The IXO- X-ray Grating Spectrometer (XGS)

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Key Performance Requirements

Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV with a goal of 1 m^2 150 cm^2 @ 30 keV with a goal of 350 cm^2	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV) ΔE < 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV) $E/\Delta E$ = 3000 from 0.3–1 keV with an area of 1,000 cm^2 for point sources ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Mirror Angular Resolution	≤5 arc sec HPD (0.1 – 10 keV) 30 arc sec HPD (10 - 40 keV) with a goal of 5 arc sec	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV (0.1 – 15 keV)	Strong gravity, EOS
Polarimetry	1% MDP on 1 mCrab in 100 ksec (2 - 6 keV)	AGN geometry, strong gravity
Astrometry	1 arcsec at 3 σ confidence	Black hole evolution
Absolute Timing	50 μ sec	Neutron star studies

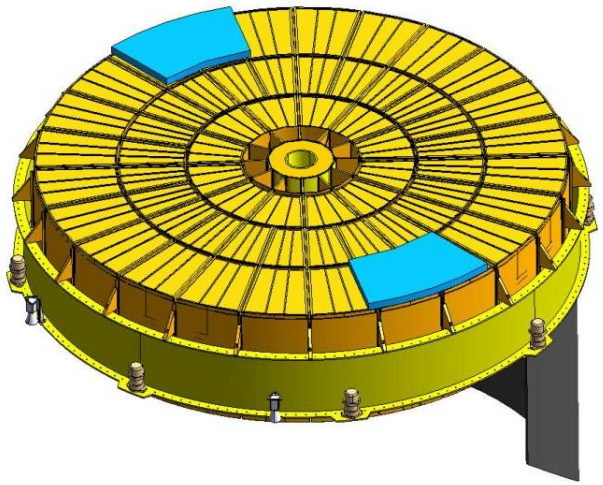
CAT:

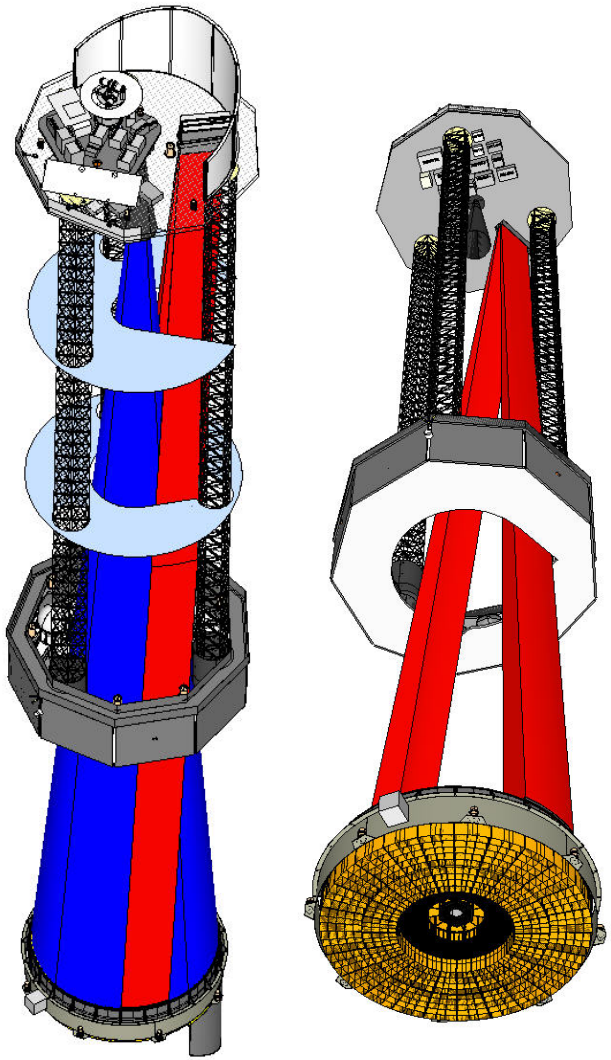
Grating mirror coverage assumption:

- Selected 1.15 m < R < 1.59 m; two sectors of 30˚
- 6-12 kg incl. 32% margin for all gratings+supports

XGS camera assumptions:

- Mass ~ 49 kg incl. 19% margins.
- Power ~113.6 W incl. margin & CCD thermal control
- No translation stage needed at 3 σ error level
- Refocusing mechanism



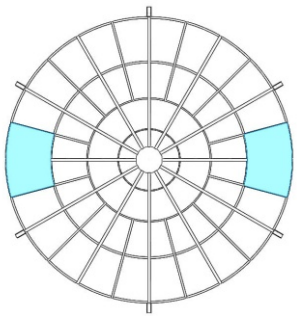


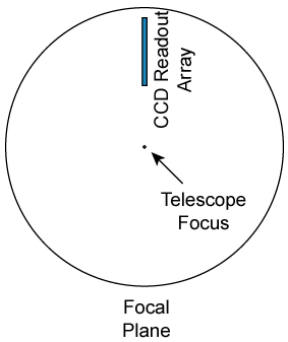
Critical-Angle Transmission Grating Spectrometer (CAT-GS)

