



Testing of a stacked core mirror for UV applications

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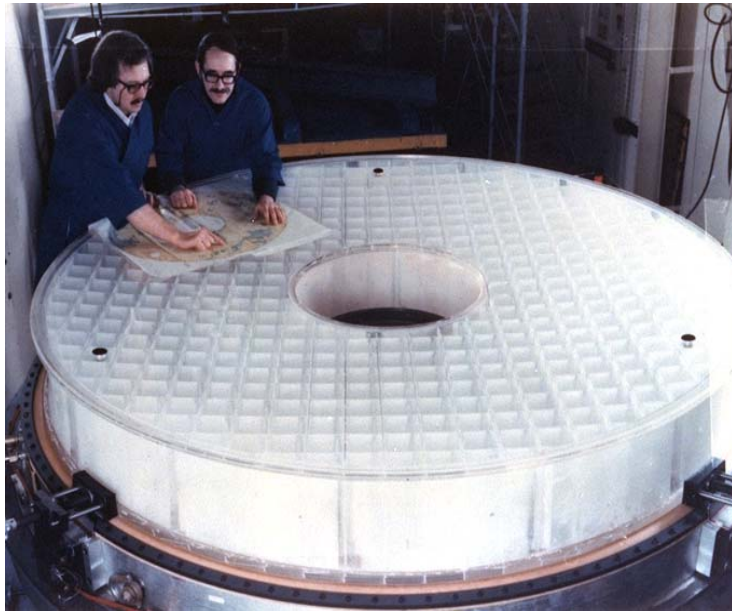
A horizontal orange line is positioned above the text. Below it, two orange lines extend downwards and outwards from a central point, forming a wide 'V' shape.

Advanced UVOIR Mirror Technology Development (AMTD) Program

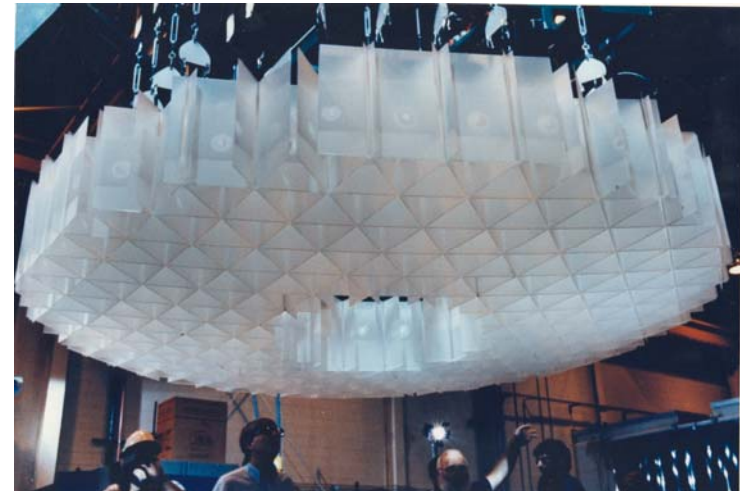
- Develop mirror blank technology applicable to building a cost effective, large (4m-8m class), passive, monolithic mirror capable of imaging in the UV spectrum
 - > 0.43m demonstration mirror fabricated
 - > 5.5nm RMS overall surface figure demonstrated
- Current limitations regarding a 4m class mirror
 - > Significant mirror depth required to achieve stiffness
 - > Core depth drives up cutting costs, schedule, risk, and areal density
 - > Stack sealing of boules to achieve overall depth is very expensive and time consuming
- AMTD program addresses these issues to reduce the cost and lead time for building a 4m class mirror blank and demonstrates the ability to polish and test the blank to UV quality



Large Lightweight ULE Primary Mirrors at Exelis



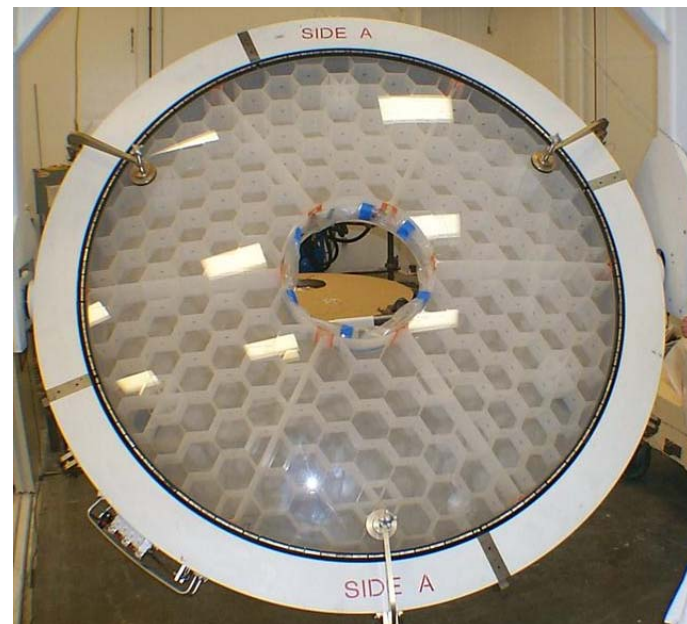
High Temperature Fusion – 1970's
(Hubble Primary Mirror)



