MSFC-034-ABSTRACT

ABSTRACT

An Evaluation of Grazing-Incidence Optics for Neutron Imaging

Author

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The refractive index for most materials is slightly less than unity, which opens an opportunity to develop the grazing incidence neutron imaging optics. The ideal material for the optics would be natural nickel and its isotopes. Marshall Space Flight Center (MSFC) has active development program on the nickel replicated optics for use in x-ray astronomy. Brief status report on the program is presented. The results of the neutron focusing optic test carried by the MSFC team at National Institute of Standards and Technology (NIST) are also presented. Possible applications of the optics are briefly discussed.

MSFC-034-PRESENTATION

An Evaluation of Grazing-Incidence Optics for Neutron Imaging

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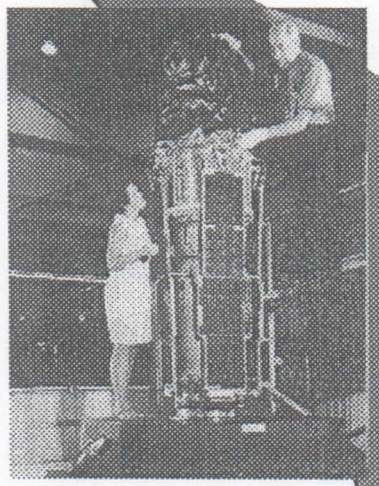
X-ray Optics for Astrophysics

Why focus x rays ?

1) Imaging - obvious
2) Background reduction
   - Signal from cosmic sources very faint, observed against a large background
   - Background depends on size of detector and amount of sky viewed →

     Concentrate flux from small area of sky on to small detector



First dedicated x-ray astronomy satellite – UHURU →
mapped 340 sources with large area detector (no optics)

Chandra observatory - ~ same collecting area as UHURU

- 5 orders of mag more sensitivity --- 1,000 sources / sq degree in deep fields

- Hard X-ray Region is relatively unexplored - transition between thermal and non-thermal mechanisms, nuclear lines appear, observe obscured objects + new discoveries made possible by increase in sensitivity

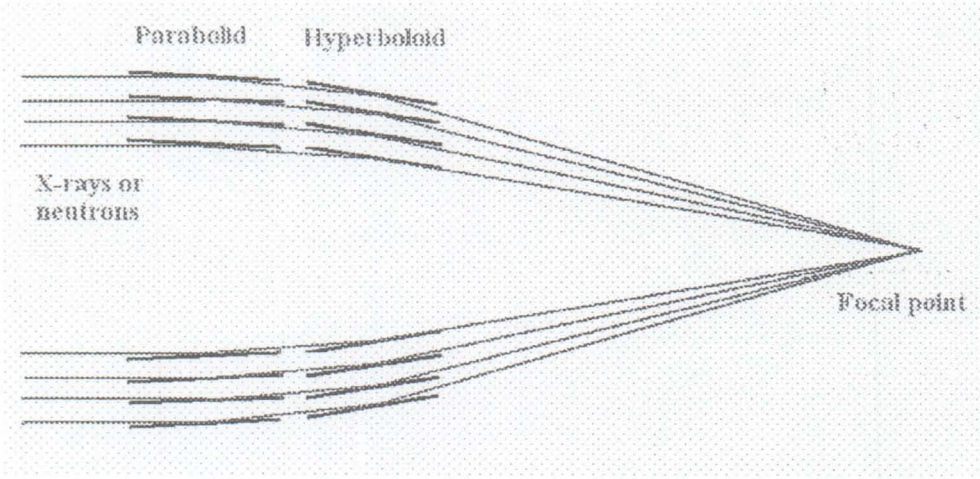
Total External Reflection

- ✓ The refraction index is less than unity for most of materials for neutrons and x-rays.
- ✓ Imaging optics based on the Wolter optical geometries developed for the x-ray grazing incidence beams can be designed for the neutron beams.
- ✓ MSFC has an active development program in grazing-incidence, ***nickel***-electroformed replicated optics for use in x-ray astronomy. This opens a possibility to develop a *grazing incidence* ***neutron*** *imaging optics…*

Wolter geometries for x-rays and neutrons

These configurations gives coma-free imaging off axis:

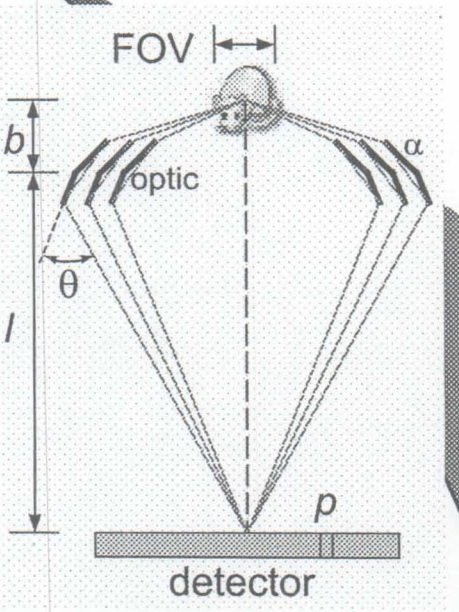
Infinite source – Telescope



Paraboloid-hyperboloid (2 types)