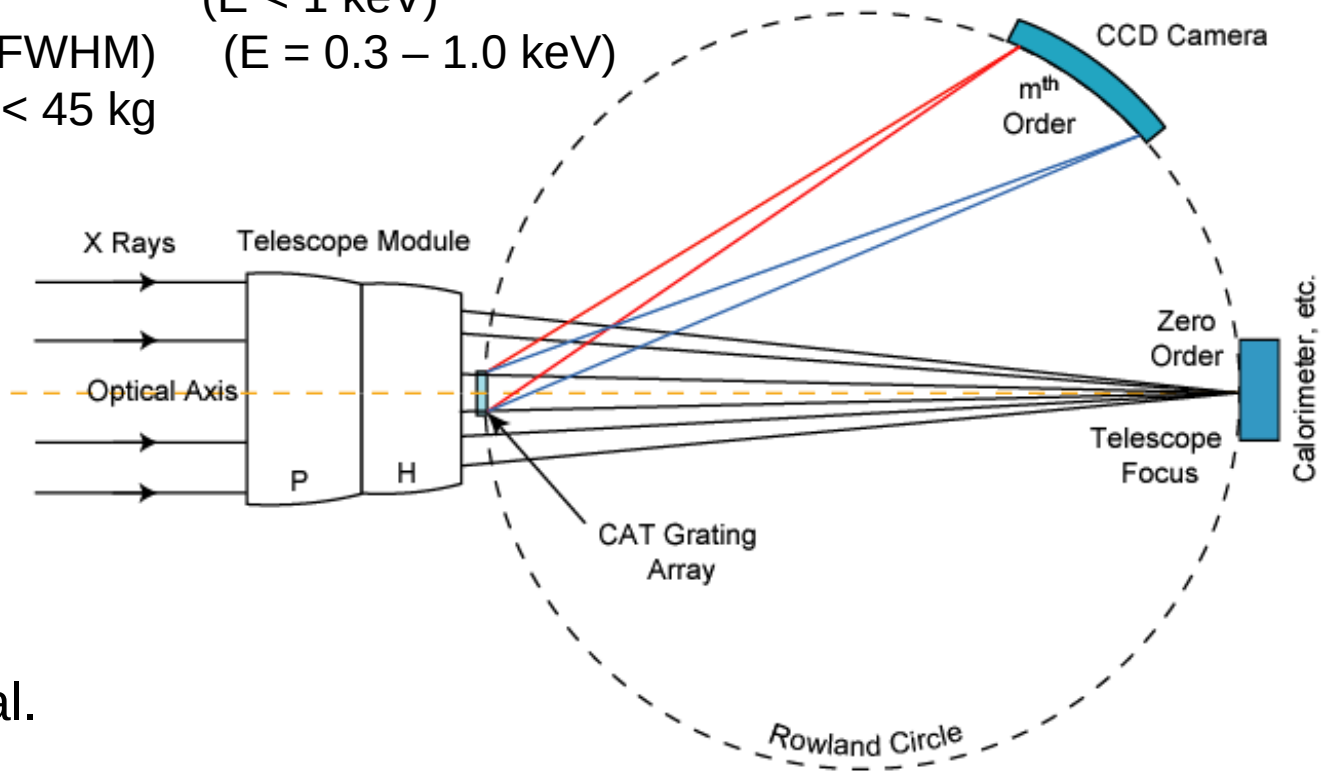
- Based on Chandra TGS heritage
- Similar to Chandra: Low weight, relaxed alignment tolerances
- Improvements:
  - Blazed transmission gratings -> use of higher orders -> higher spectral resolution
  - Broadband high-efficiency gratings -> large effective area
  - Sub-aperturing -> higher spectral resolution

Strawman configuration:

- Cover two opposing pairs of outer mirror modules (2 x 30º)
- Effective area > 1,000 cm^2 (E < 1 keV)
- Resolution $E/\Delta E$ > 4500 (FWHM) (E = 0.3 – 1.0 keV)
- Mass (gratings + readout) < 45 kg