Frit Technology with Flame Welded Core – 1980's



ATT – Waterjet Cut Core – Low Temp Fusion – 1990's

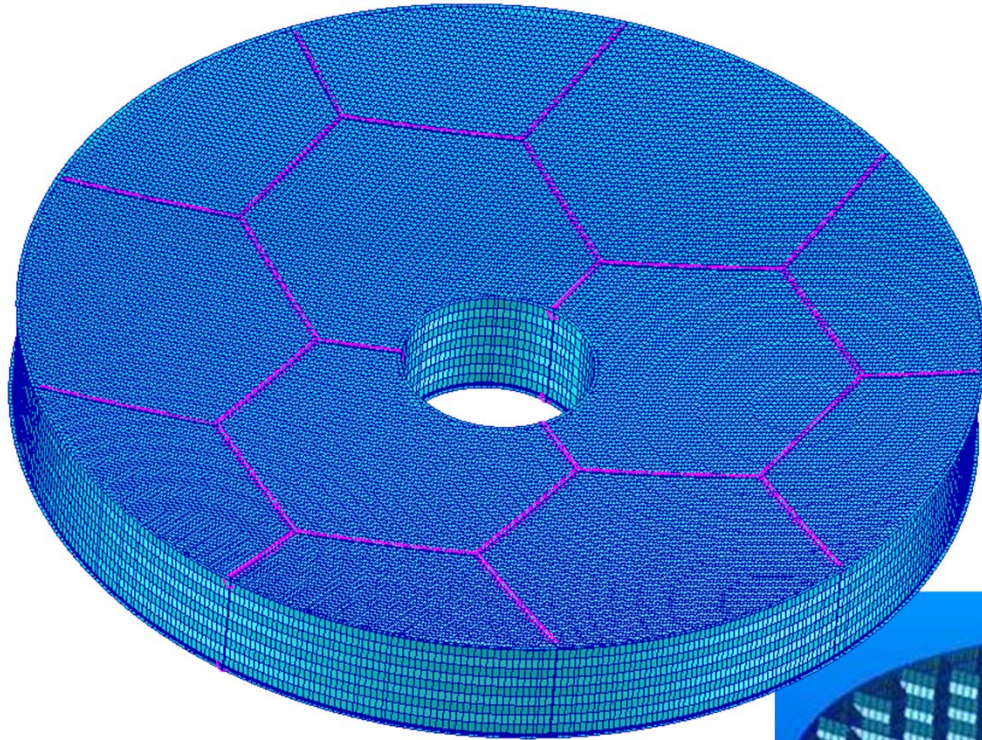


Primary Mirror – Low Temp Fusion – 2000's



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4m Mirror Concept

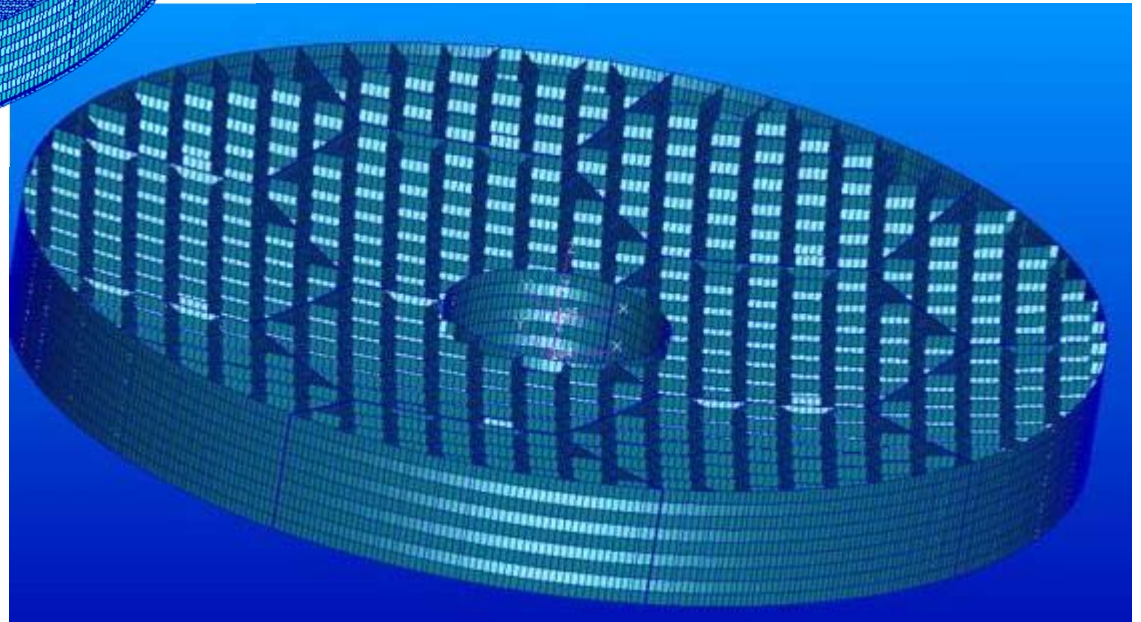


4m Mirror Physical Attributes

- Pocket Milled Facesheet allows larger core cells while controlling quilting
- 12 Core Segments
- 3 Stacked Core Deep
- 10m RoC (F#1.25)