Paraboloid-ellipsoid

Finite source – Microscope

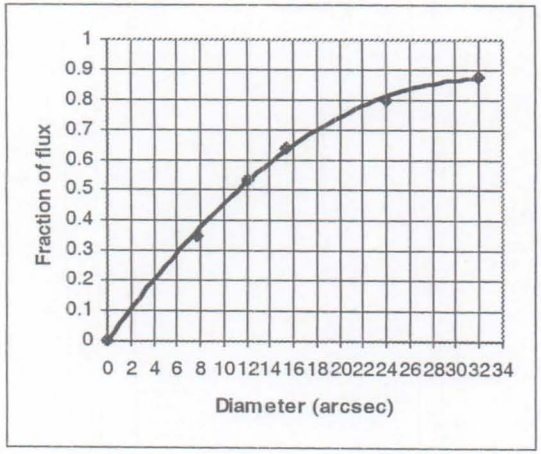


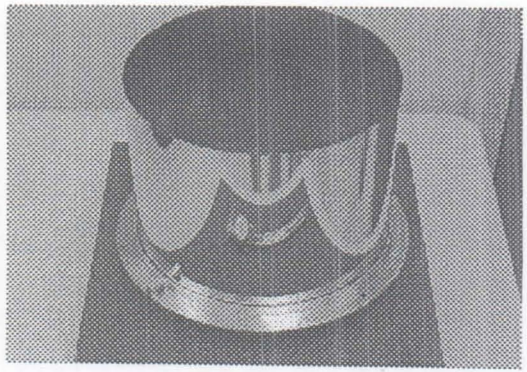
Hyperboloid-ellipsoid

Paraboloid-paraboloid

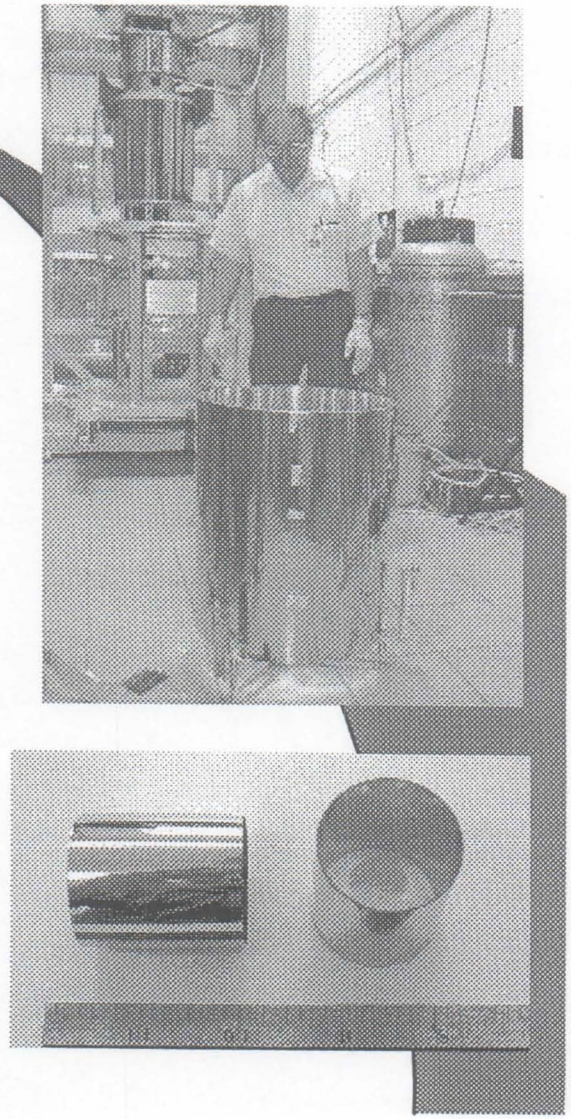
Conical Approximations would work too

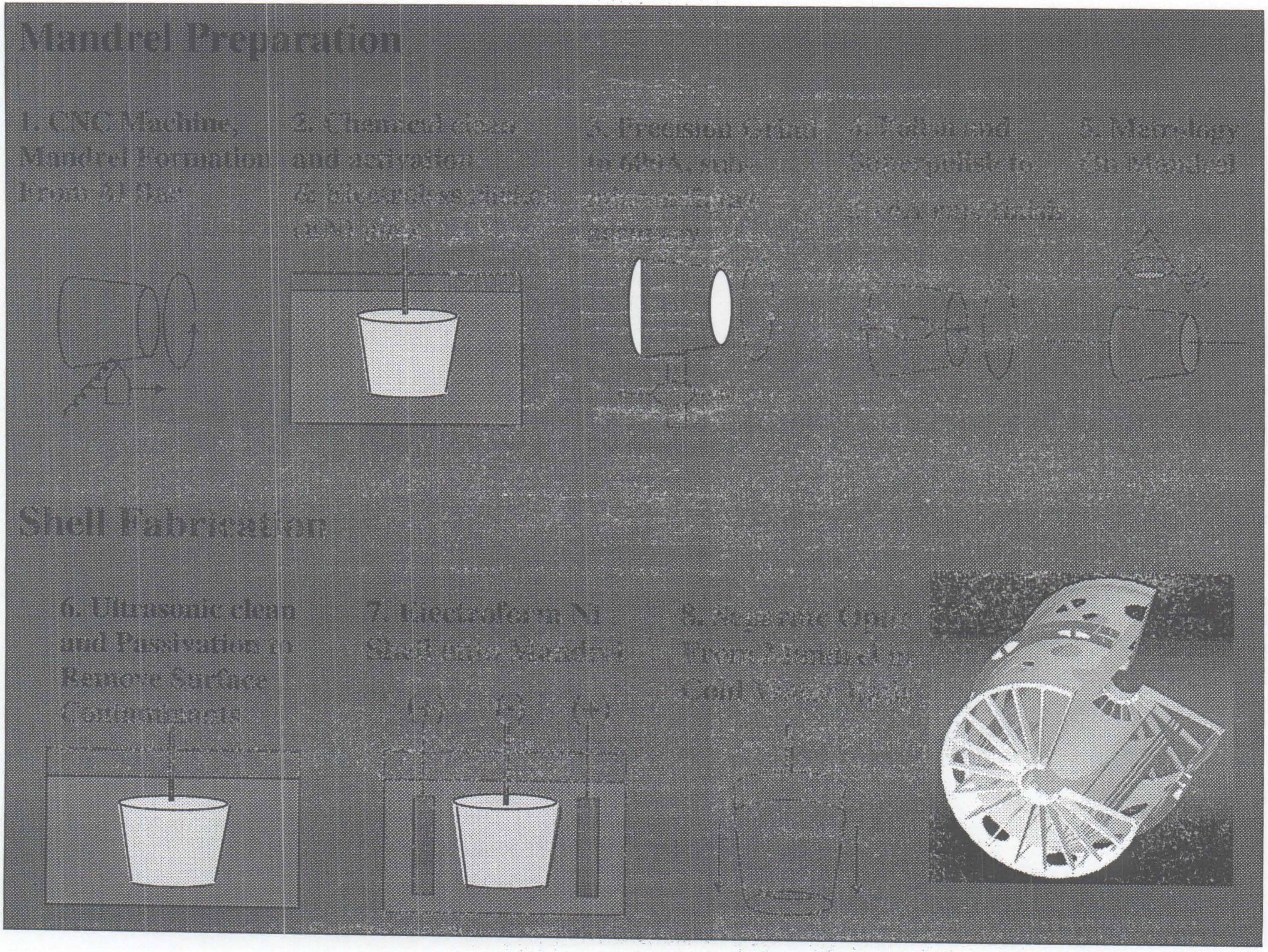
