# Development of multilayer coated neutron focusing optics

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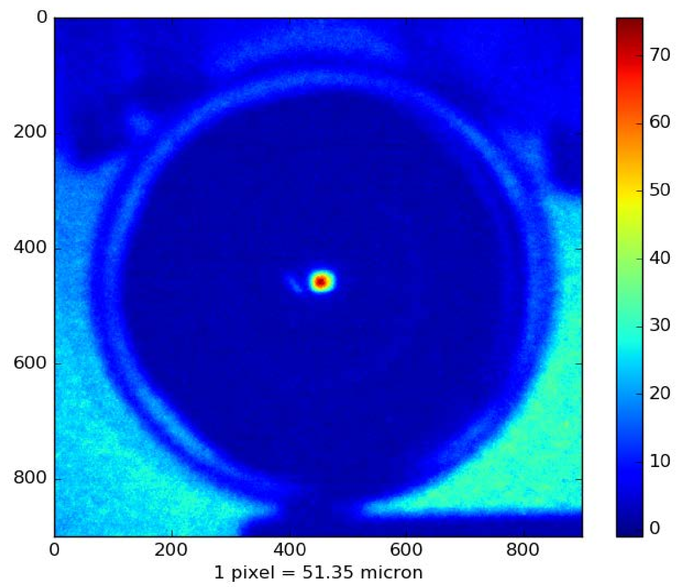
## ABSTRACT

We have been developing multilayer coated X-ray optics for future X-ray missions using an electroformed nickel replication process to fabricate complete shells which are then coated with multilayers using DC magnetron sputtering. However, for small diameter optics the cathodes used to deposit the coatings can no longer fit inside the optic for direct deposition. Therefore we have developed an indirect coating process which allows us to achieve multilayer coatings on the inside surface of arbitrarily small diameter integral optics. The multilayer coating is applied to the mandrel and is released with the optic as part of the electroformed nickel replication process. We are now applying this same technology to fabricate multilayer coated neutron focusing optics. We present results from the first prototype multilayer coated neutron focusing optic which was recently tested at the National Institute of Standards and Technology.

## FIRST NEUTRON ML IMAGE

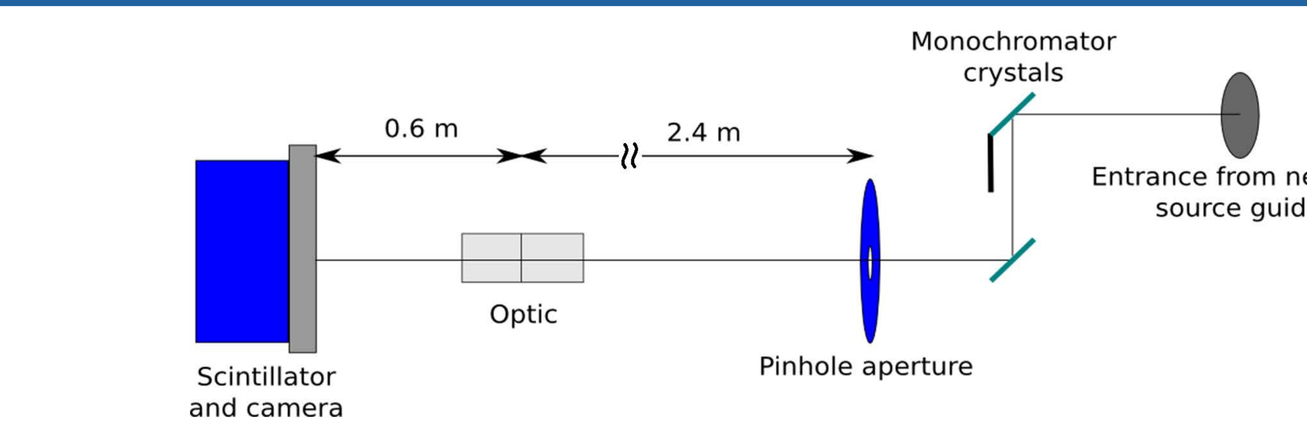
Spot at center shows focused neutron beam. Outer ring indicates diameter of optic.