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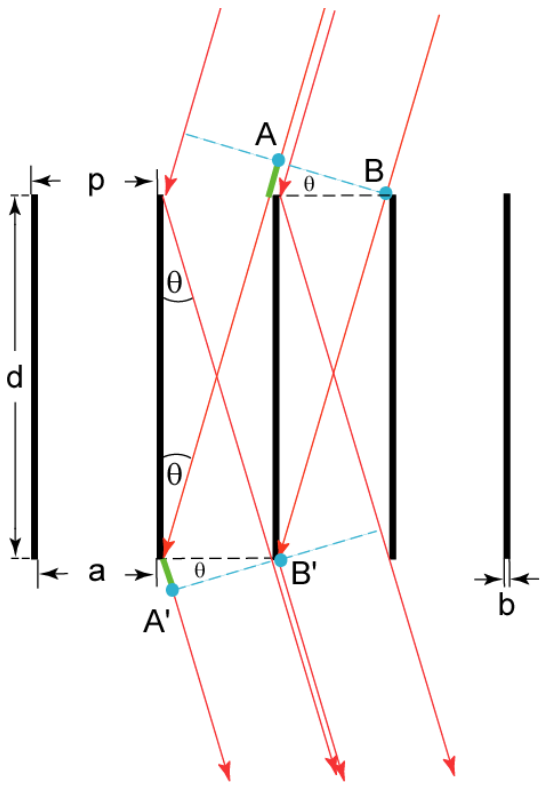
Critical-Angle Transmission Grating Spectrometer: Blazed transmission enabled by the CAT grating

- CAT grating combines advantages of transmission gratings (relaxed alignment, low weight) with high efficiency of blazed reflection gratings.
- Blazing achieved via reflection from grating bar sidewalls at graze angles below the critical angle for total external reflection.
- High energy x rays undergo minimal absorption and contribute to effective area at focus.

CAT grating principle



Grating equation:

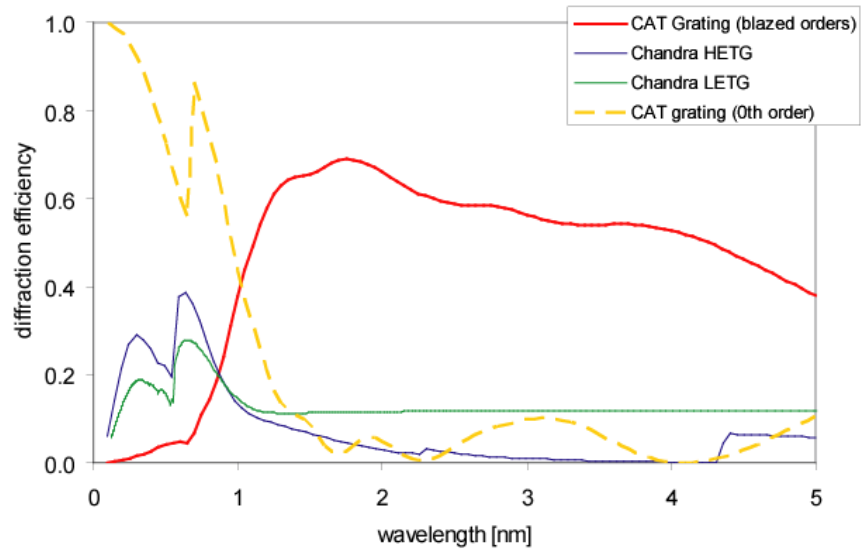
$m\,\lambda = p\,(\sin(\theta) + \sin(\beta_m))$,
m = diffraction order

Blazing: $\beta_m \sim \theta$

High reflectivity:
$\theta < \theta_c$ = critical angle of total external reflection

Strawman:
Silicon grating, $\theta = 1.5^\circ$
p = 200 nm
b = 40 nm
d = 6 μm
aspect ratio d/b = 150

Efficiency comparison with Chandra gratings



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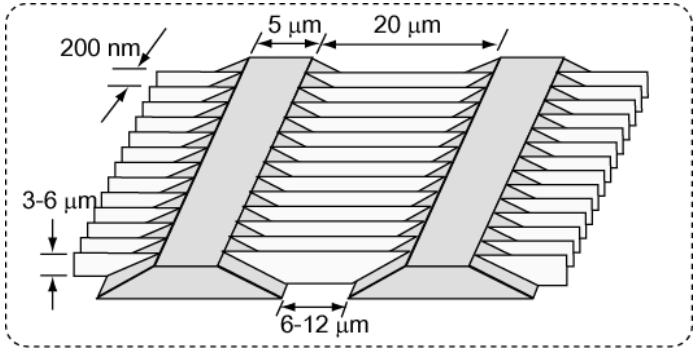
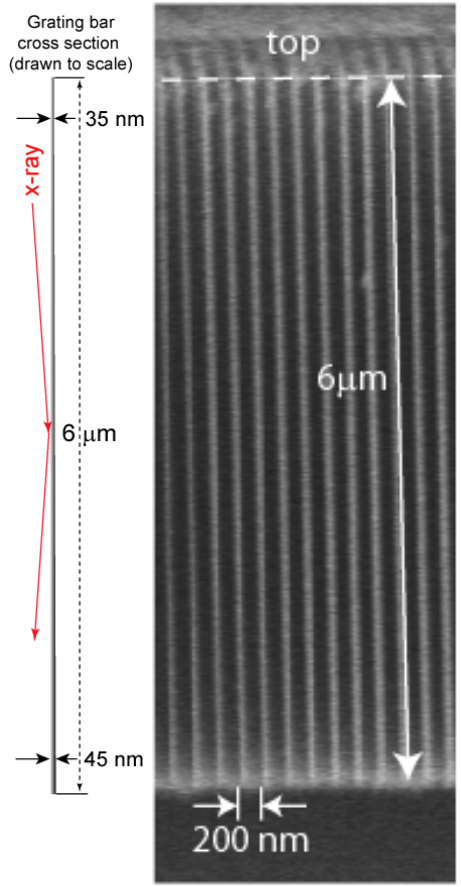
Critical-Angle Transmission Grating Spectrometer: CAT grating fabrication and testing