Efficient use of ULE Boules

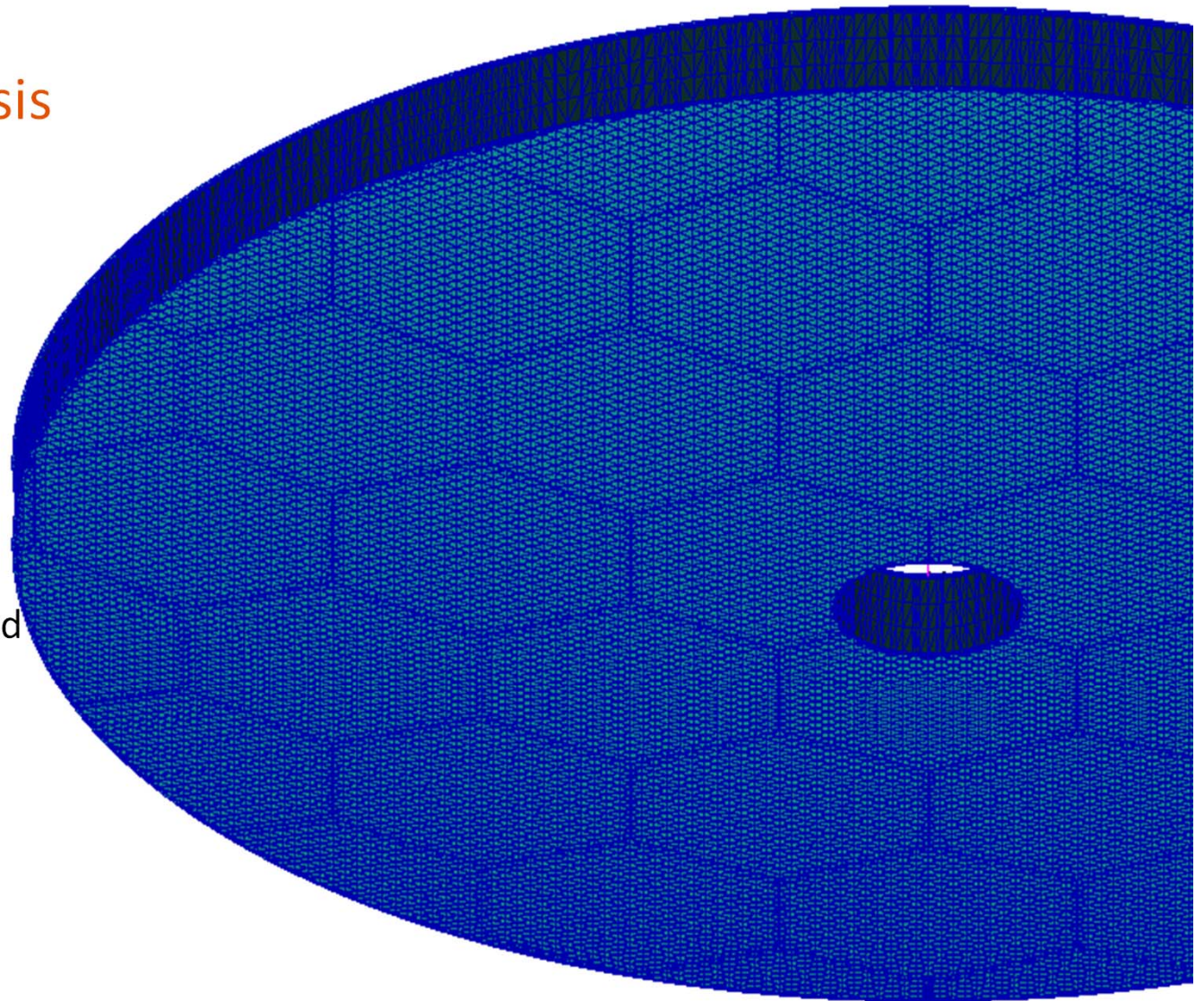
- 27 boules to fabricate the 36 core segments
- 9 boules to fabricate the 2 faceplates (with spares)
- 36 flight boules



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AMTD 8m Mirror Design and Analysis

- Stacked core and Pocket milled facesheet design
- 24.2m RoC (f#1.5)
- The 8 meter mirror modeled to assess performance
 - Model includes light-weighted face plates joined to a light-weighted core.
 - 5% additional mass added to light-weighted sections to account for corner radii.
- Total mass was 3042 kg, 60 kg/m²
- First Free-Free mode at 33 Hz

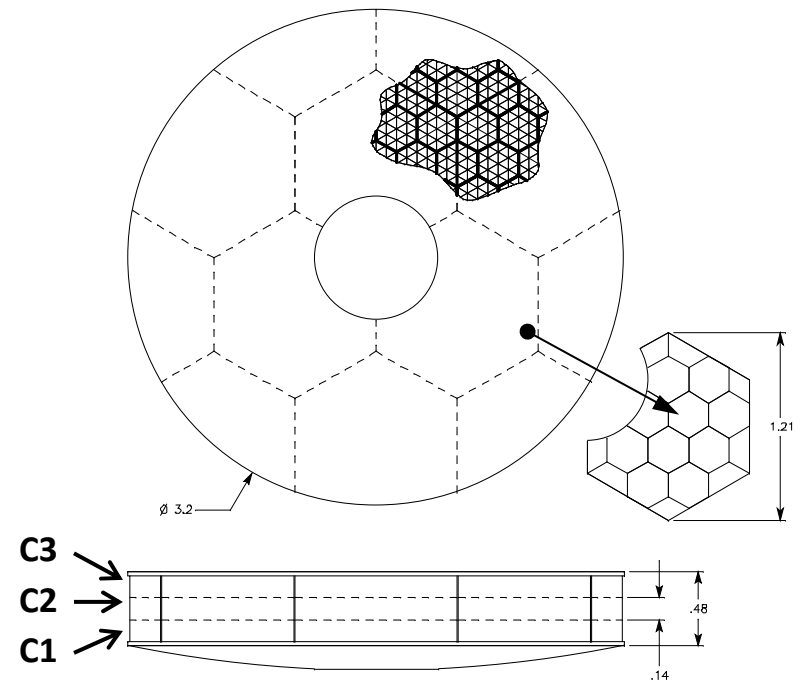
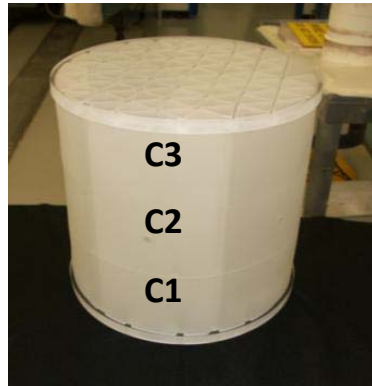