Nickel replicated Optics at MSFC





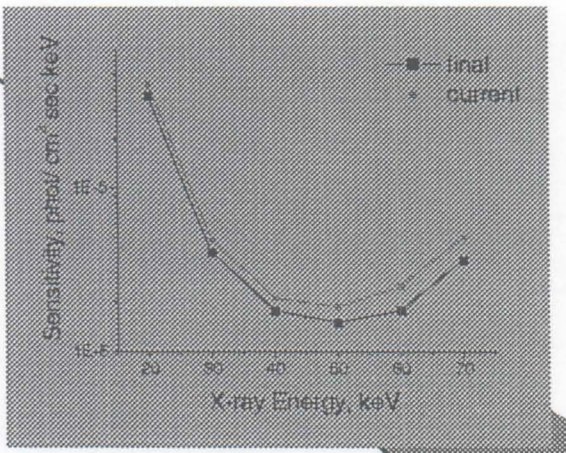
- ✓ Resolution as good as 10 arc sec HPD.
- ✓ Diameters from 2 cm to 0.5 m
- ✓ Focal distances from 1 to 10 m
- ✓ Thickness 50 micron demonstrated
- ✓ Bare nickel, Gold, Iridium or multilayer coatings
- ✓ Optics for soft and hard (up to 70 keV) x-rays

