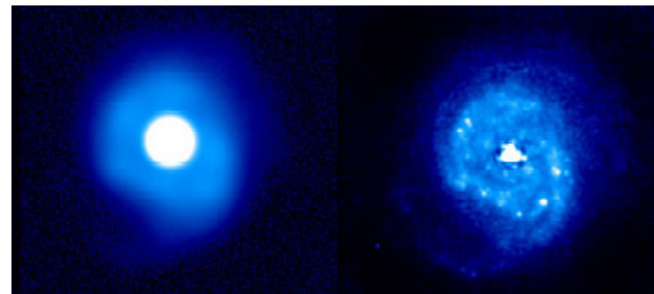
Active full-shell grazing-incidence optics

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Benefits of Active Optics

- Optical deformable mirrors
 - Surface normal
 - Surface parallel
 - Multichannel
- Potential scientific studies
 - Formation and growth of black hole seeds
 - Emergence of first galaxy groups
 - Details of galaxies and galaxy clusters
- X-ray astronomy desired technology
 - Wide field of view
 - Large effective area x-ray telescope
 - High angular resolution

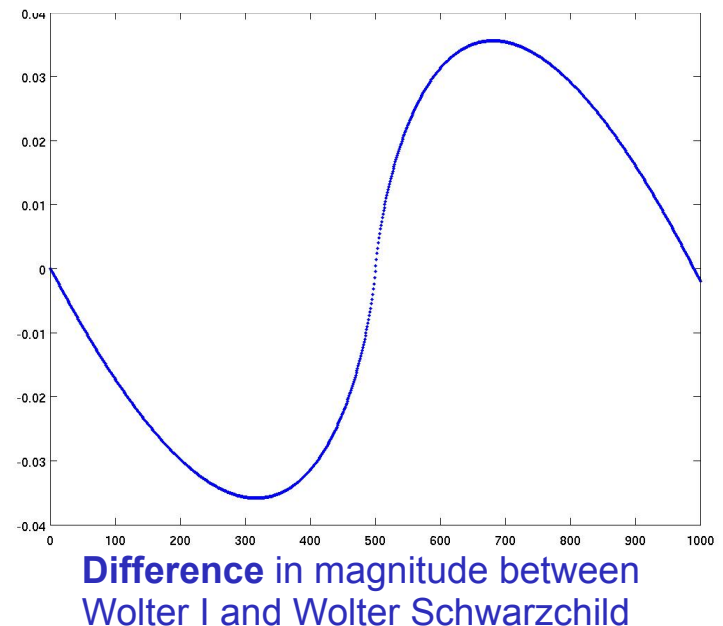
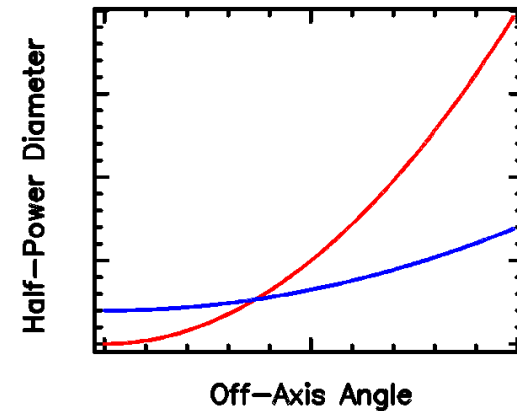
Keck Observatory with Adaptive Optics



- MSFC focusing on full-shell grazing-incidence optics
 - Lightweight, tightly nested
 - Manufacture, assemble and align updates
 - X-ray surveyor
- Active full-shell grazing-incidence optics
 - Correct Low-order figure
 - Manufacturing error
 - Mounting error
 - Change prescription