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AMTD is Developing Technologies for Near Term Large Lightweight Primary Mirrors

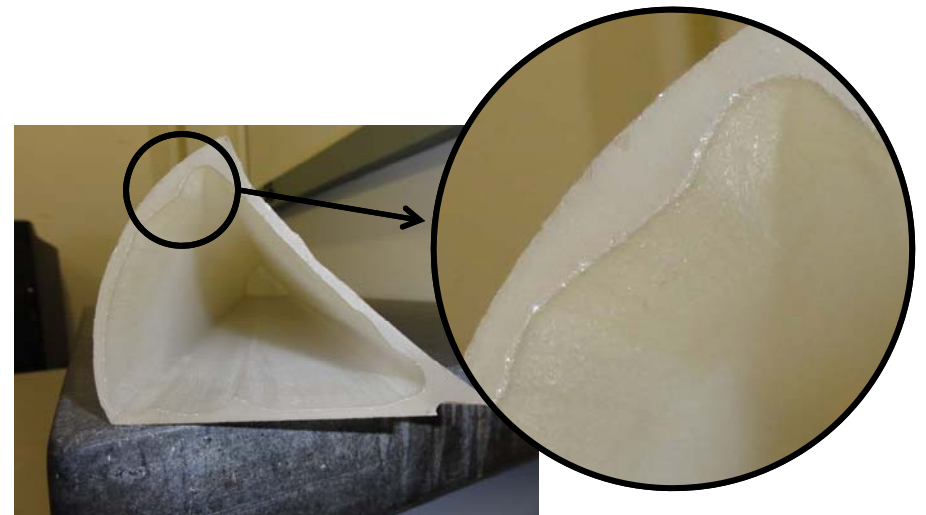
Stacked core

- > Core segments are fabricated from standard thickness boules, then stacked & fused during blank assembly to achieve a deep core
- > Eliminates need for stack sealing of boules and deep AWJ cutting of cores
- > Enables lighter weight cores and reduces cost & schedule for blank fab



Deep AWJ Cutting

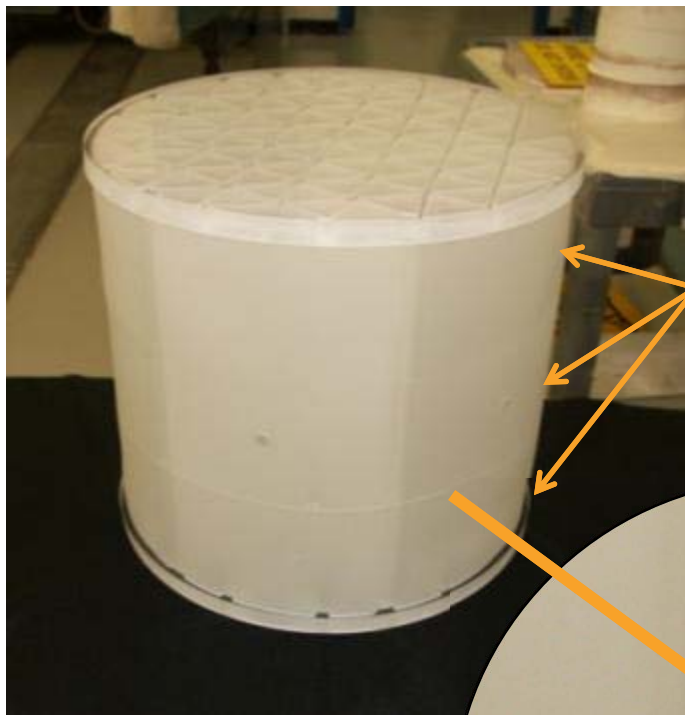
- > Extend AWJ cutting depth for LW cores from current 300mm (11.6 in) up to 480mm (19 in) depending on mirror stiffness
- > More difficult to control exit surface parameters



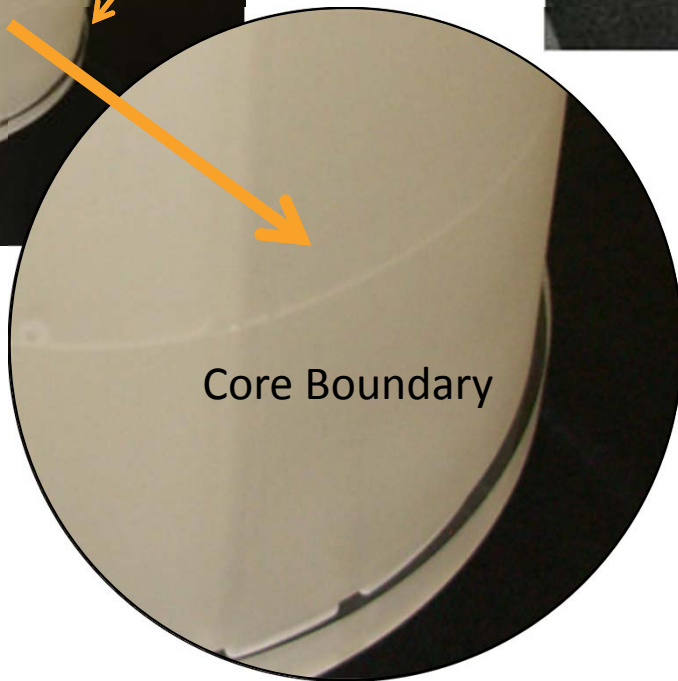
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Stacked Core Mirror Demonstration