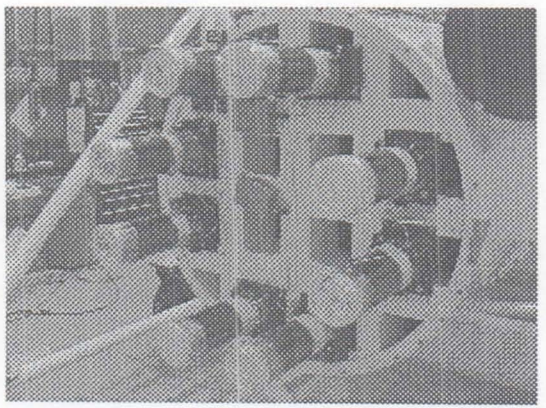


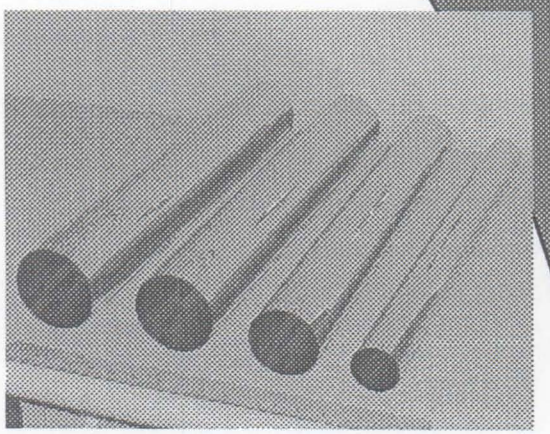

Mandrel Preparation
1. CNC Machine, Mandrel Formation From Al Bar
2. Chemical clean and activation
3. Precision Grind
4. Polish and Superpolish to
5. Metrology On Mandrel
Shell Fabrication
6. Ultrasonic clean and Passivation to Remove Surface Contaminants
7. Electroform Ni Shell onto Mandrel
8. Separate Optic From Mandrel in Cold Water Bath

HERO (High Energy Replicated Optics)

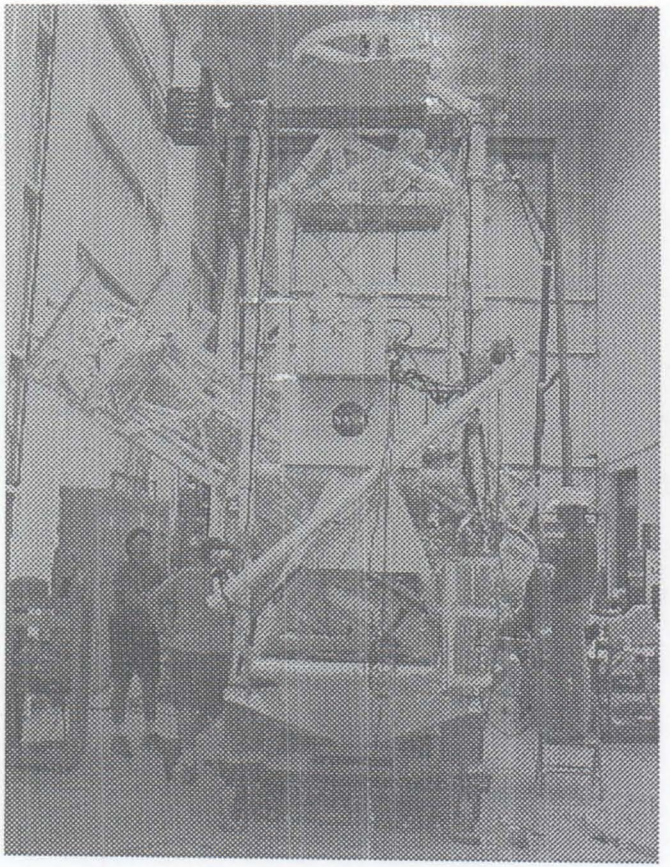
- 8 mirror modules, each containing 15 nested mirrors
- 600 mm in length (300 mm for each segment)
- 0.25 mm thick
- 50 nm sputtered iridium
- a focal length of 6 meters
- diameters vary - 50 mm to 94 mm.
- goal - 15 arc seconds HPD for module