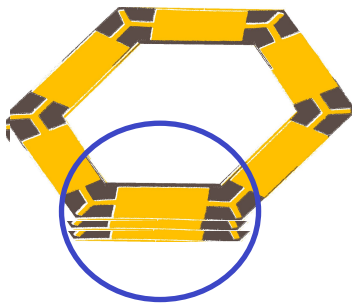
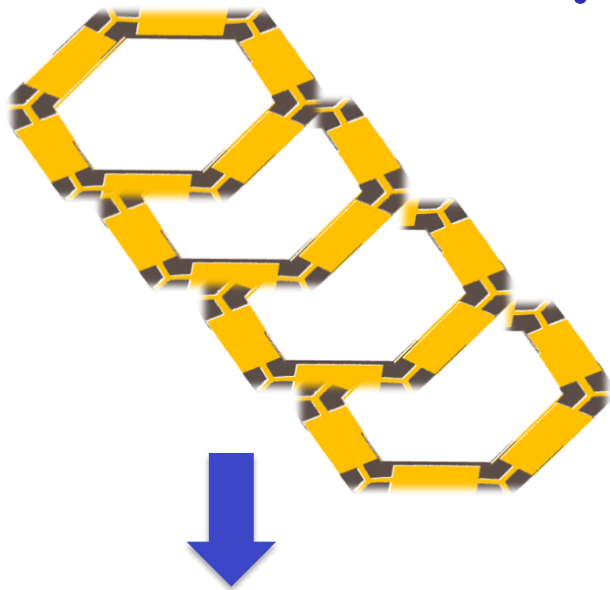
Active Optics for Prescription Change

- Ability to adjust optic in orbit
 - optimize angular resolution for wide field of view
 - optimize angular resolution for narrow field of view
- Demonstrate of ability to change optic between Wolter I and Wolter Schwarzschild
- Potential to change to polynomial prescription

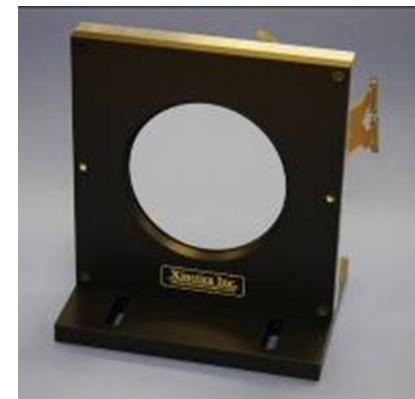
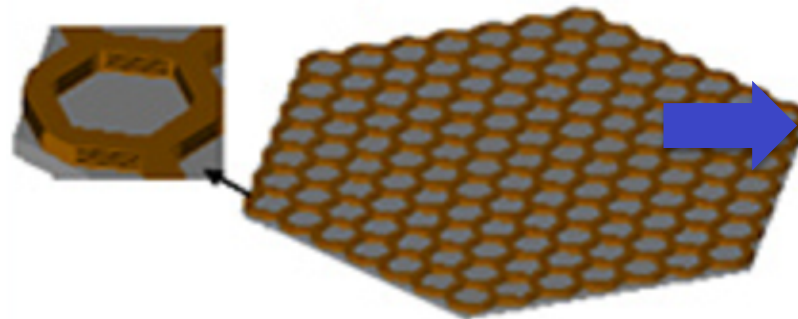


Multichannel Surface Parallel Array

- Surface Parallel Array (SPA)
 - Northrop Grumman Xinetics AOA patented technology
 - Individually activated
 - Bonded to thin facesheet
 - Micro-machined electrostrictive ceramic actuator array
 - Electrical connections are made via a flexcircuit
 - Bonding performed after coating facesheet, allowing for stress balancing coating designs.