0.4m Demonstration part fabricated



Mirror Blank
is 3 cores
high



Single Mirror Core
(Note large cell size)

- The individual core segment surfaces are polished and AWJ just like traditional LTF mirrors
- During Low Temperature Fusion (LTF), the faceplates **and** the core segments are fused together (Co-Fired)



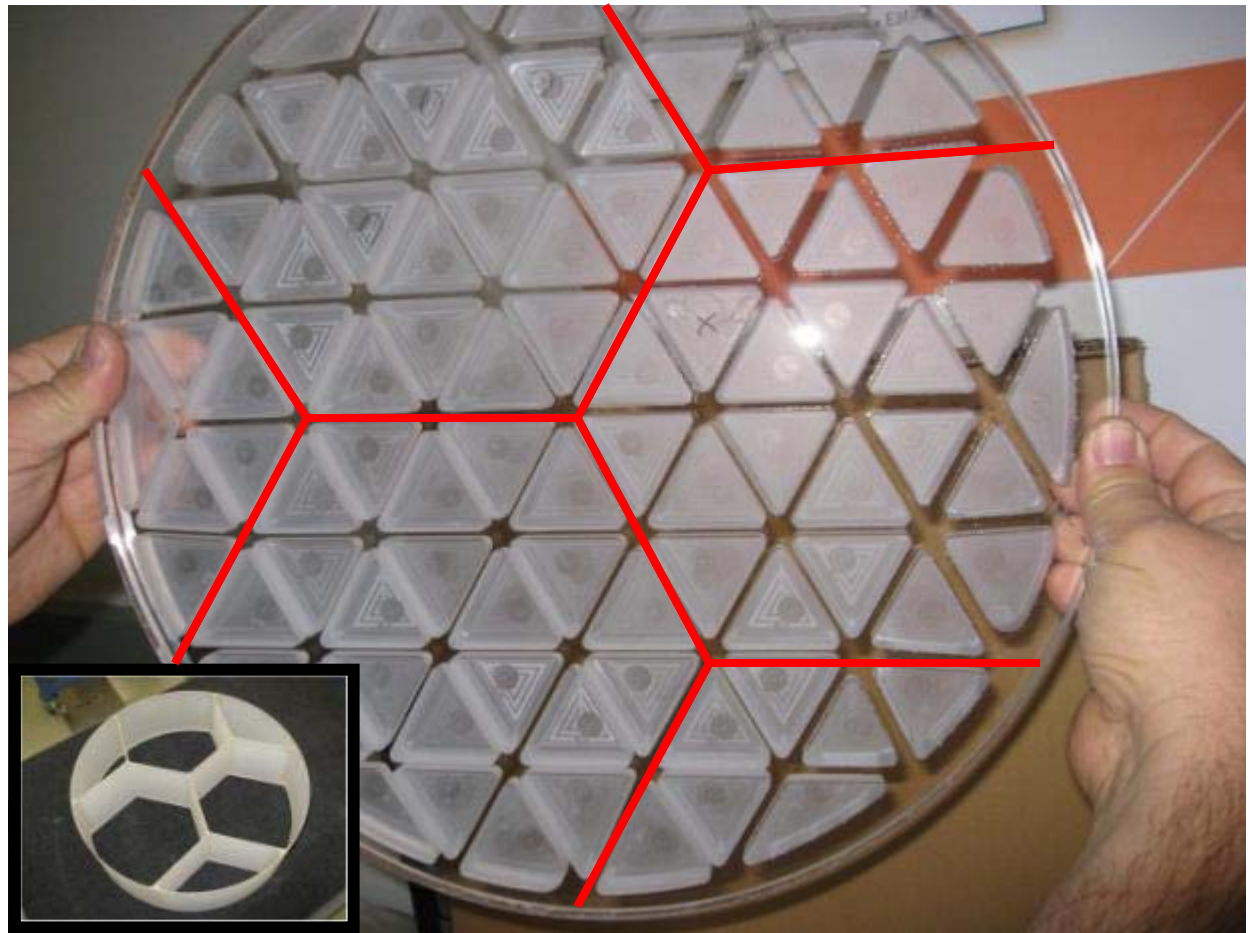
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Faceplate Pocket Milling

- Pocket milled facesheets have been used on other mirrors to provide additional stiffness between cell supports
- Allow for much larger core cell size to reduce overall areal density
- Extended to 24 pockets to enhance UV performance



Pocket Milled Facesheet



Pocket Milled Facesheet
Core cells locations shown in red
(Core shown for reference)