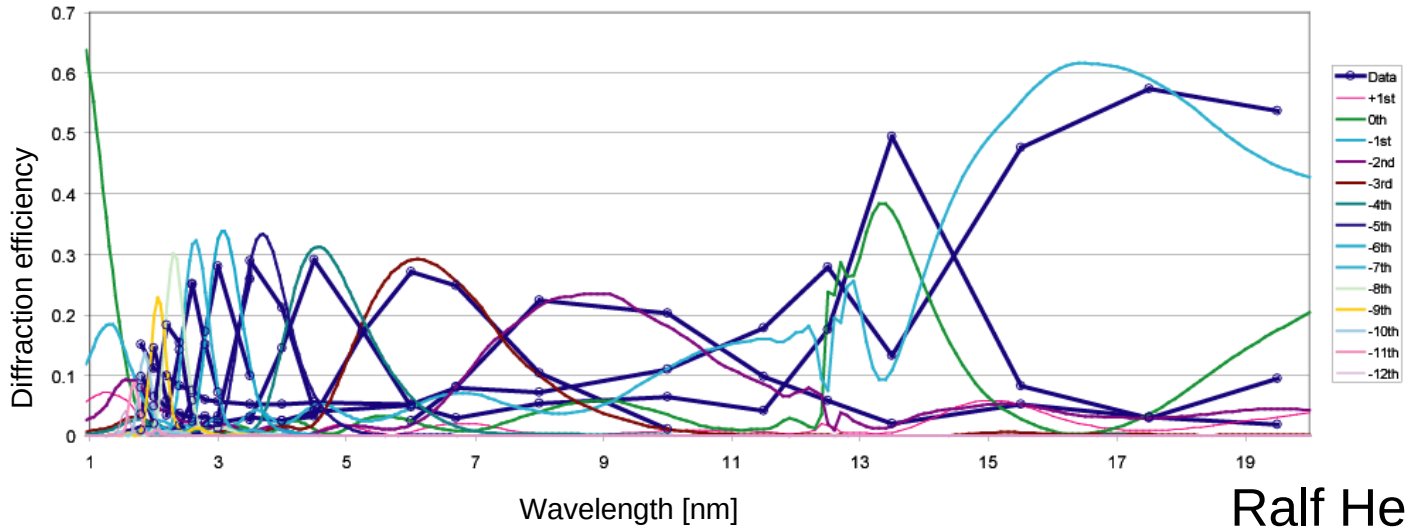
- Monolithic silicon structure with integrated support bars
- 200 nm period
- achieved design goal of 6 μm tall, 40 nm wide grating bars



CAT grating schematic

Scanning electron micrograph of cleaved cross section of 200 nm-period CAT grating





Comparison between data and theory:
~ 80-100% of theoretical diffraction efficiency