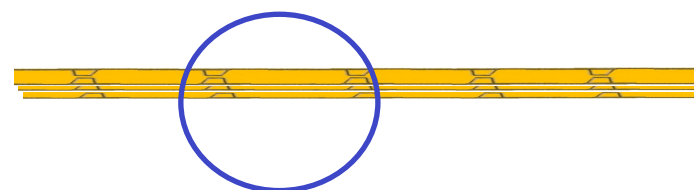


Individually activated

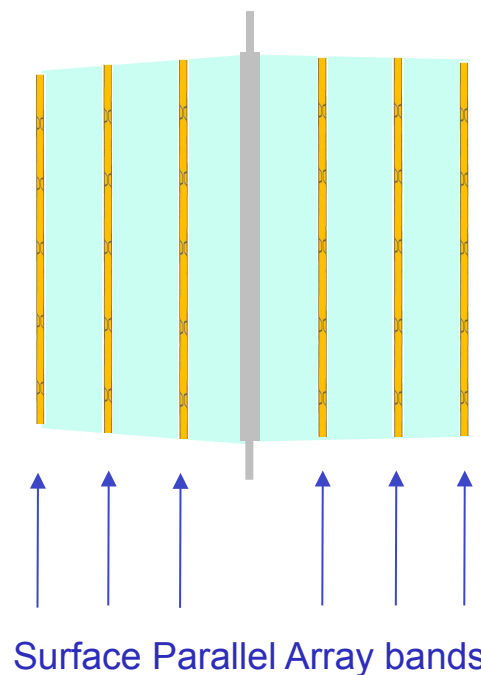
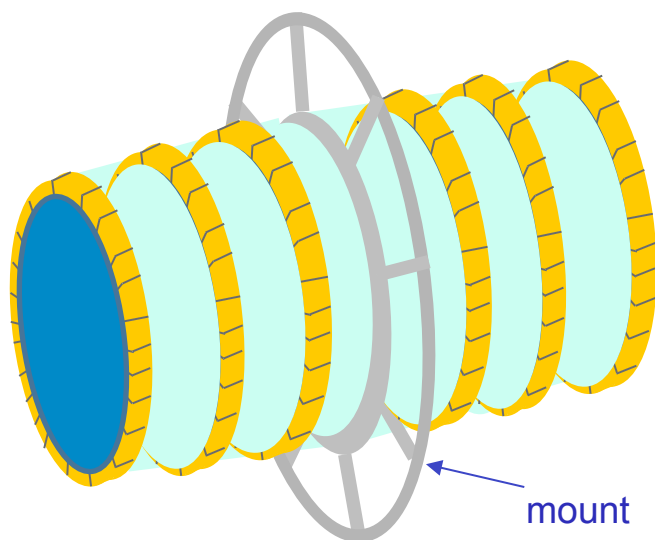