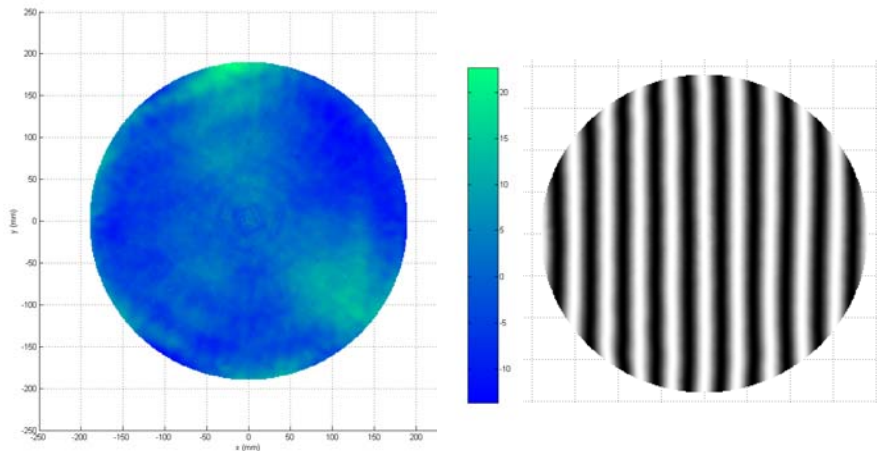
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Processing Quality

Processing completed to demonstrate that UV quality (5nm RMS) could be achieved

Multiple orientation test minimized test errors and analytical backouts

- > Some minimal trefoil did not cancel out during testing
- > Mount repeatability ultimately limited final performance



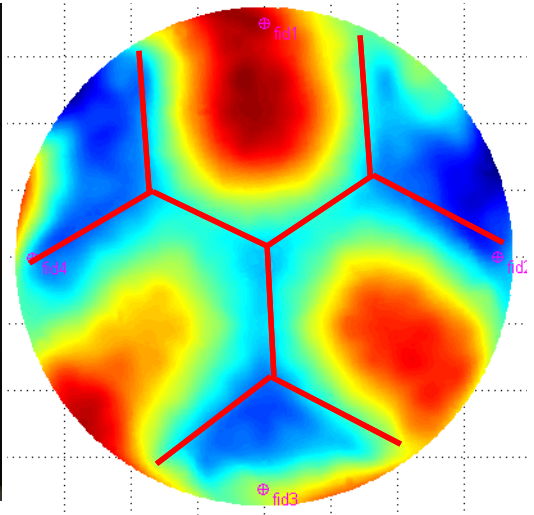
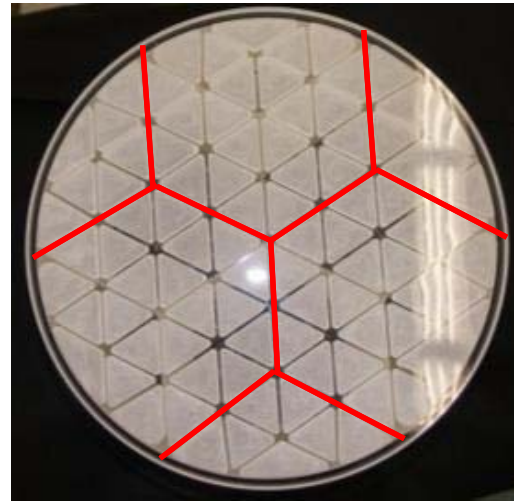
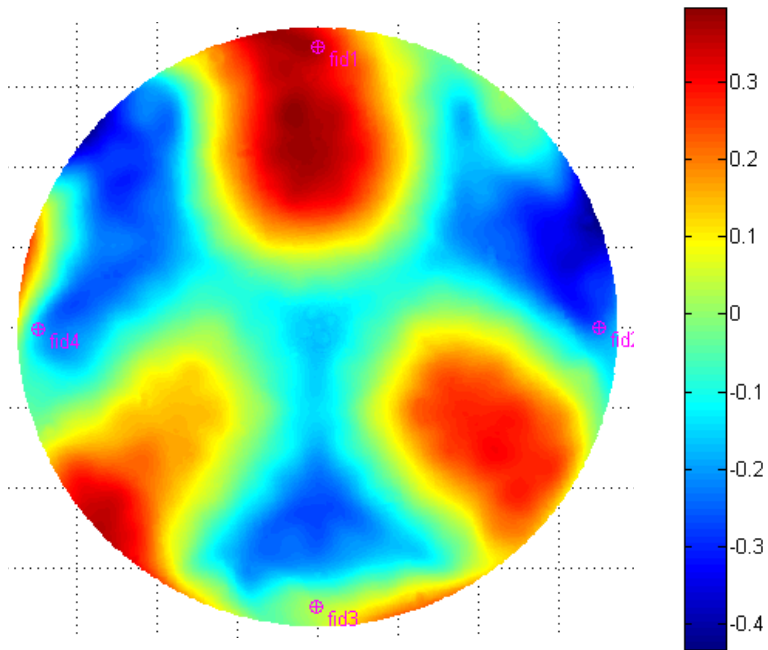
Final Optical Test – 5.5nm RMS