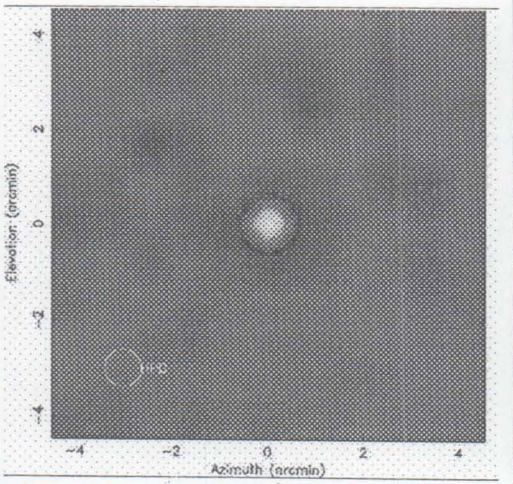


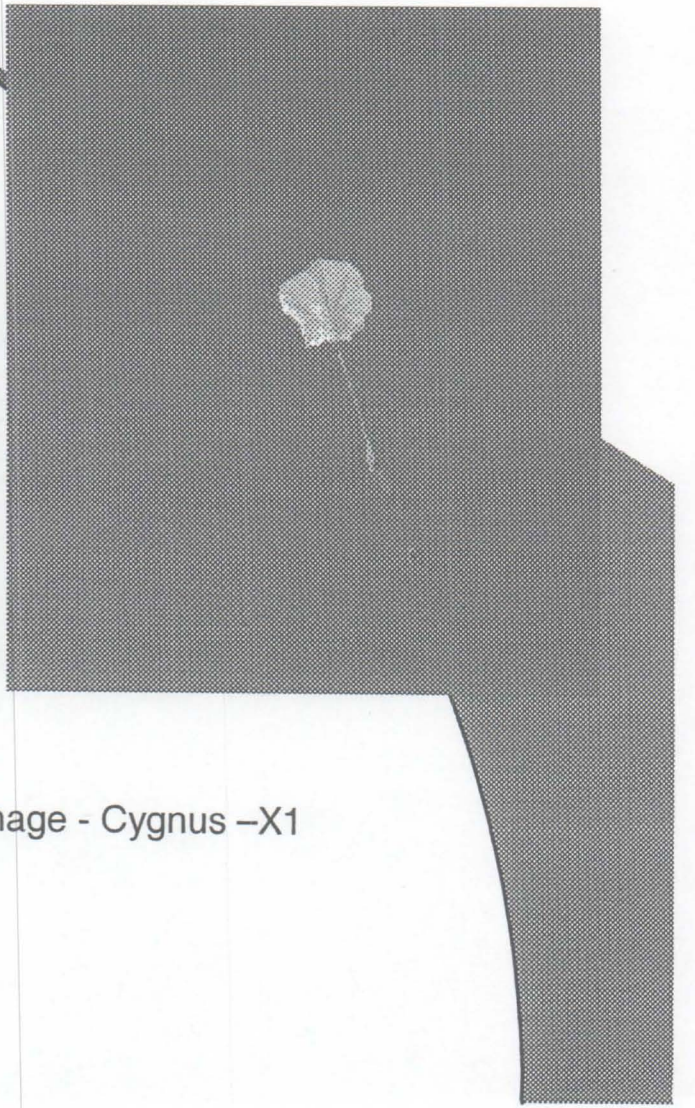




HERO (High Energy Replicated Optics)