Active Full-Shell Grazing-Incidence Optics

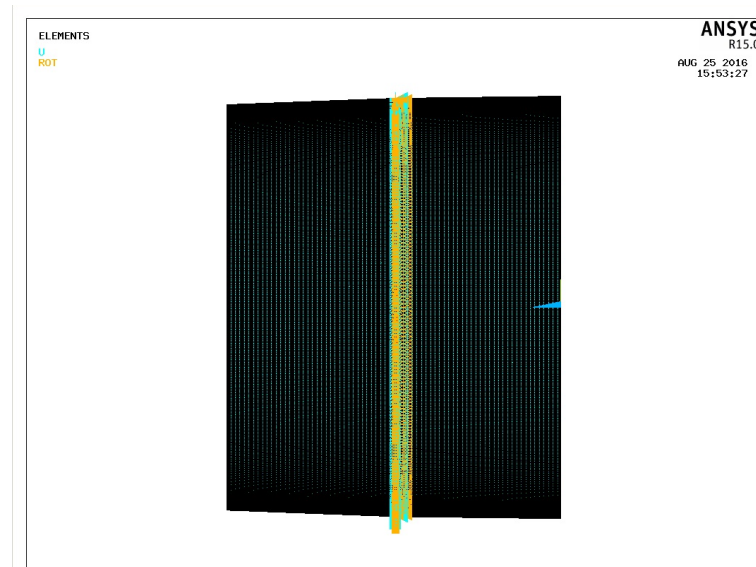
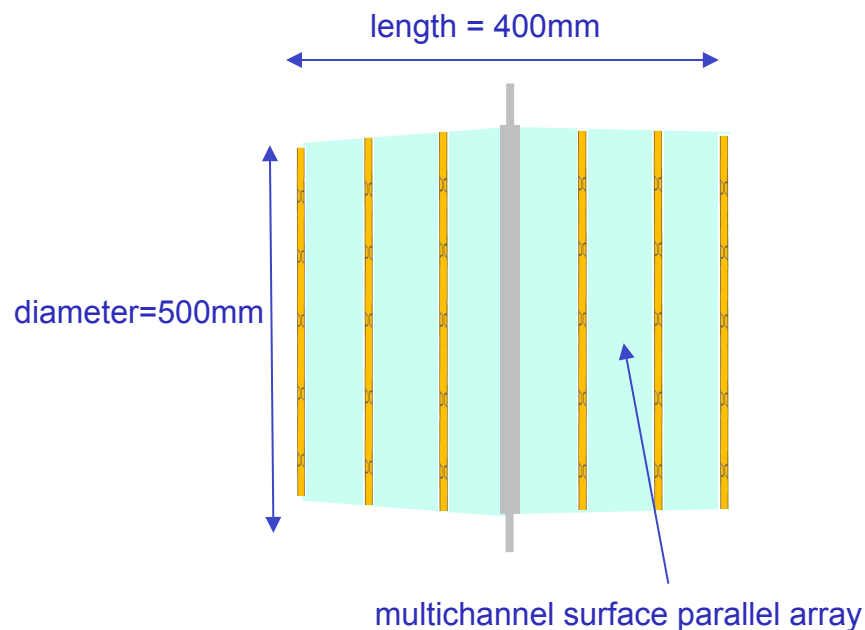
- Bands of actuators at six positions along shell
 - Using Surface Parallel Array technology
 - Machine electrostrictive ceramic actuator array into bands around full-shell grazing incidence optics
 - Activated together or individually