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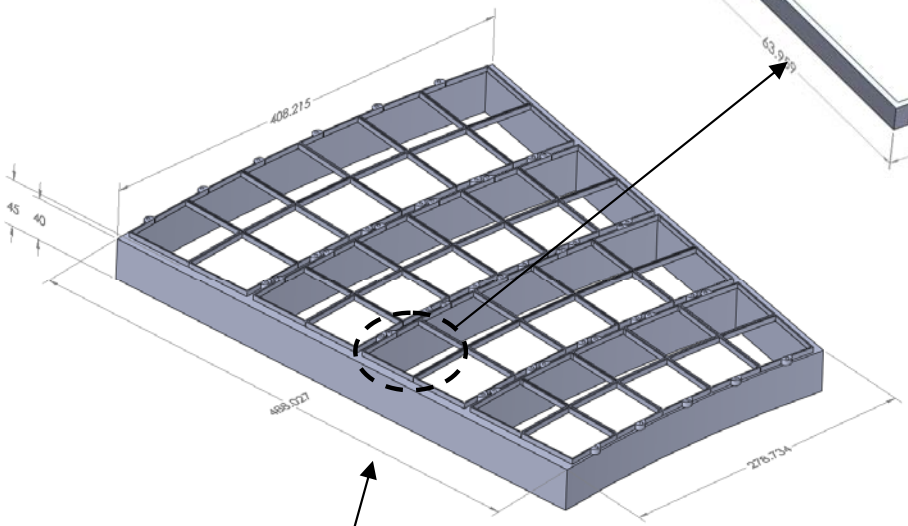
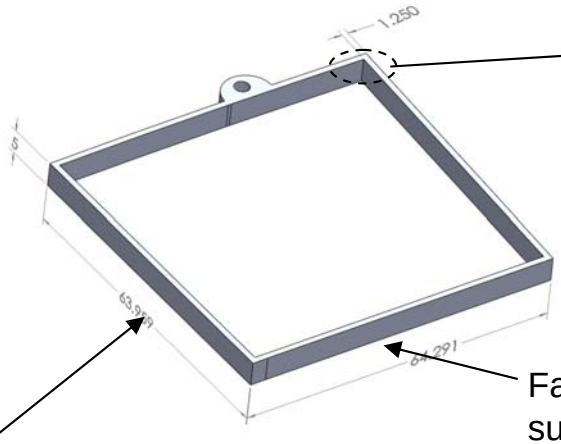
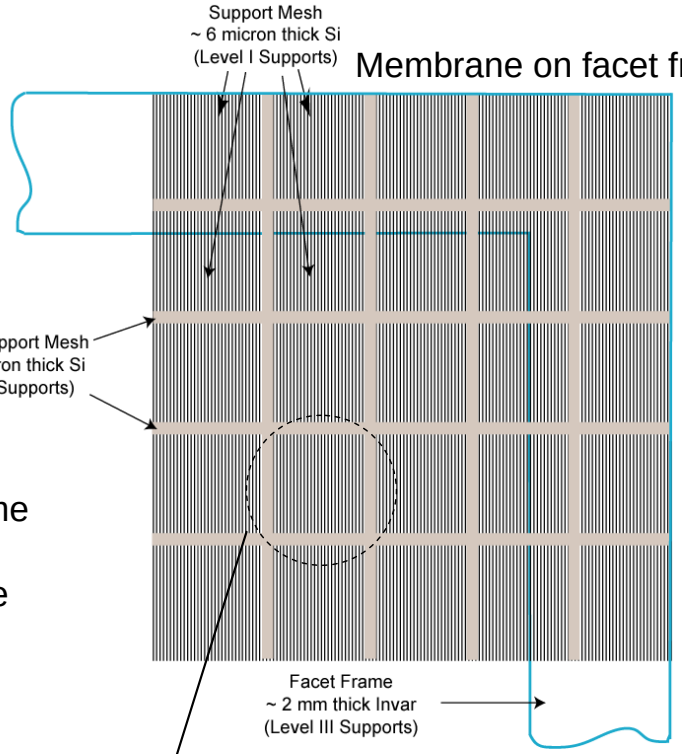
Grating Array & Facet Concept

Grating Array Structure (GAS)





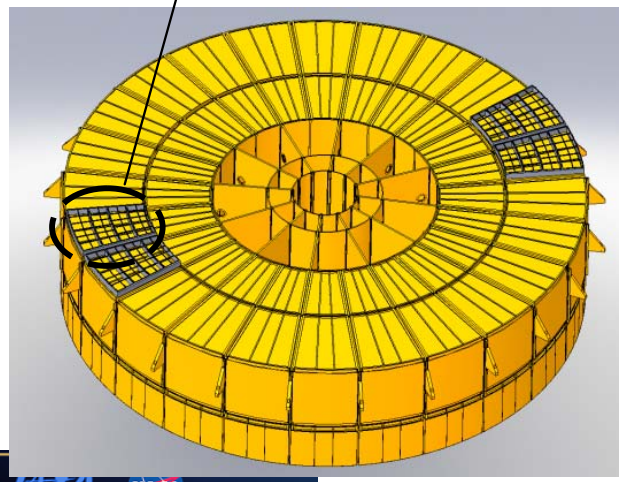
Facet frame supports membrane



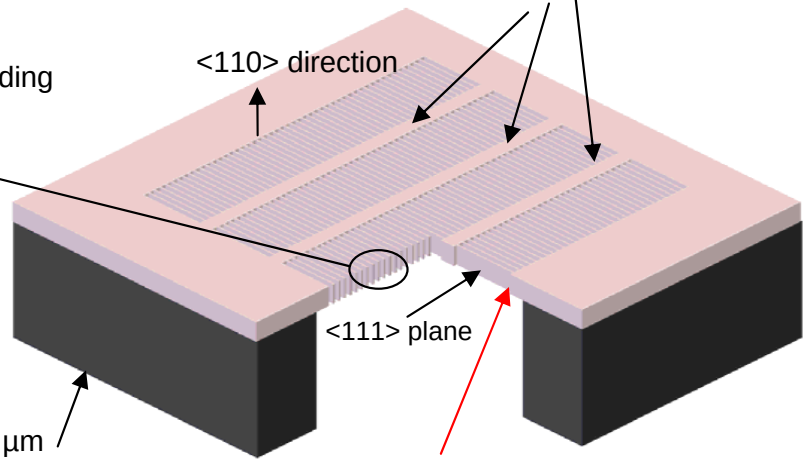
Membrane cell

Support mesh
(Level I supports)