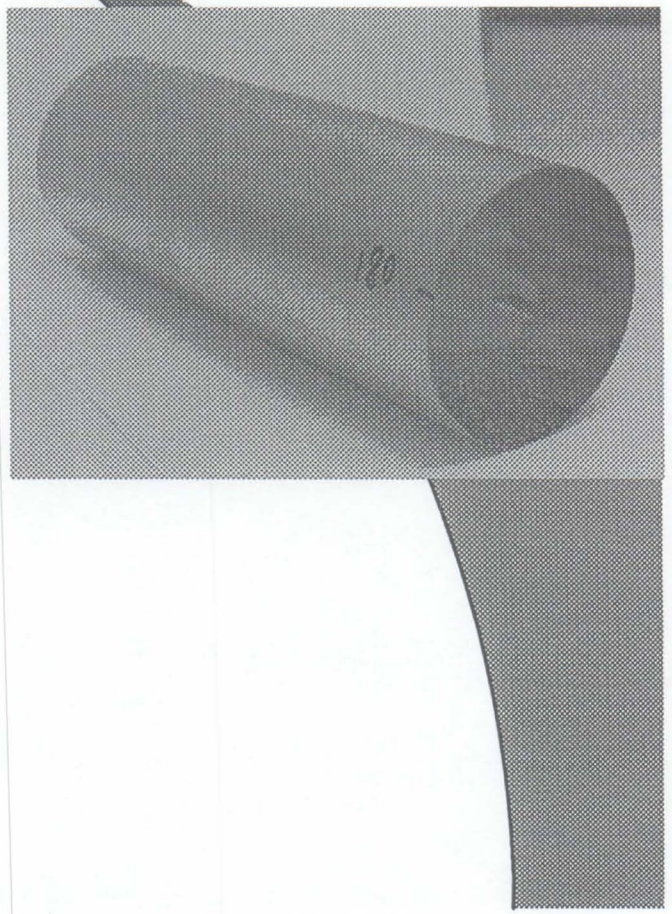


First Hard X-ray image - Cygnus –X1

Neutron Mirror

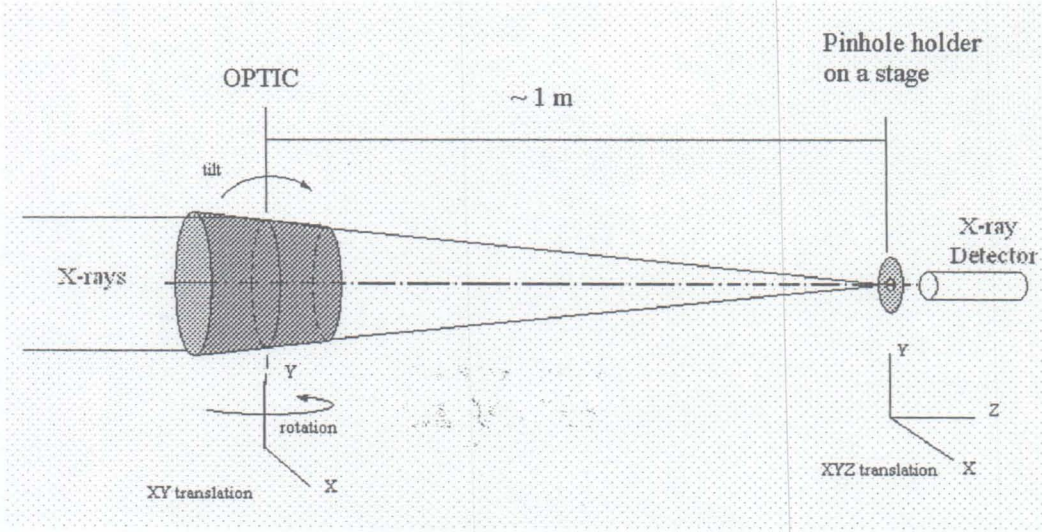
Diameter	62 mm,
Length	175 mm,
Focal distance	1 m
Graze angle	8.0 mrad
Material	pure nickel
Cut-off neutron wavelength	4.6 Å

Mandrel was originally designed as a 1/10-scale version of the innermost mirror of NASA's Chandra X-Ray Observatory.



X-ray test

- An evaluation of the x-ray performance of the mirror was carried out at the Stray Light Facility at MSFC. The optic was placed 100 meters from a 0.2-mm-diameter x-ray source.
- Resolution 6 to 8 keV was found to be 0.140 ± 0.003 mrad. which corresponds to a focal spot size of about 140 micron diameter.



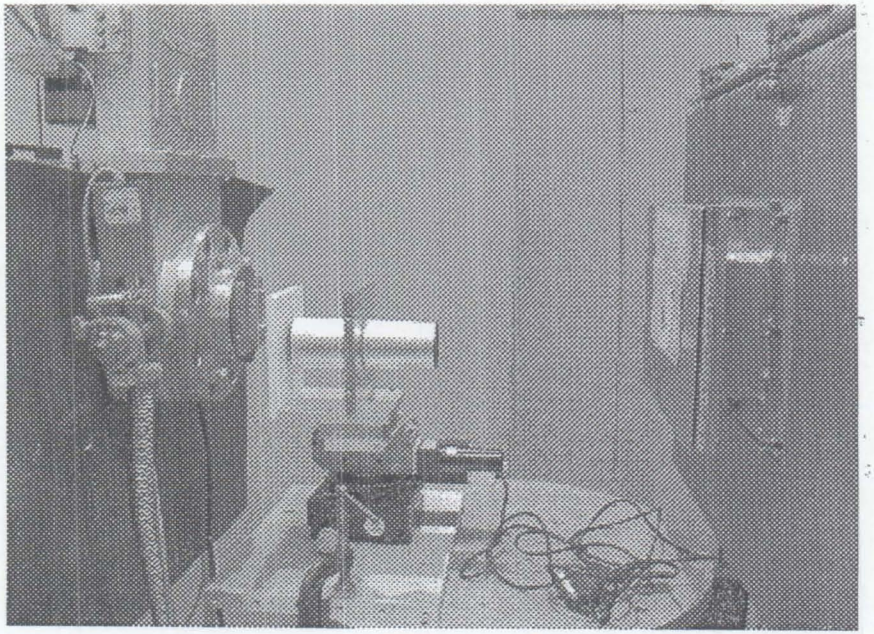
Neutron Test

Neutron beam-line at National Institute of Standards and Technology:

✓ Beam diameter is 25 mm – only sub-aperture test and maximal geometric area of the mirror is 17.7 **mm²**. The footprint area of the mirror at the beam is only 44 mm²

✓ Neutron wavelength range is from 5 to 20 Å

✓ The shortest distance between detector and the mirror focal spot is ~ 1.5 m, the detector resolution is 5 mm – extra-focal measurements.