Individually activated



Finite Element Analysis Model

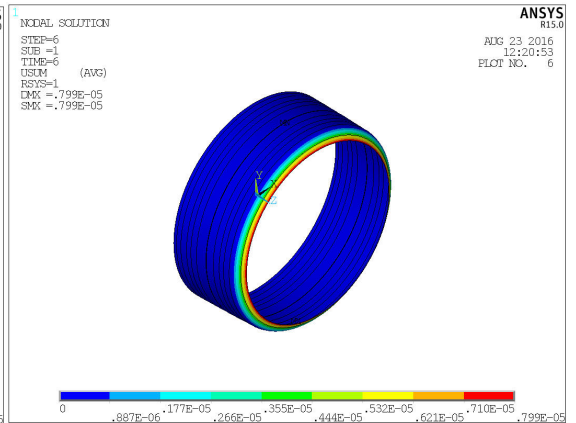
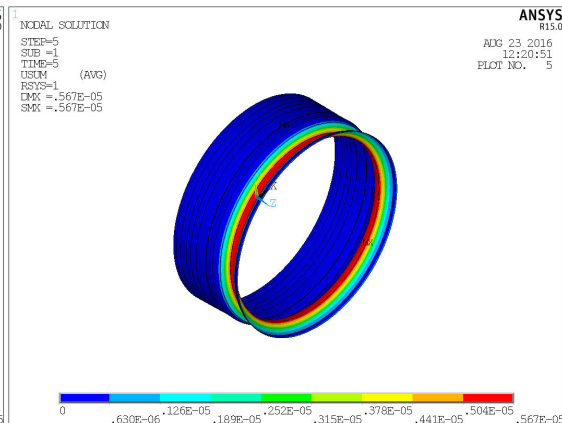
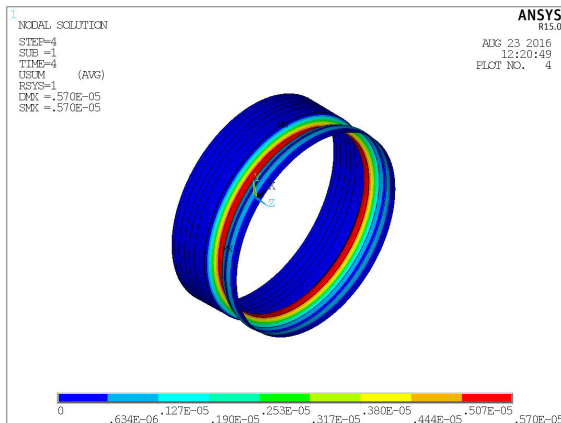
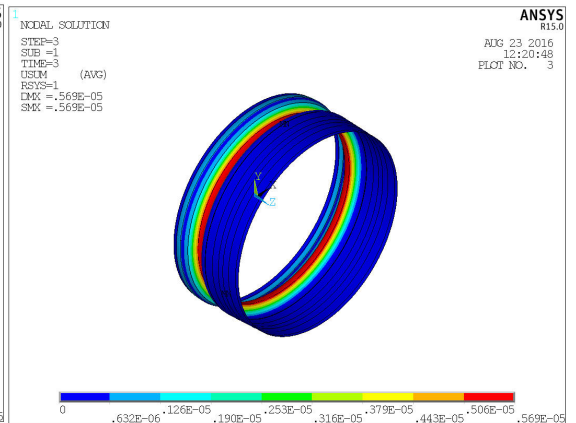
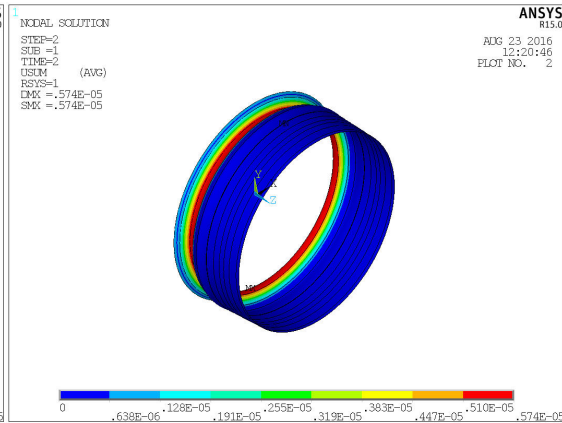
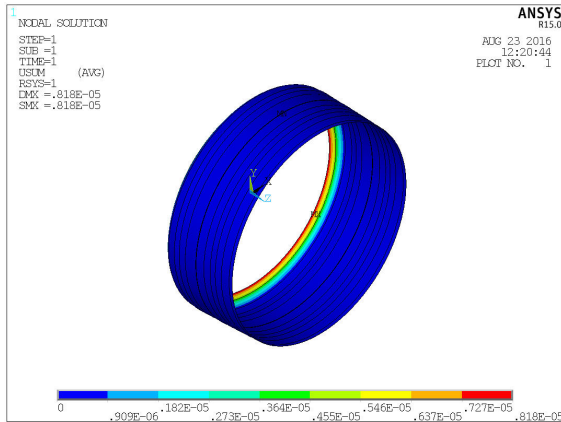


- Wolter I specifications
 - focal length = 10 m
 - diameter=500mm
 - length=400mm
 - thickness=2mm
- Beryllium Aluminum
- Multichannel surface parallel array
 - stacked PMN
 - electrostrictive
 - individually addressable



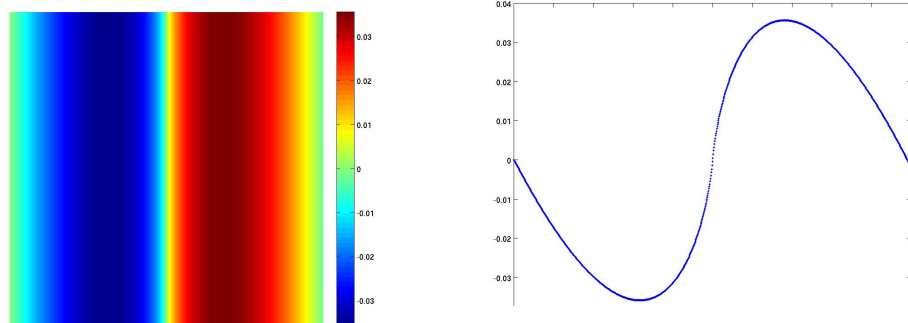
FEM: Multichannel Surface Parallel Array