FMA



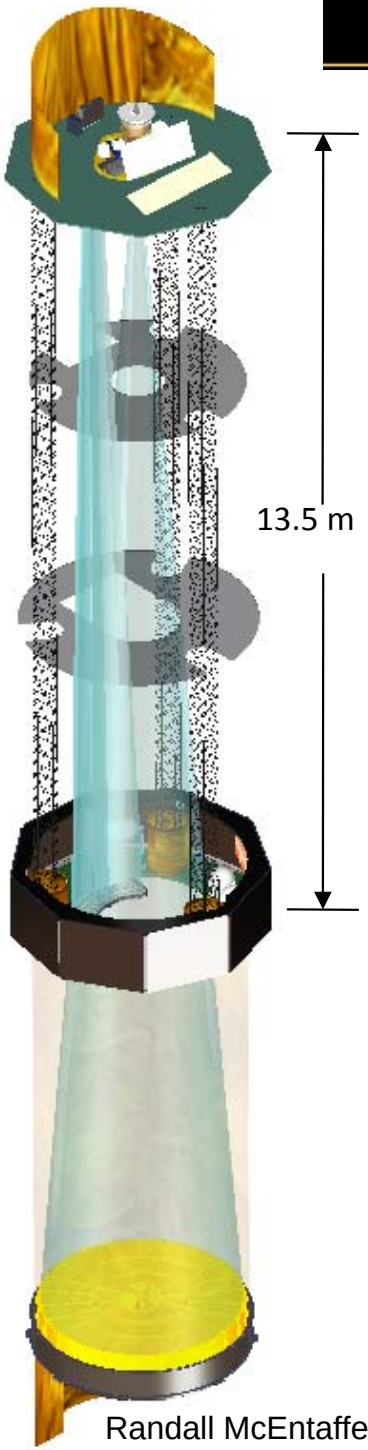
Freestanding grating

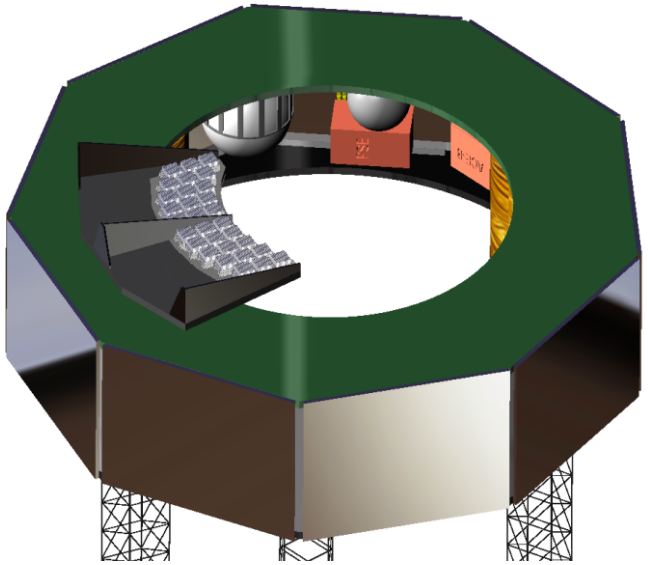


500 µm
SOI handle layer
(Level II supports)