Demo Part in V-Block for Horizontal Testing

First Light Test

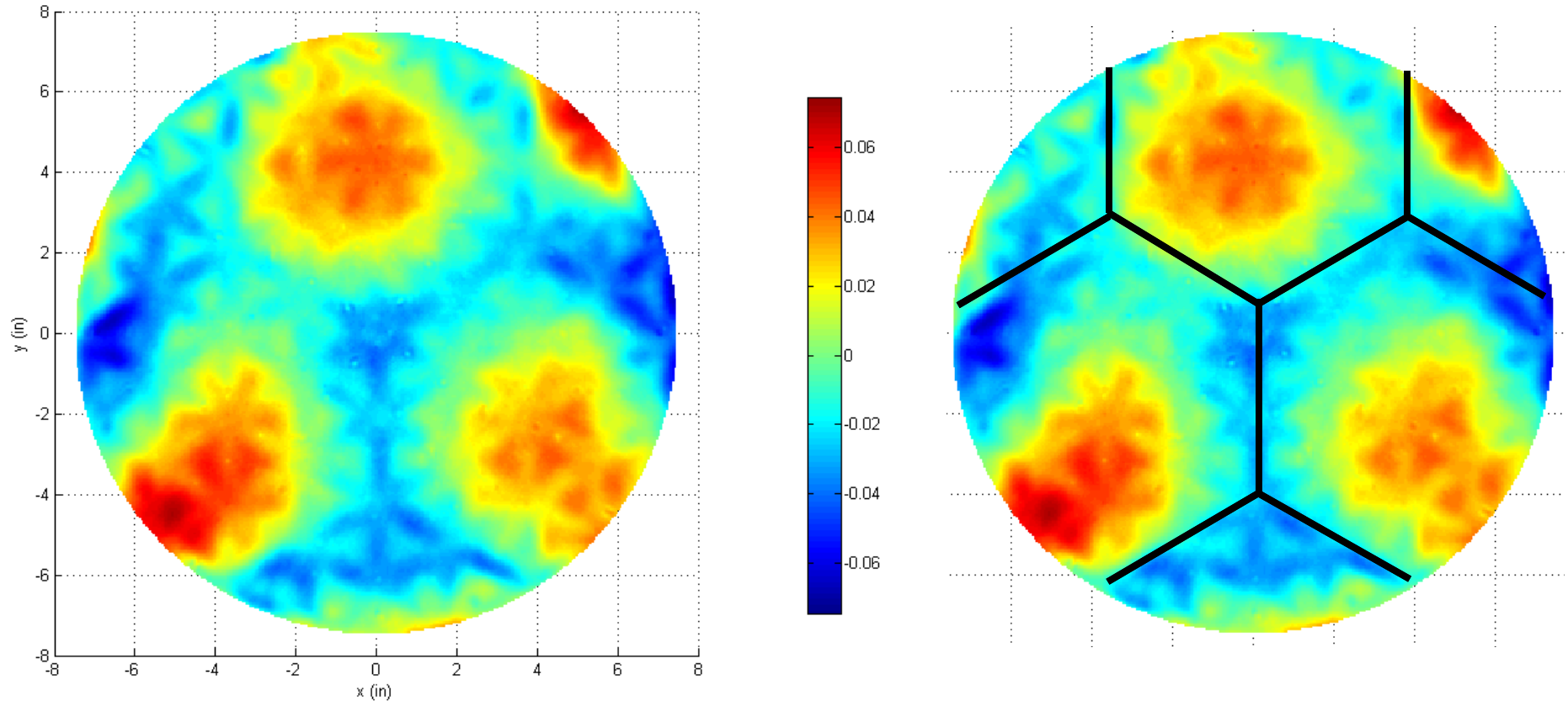
117nm RMS – 524nm P-V
Power Removed



Global polishing quilting over the large cells is observed after initial polishing

Post Ion Figuring #1

16nm RMS – 87nm P-V
Power Removed



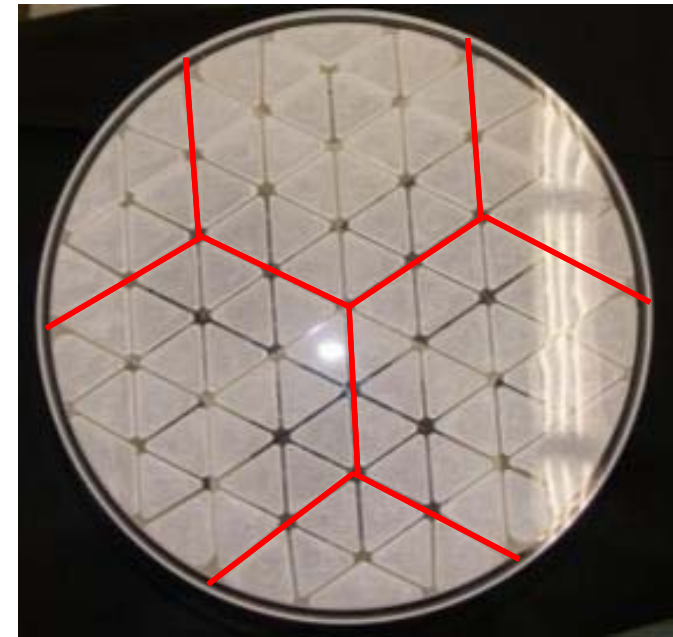
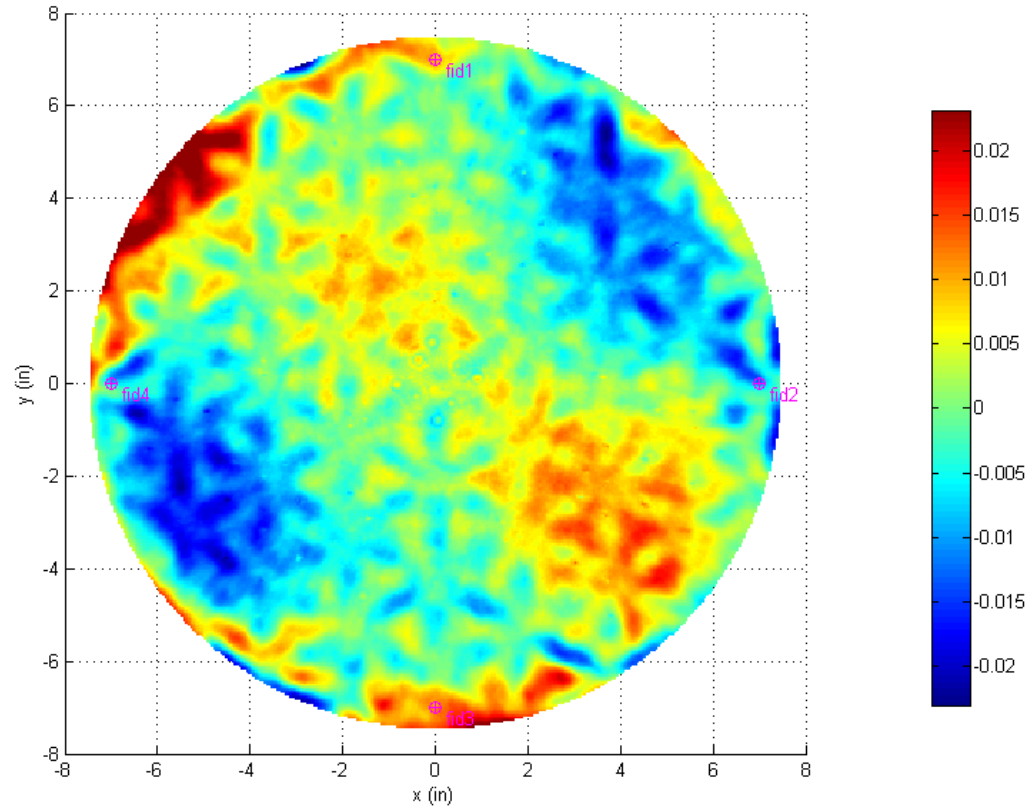
- First ion cycle greatly reduced the global figure error by 86%.
- Some cell quilting still visible