Influence Functions

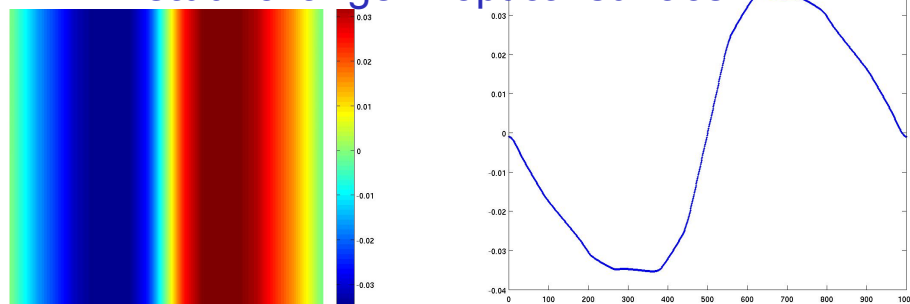


Wolter Schwarzschild Adjustment

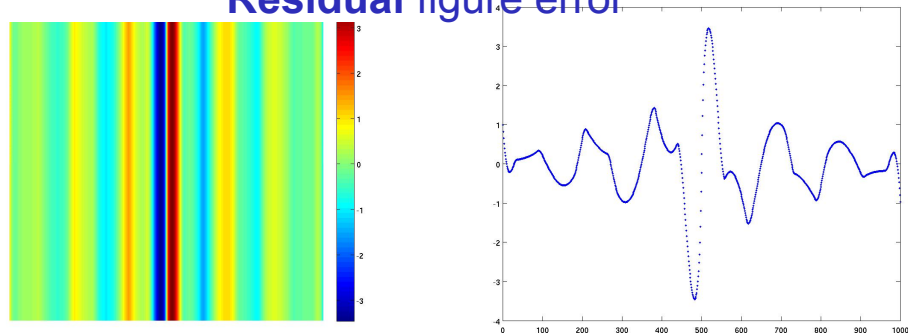
Desired change in optical surface



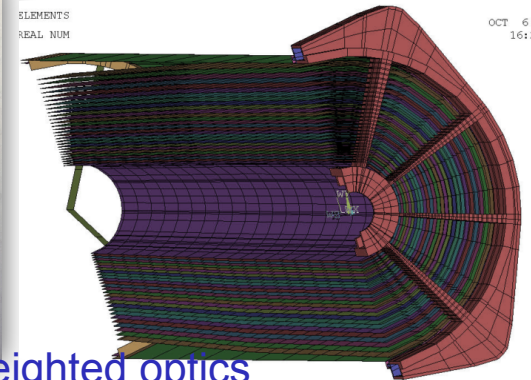
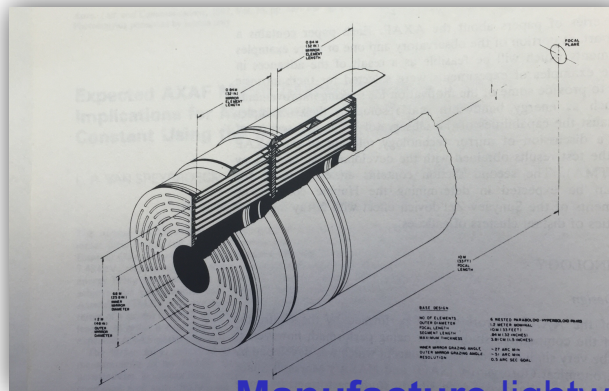
Actual change in optical surface



