# Vacuum Vibration Qualification of Large-Aperture Silicon Carbide Grids for X-ray Microcalorimeter Blocking Filters


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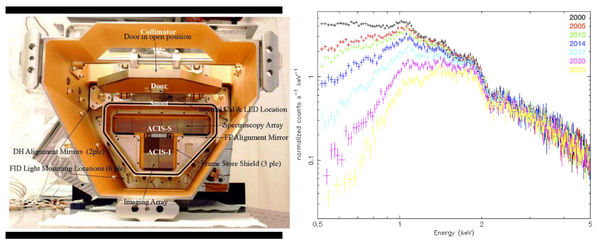
## Motivation

Astro2020 identified open questions about the hot, energetic universe — AGN-driven feedback, missing baryons in the CGM/WHIM, and velocities and abundances in hot plasmas — that demand high-resolution soft X-ray microcalorimetry on next-generation, large-aperture observatories.




*The Chandra ACIS focal plane (left) and the measured loss of soft X-ray effective area from hydrocarbon contamination buildup, 2000–2023 (right). Adapted from Grant et al. 2024.*

Realizing that science depends on solving a persistent bottleneck: optical blocking filters remain a NASA Tier 1 technology gap. Contamination buildup degrades throughput over a mission's lifetime, and warmed-filter strategies become harder to scale toward the 160–180 mm apertures needed for an X-ray flagship mission.

### Tier 1

NASA technology gap: optical blocking filters for large-aperture soft X-ray observatories

### Why Silicon Carbide?

SiC grids provide substantially higher radial thermal conductance than heritage BeCu honeycomb designs, at the cost of a brittle failure mode and low inherent damping — the qualification risk this campaign addresses.

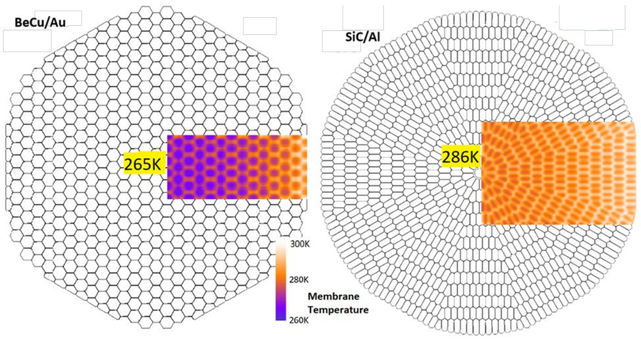
- High strength & resonant frequency
- Chip- and scratch-resistant
- Low fluorescence, reduced scatter
- High transmittance

### Candidate Materials

| | X-IFU BeCu/Au | SXS Si | SiC |
|---|---|---|---|
| Strength (MPa) | 750 | 200 | 1000 |
| Modulus (GPa) | 120 | 148 | 400 |
| Hardness (Mohs) | 6 | 6.5 | 9.5 |
| Therm Cond(W/m-K) | 160 | 130 | 490 |

*Mechanical/thermal properties: heritage X-IFU BeCu/Au honeycomb, SXS silicon, and single-crystal SiC.*

### BeCu/Au, SiC/Al thermal conductance comparison

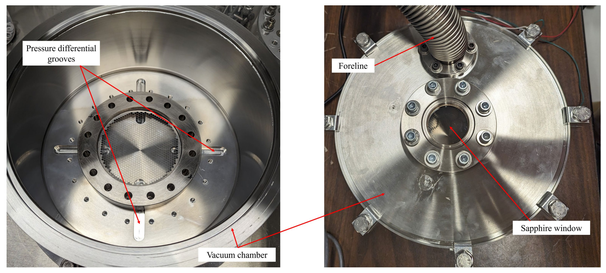



*Modeled 30nm Al/456nm polyimide membrane temperatures for a 128 mm BeCu/gold (left) and SiC/Al grid in a 253K blackbody environment with a 300K frame temperature.*

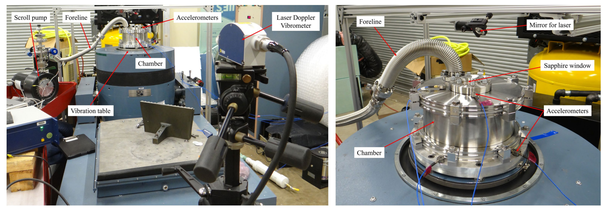
## Vibration Qualification Approach

We report on a vacuum vibration test campaign at the Penn State Advanced Research Laboratory, using an Unholtz Dickie shaker and laser Doppler vibrometry (LDV), qualifying SiC grid assemblies up to 180 mm against GEVS Qualification Level (+3 dB) loads.

