

National Aeronautics and Space Administration



Optics

Nested Focusing Optics for Compact Neutron Sources

Enabling high performance neutron imaging and analysis

NASA's Marshall Space Flight Center, the Massachusetts Institute of Technology (MIT), and the University of Alabama Huntsville (UAH) have developed novel neutron grazing incidence optics for use with small-scale portable neutron generators. The technology was developed to enable the use of commercially available neutron generators for applications requiring high flux densities, including high performance imaging and analysis. Nested grazing incidence mirror optics, with high collection efficiency, are used to produce divergent, parallel, or convergent neutron beams. Ray tracing simulations of the system (with source-object separation of 10m for 5 meV neutrons) show nearly an order of magnitude neutron flux increase on a 1-mm diameter object. The technology is a result of joint development efforts between NASA and MIT researchers seeking to maximize neutron flux from diffuse sources for imaging and testing applications.

BENEFITS

- **Improved performance:** enabling use of smaller neutron sources for imaging and analytical techniques
- **Increased flexibility:** removable mirrors enables easy experimental flux adjustments
- **Reduced optic cost:** novel replication technique enables copies from a single master
- **Increased collection efficiency:** superior to neutron focusing guides and Kirkpatrick-Baez mirrors

APPLICATIONS

The NASA technology can enable the use of compact radiation sources in the following applications:

Non-Destructive Inspection:

- Jet-engine turbine blades
- O-ring placement in critical componentry
- Fuel cells
- Archaeological artifacts
- Weld inspection

Analytical Techniques:

- Small angle neutron scattering (SANS)
- Time-of-flight spectroscopy
- Convergent beam crystallography
- Inelastic scattering instruments

technology solution



THE TECHNOLOGY

Conventional neutron beam experiments demand high fluxes that can only be obtained at research facilities equipped with a reactor source and neutron optics. However, access to these facilities is limited. The NASA technology uses grazing incidence reflective optics to produce focused beams of neutrons (Figure 1) from compact commercially available sources, resulting in higher flux concentrations. Neutrons are doubly reflected off of a parabolic and hyperbolic mirror at a sufficiently small angle, creating neutron beams that are convergent, divergent, or parallel. Neutron flux can be increased by concentrically nesting mirrors with the same focal length and curvature, resulting in a convergence of multiple neutron beams at a single focal point. The improved flux from the compact source may be used for non-destructive testing, imaging, and materials analysis.

The grazing incidence neutron optic mirrors are fabricated using an electroformed nickel replication technique developed by NASA and the Harvard-Smithsonian Center for Astrophysics (Figure 2). A machined aluminum mandrel is super-polished to a surface roughness of 3-4 angstroms root mean square and plated with layers of highly reflective nickel-cobalt alloy. Residual stresses that can cause mirror warping are eliminated by periodically reversing the anode and cathode polarity of the electroplating system, resulting in a deformation-free surface. The fabrication process has been used to produce 0.5 meter and 1.0 meter lenses.

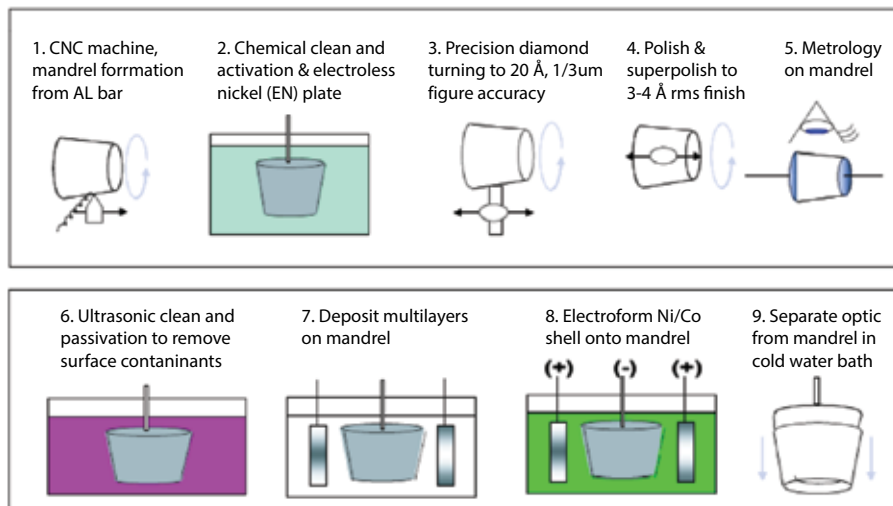


FIGURE 2 – The optics are made by electroforming a nickel alloy shell over a CNC formed and polished mandrel to create a deformation-free surface.

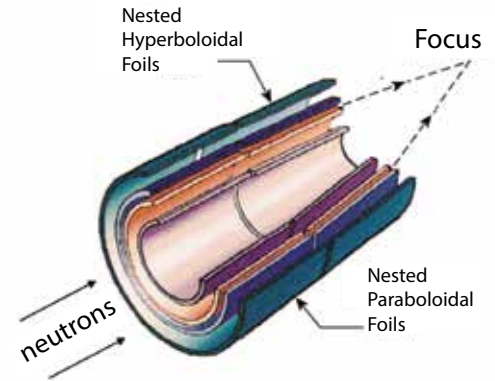


FIGURE 1 – Grazing incidence mirror optics are used to focus neutron radiation to increase flux from a disperse source.

PUBLICATIONS

U.S. Patent No. 8,735,844

Liu, D., et al. Demonstration of achromatic cold-neutron microscope utilizing axisymmetric focusing mirrors. Applied Physics Letters. Volume 102. Issue 18. 2013.

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