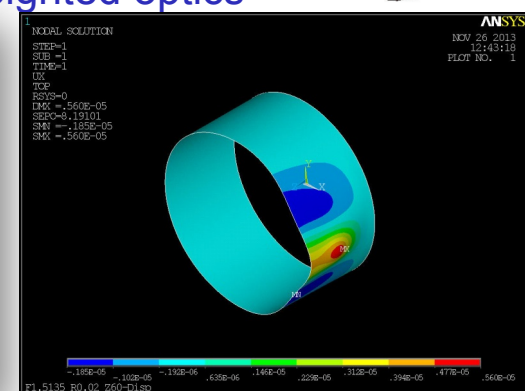
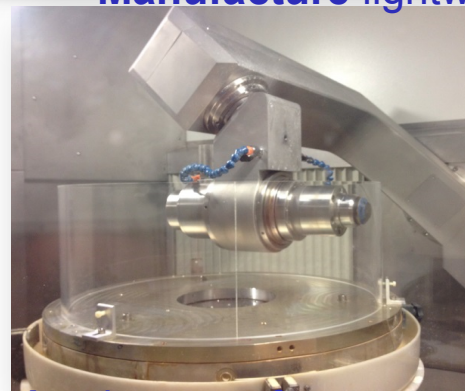
Residual figure error



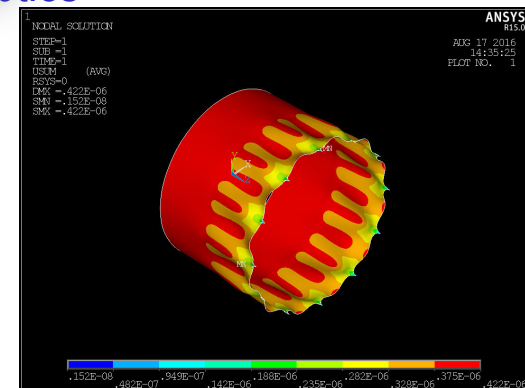
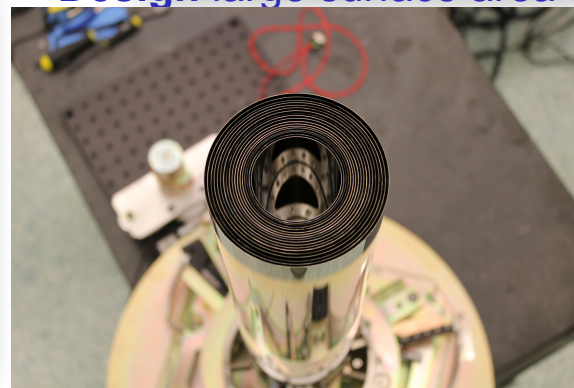
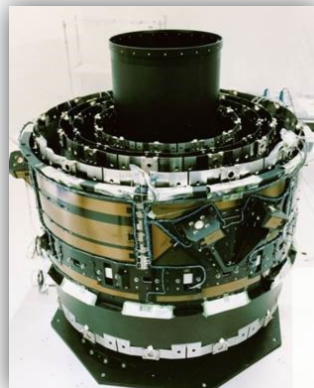
Manufacturing and Mounting Correction