### Test Hardware




*Vacuum chamber used for grid vibration testing, with pressure-differential relief grooves and a sapphire window added for in-vacuum LDV access.*




*Chamber mounted on the Unholtz Dickie shaker at the Penn State Center for Acoustics and Vibration, with the LDV beam relayed through the sapphire window via a 45° mirror.*

### Damped Grid Design

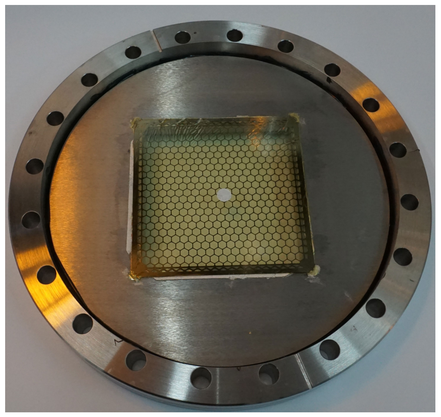
Smaller-aperture grids (78–128 mm), built with a two-part frame and backing-plate damping design, showed order-of-magnitude reductions in resonant Q and peak acceleration — informing the geometry carried into the 180 mm prototype.

**180 mm**
target qualification aperture, GEVS +3 dB

**10×**
reduction in resonant Q from backing-plate damping

## Square Grids for AXIS-like cameras

Alongside the circular geometry, we developed a 76 mm square SiC grid sized for the AXIS Astrophysics Probe focal plane — the first design able to support a full AXIS-sized filter as a single unit, removing the cross-bar shadow of the original 4-segment baseline.



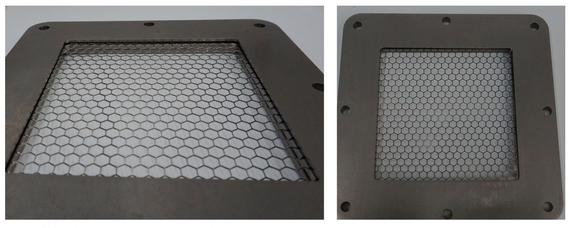
*Grid P5065: 76 mm square SiC grid with 1 µm Al coating, mounted in a titanium frame and covered with a 3 µm polyimide membrane. A small reflector tab (center) enables LDV motion measurement.*

### Material Comparison (SS/Au vs. SiC)

**1.6×**
higher rupture strength (750 → 1200 MPa)

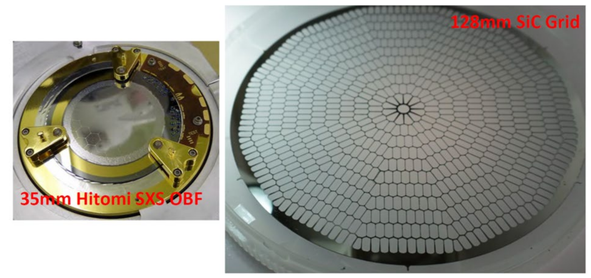
**3.1×**
higher thermal conductivity (160 → 490 W/m·K)

The square grid passed air vibration testing with no membrane tears or cell damage. Damping was characterized via the autocorrelation of measured Doppler velocity at 3 and 14.1 g rms, showing a consistent damping time constant across vibration levels — evidence that damping is dominated by linear out-of-plane bending strain.

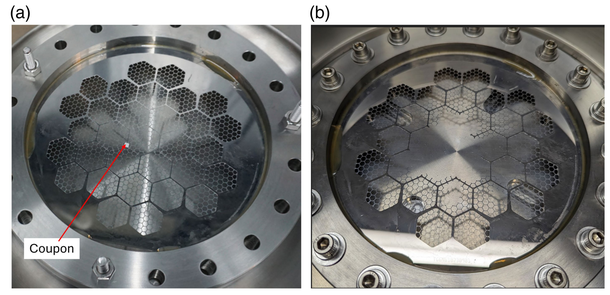


*A square SiC grid mounted into a titanium frame*

## Environmental Test Results

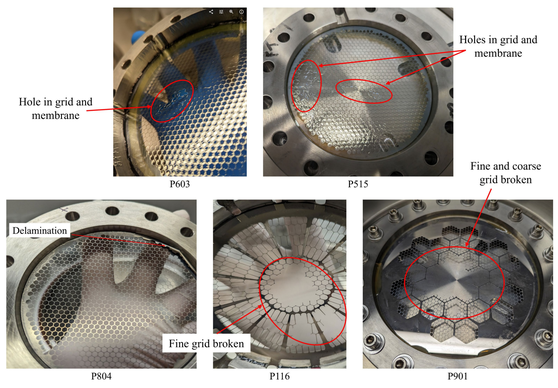



*Scale comparison: the 35 mm Hitomi SXS optical blocking filter (left) beside a 128 mm SiC grid (right) — roughly a 13× increase in open area.*