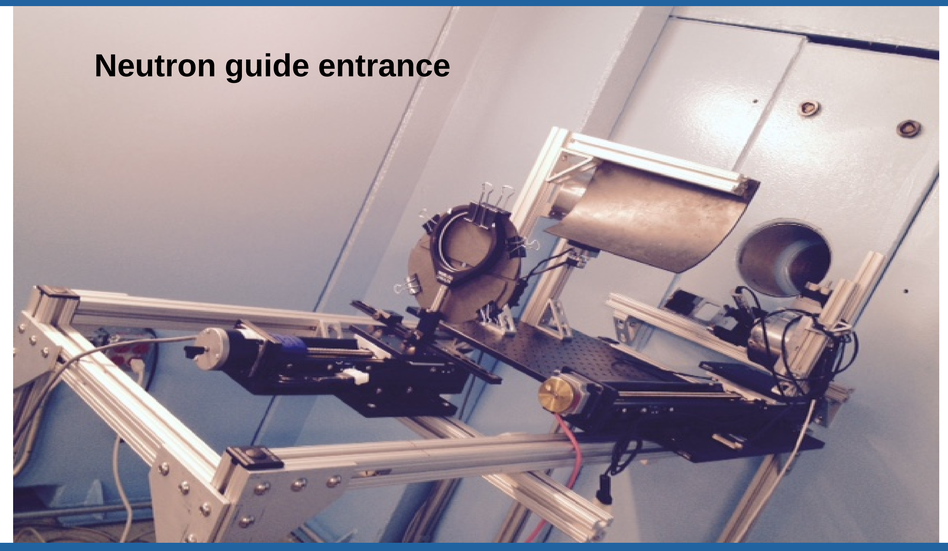

## ML COATED TEST OPTIC

ML coated test optic used to focus neutron flux, shown at left. N=15 Ti/NiC multilayer coating on the inner surface

Mandrel used to fabricate optic at left



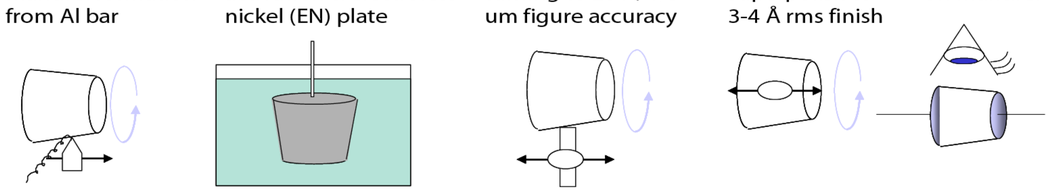

**Sketch defining the NIST Imaging beamline shown at right**




## Replicated Optics

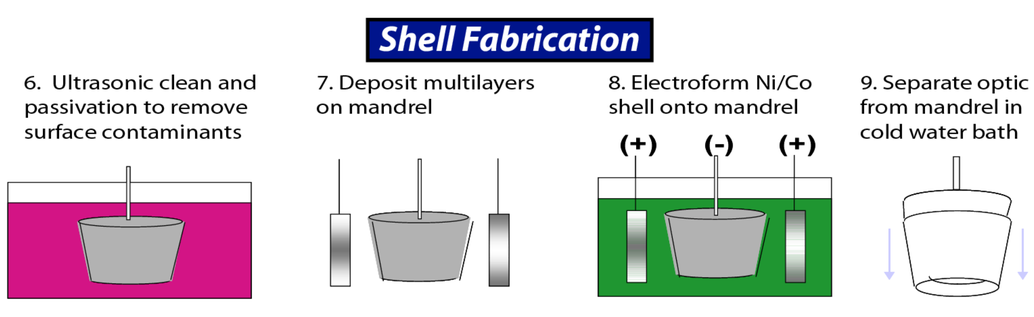
**Mandrel Preparation**

1. CNC machine, mandrel formation from Al bar
2. Chemical clean and activation & electroless nickel (EN) plate
3. Precision diamond turning to 20 Å, 1/3 um figure accuracy
4. Polish & superpolish to 3-4 Å rms finish
5. Metrology on mandrel



**Shell Fabrication**

6. Ultrasonic clean and passivation to remove surface contaminants
7. Deposit multilayers on mandrel
8. Electroform Ni/Co shell onto mandrel
9. Separate optic from mandrel in cold water bath




- Leverages 40+ years of experience of the astronomy community in making Wolter optics
- Takes advantage of recent advances in multilayer deposition (similar to a synthetic Bragg crystal) and replicated optics fabrication
- Originally developed by European groups for space missions in the 1980s
- NASA Marshall Space Flight Center began an effort in the 1990s
- Significant investment & innovation has led to regular production of optics with $\Delta\alpha \approx 15''$

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