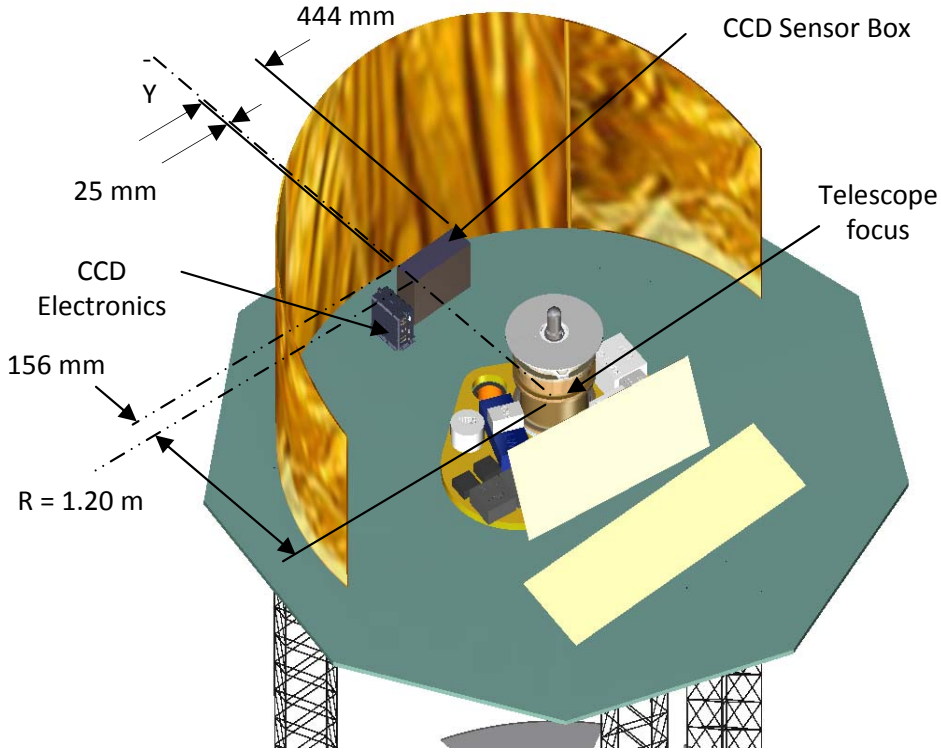
6 µm SOI device layer

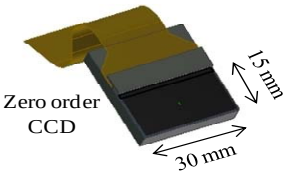
Off-Plane Grating XGS 13.5 m configuration

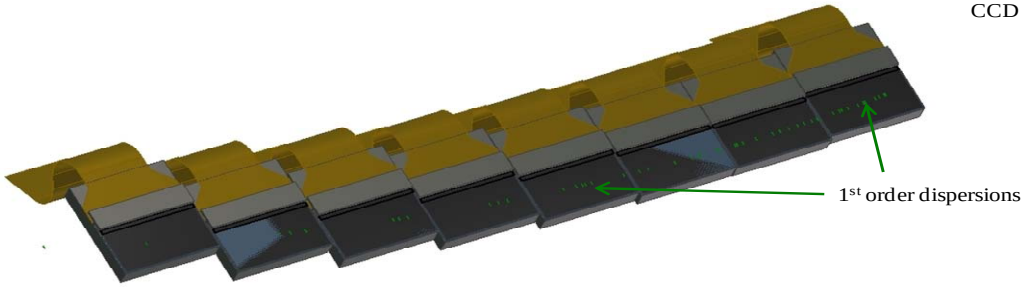




Grating Mirror Assembly Platform mounted to S/C Platform 13.5 m from telescope focus







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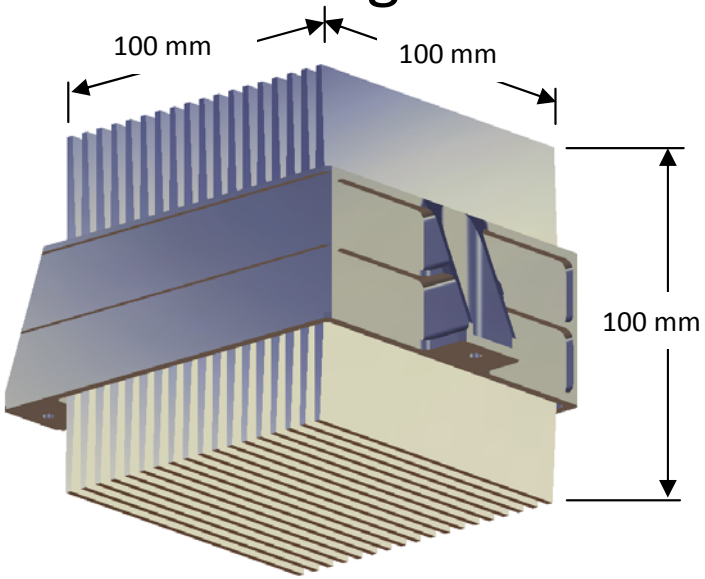
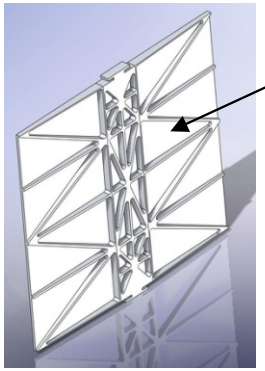
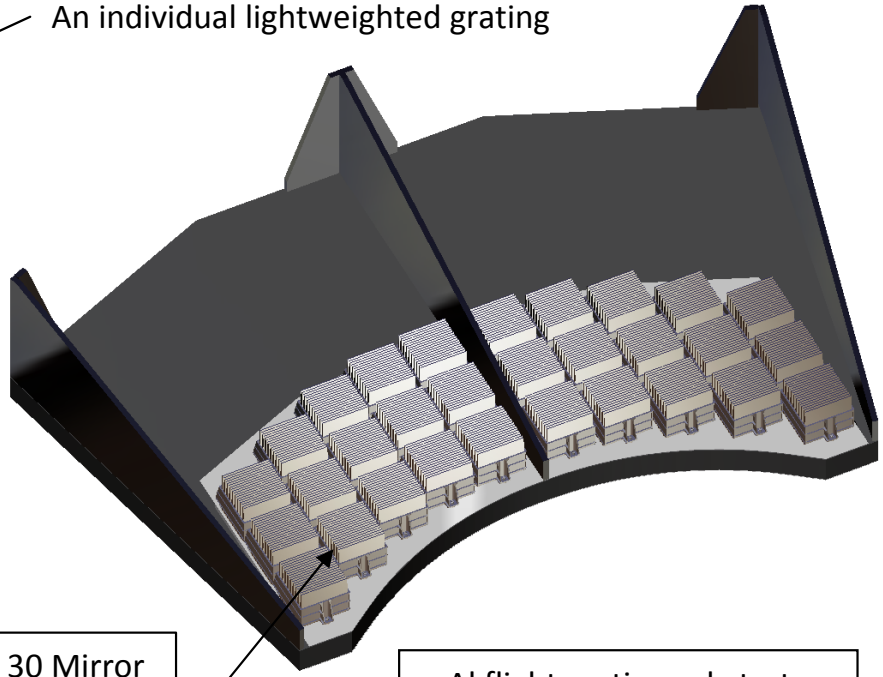
Grating Mirror Assembly Platform Modular Concept