The test mirror installed in the neutron beamline
National Institute of Standards and Technology's
Center for Neutron Research

Extra-focal image measurements

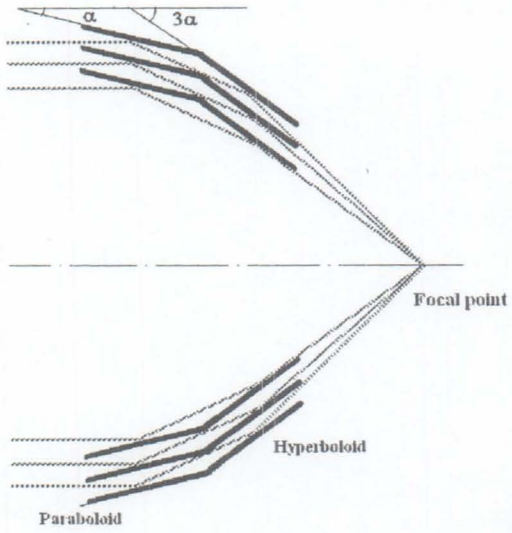
0.67 m 2.67 m 4.67 m

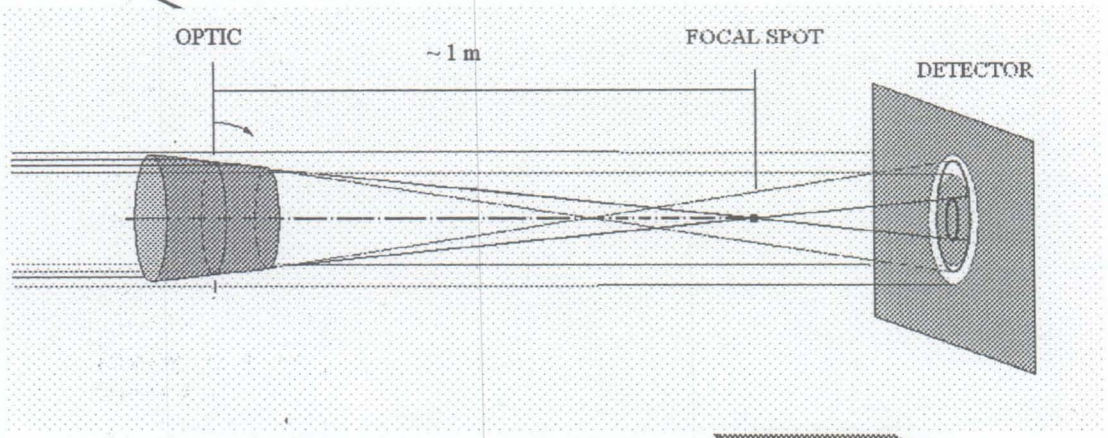
Distance from focal spot to the detector

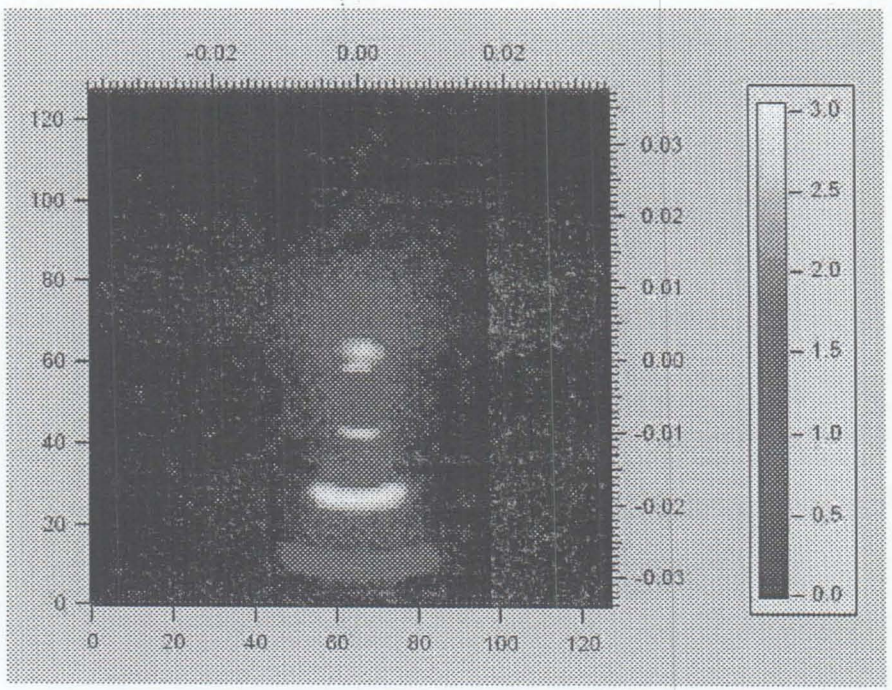
The mirror focal spot size was estimated to be 1.15 mm (FWHM) with the divergence of the neutron beam of ~1 mrad