Manufacture lightweighted optics

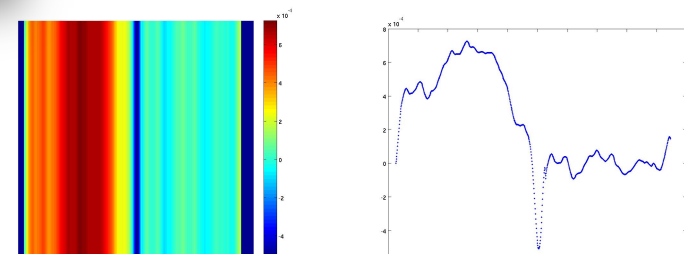
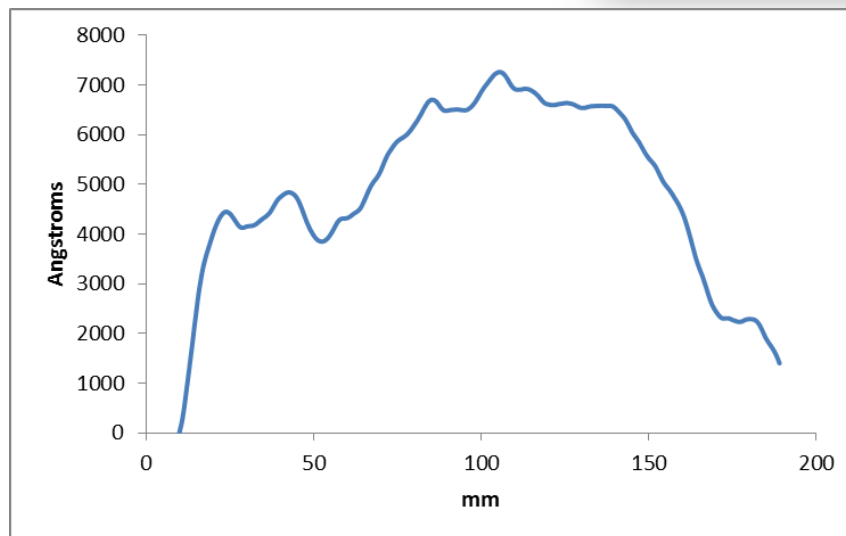
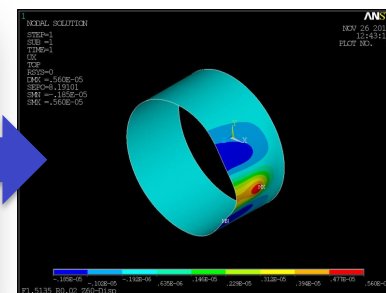
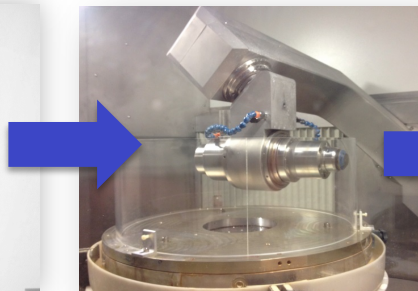


Design large surface area optics

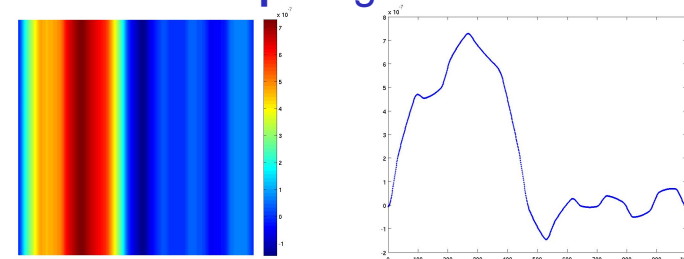


Assemble tightly nested, flimsy optics

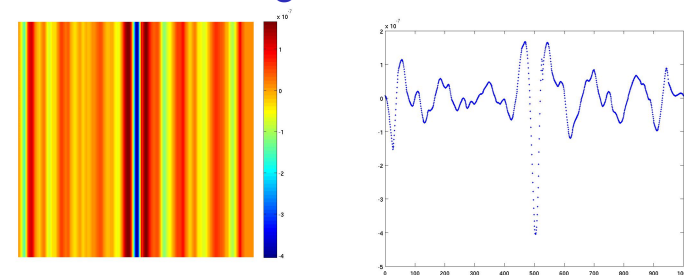
Manufacturing Error Correction



Example figure error



Low-order figure error correction



Residual figure error

Mounting error correction

Discussion

- Ability to adjust optic in orbit
- Correct low-order frequency figure error
- Benefits
 - Small number of actuators
 - Can be used in conjunction with corrective polishing and differential deposition for the high frequency errors
- Moving forward
 - Polynomial
 - Circumferential correction