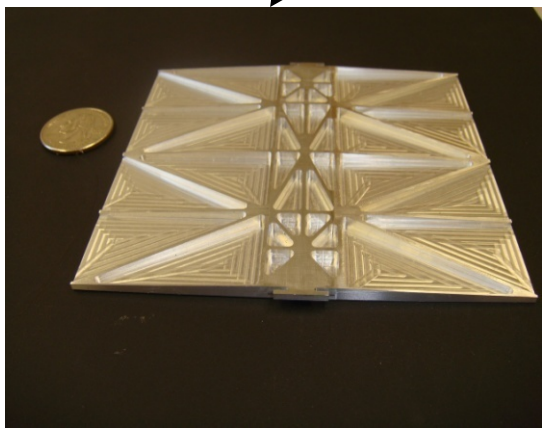


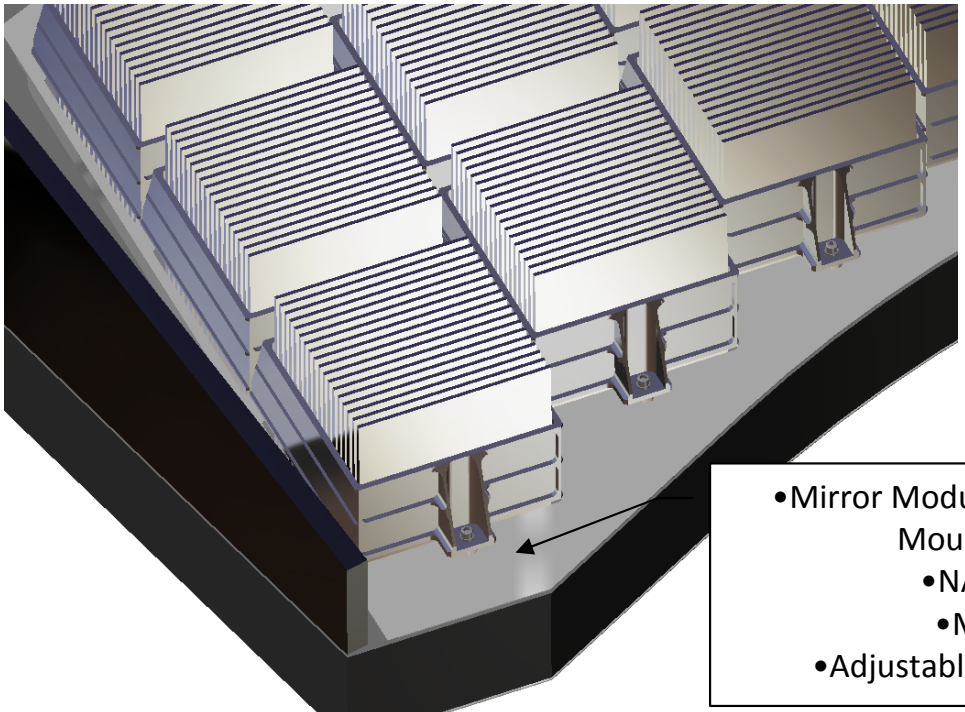
An individual lightweighted grating



30 Mirror Modules

Al flight grating substrate fabricated at Univ. of Iowa





- Mirror Modules Fasten using 3 Point Mount Attachments
- NAS1352 Screw
- MS21043 Nut
- Adjustable for Tip/Tilt & Piston

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