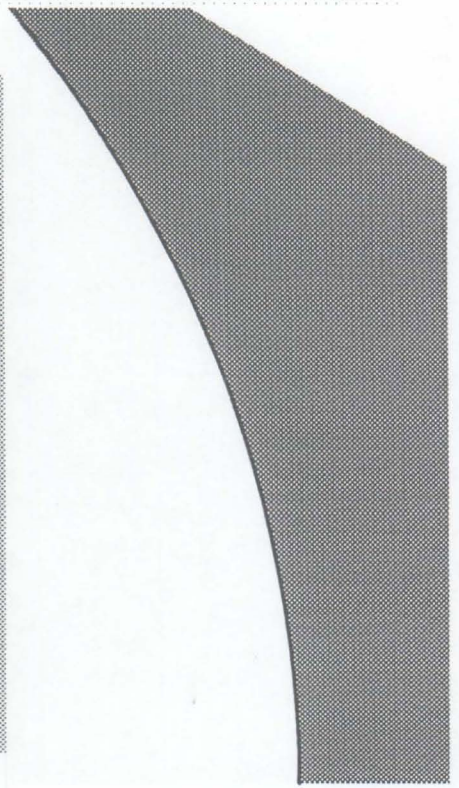
Neutron wavelength, Å	Effective area, mm^2	Gain
6	17.9±0.4	8.5
10	17.1±0.2	8.2
20	15.8±1.6	7.6

Neutron Mirror Alignment





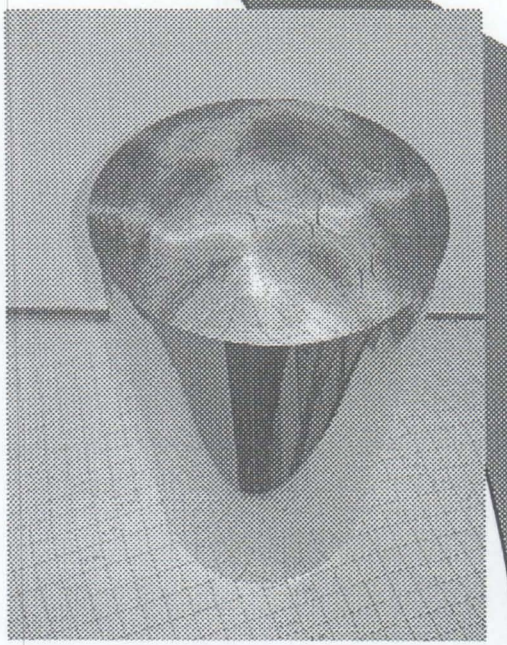




Possible applications

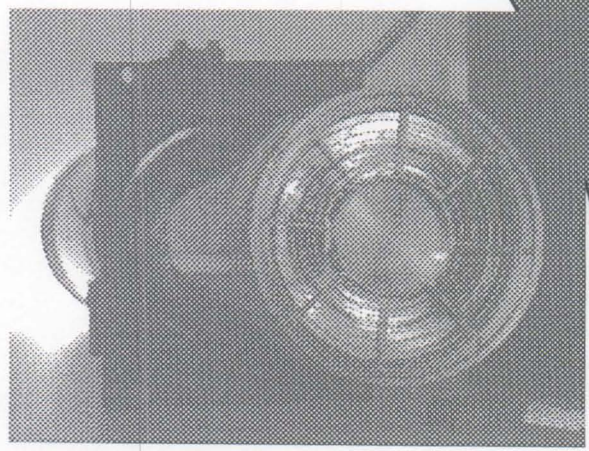
- *Neutron imaging or concentration*
- *High resolution water mapping on Lunar or Martian surface*
- *Neutron microscopy and radiography*
- *Small-Angle Neutron Scattering Analysis*
- *Light element analysis and detection*
- Medical therapies

- IDEAS?



What is next?

- Nested imaging system coupled with detector
- Coatings
- Find collaborators on applications
- Write proposals…



Conclusions

✓ The feasibility of grazing-incidence neutron imaging optics have been successfully demonstrated.

✓ Possible applications of the neutron optics need to be explored