*128 mm grid P901 before (left) and after (right) GEVS +3 dB vibration exposure. Breakage of both coarse and fine bars caused the center of the grid to fail.*

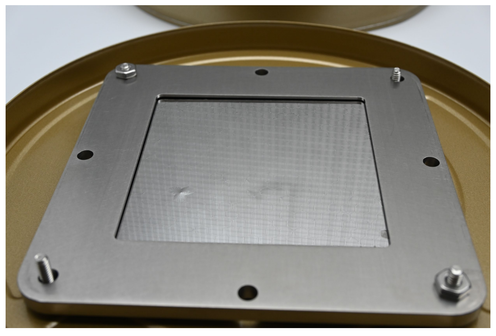
### Damage Survey Across Apertures




*Post-vibration inspection across the test series. P804 (aluminum-coated) passed with no grid failures; P116's coarse grid survived while the fine grid failed; P901 failed in both.*

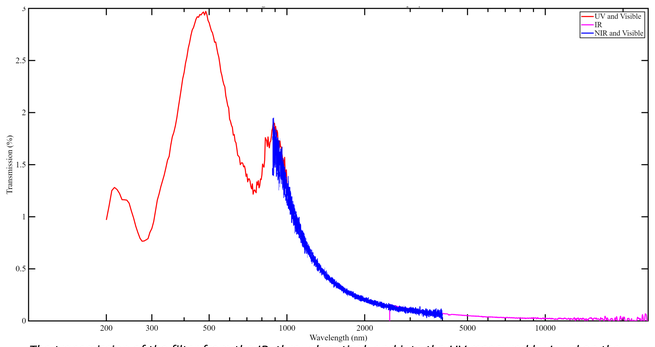
## Other Testing

### Application of blocking filter



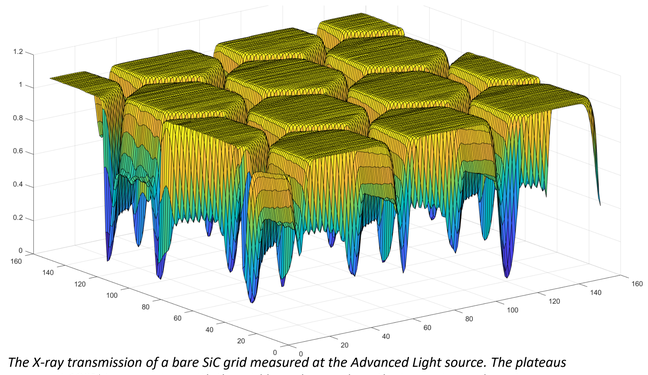
*A 30 nm Al, 40 nm Polyimide filter over a square SiC grid mounted into a Ti frame. A small tend defect can be seen in the bottom left corner thought to be caused by a imperfect etch in that area*

### UV/Optical/IR Transmission (30 nm Al/40 nm Polyimide)




*The transmission of the filter from the IR, through optical, and into the UV measured by Luxel on the witness sample made alongside the filter*

### UV/Optical/IR Transmission (30 nm Al/40 nm Polyimide)



*The X-ray transmission of a bare SiC grid measured at the Advanced Light source. The plateaus represent 100% transmission, with the grid bars shown where the transmission drops to zero.*

## Conclusions & Outlook

This vacuum vibration campaign is establishing a qualification pathway for SiC blocking-filter grids — circular apertures up to 180 mm and square grids of 75 mm — directly supporting blocking-filter readiness for a future X-ray flagship mission, and offering a transferable vibration-qualification approach for brittle-substrate filters across the soft X-ray mission portfolio.

**Circular grids:** an aluminum coating increased vibration damping enough for 100 mm grids to pass GEVS with no failures; apertures above 100 mm will need a two-level design, added strength, and/or more damping. LDV reliably identified the moment of grid failure during test.

**Square AXIS-sized grids:** the 75 mm design passed air vibration testing with no membrane tears or cell damage, with damping dominated by linear out-of-plane bending strain at both 3 and 14.1 g rms. Square filters are now being coated in Al/polyimide and evaluated for IR/UV/optical and X-ray transmission, thermal conductivity, and thermal cycling.

**Next steps:** extend qualification to full 180 mm circular and larger square apertures, characterize thermal conductance and X-ray transmission of the square design, and complete thermal-vacuum cycling to de-risk SiC blocking filters for mission selection.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1. *Tutt et al., "Testing of SiC grid-based blocking filters to increase theirtechnology readiness level", Proc. SPIE (2026)*
2. *Tutt et al., "Development of blocking filters using high-throughput SiC grids", JATIS (2025)*
3. *Tutt et al., "Updates on the development of blocking filters using high throughput SiC grids", Proc. SPIE (2025)*