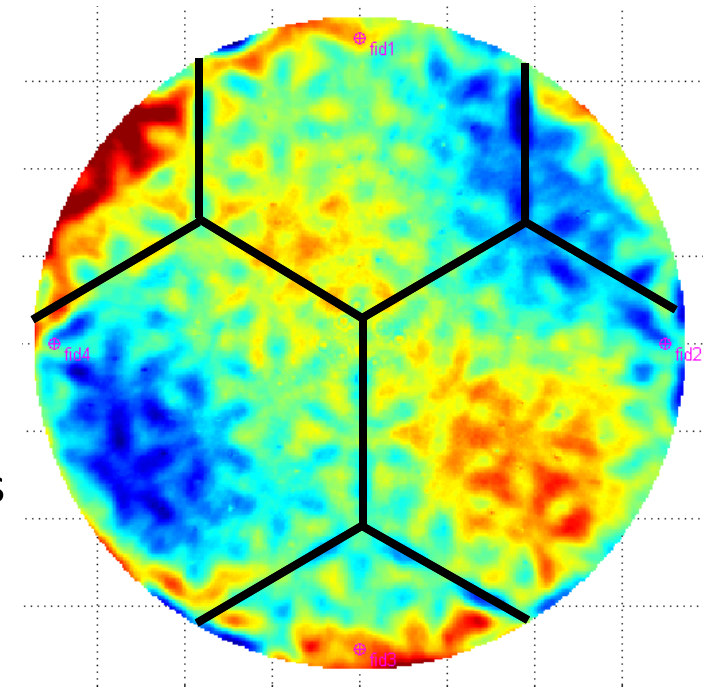
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Post Ion Figuring #2

4.9nm RMS – 37nm P-V
Power Removed



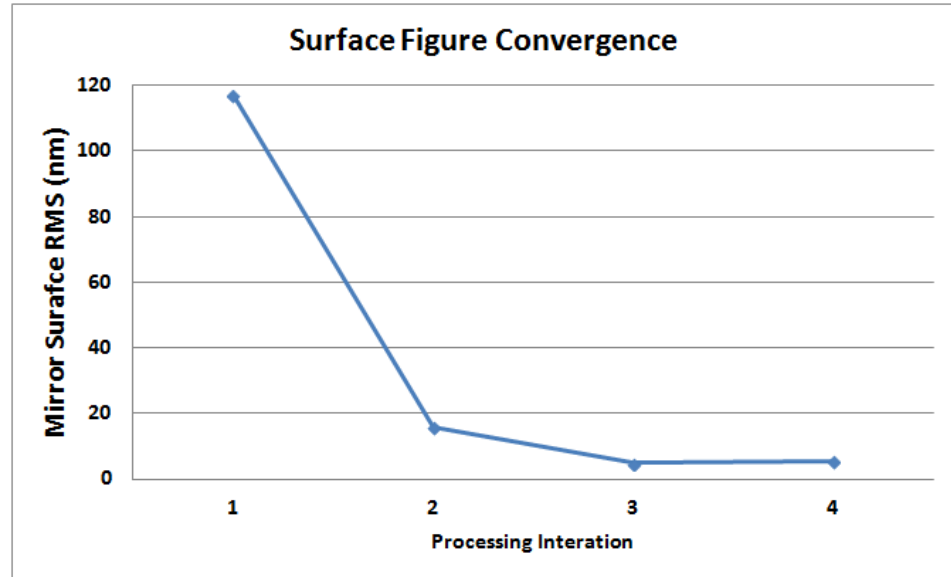
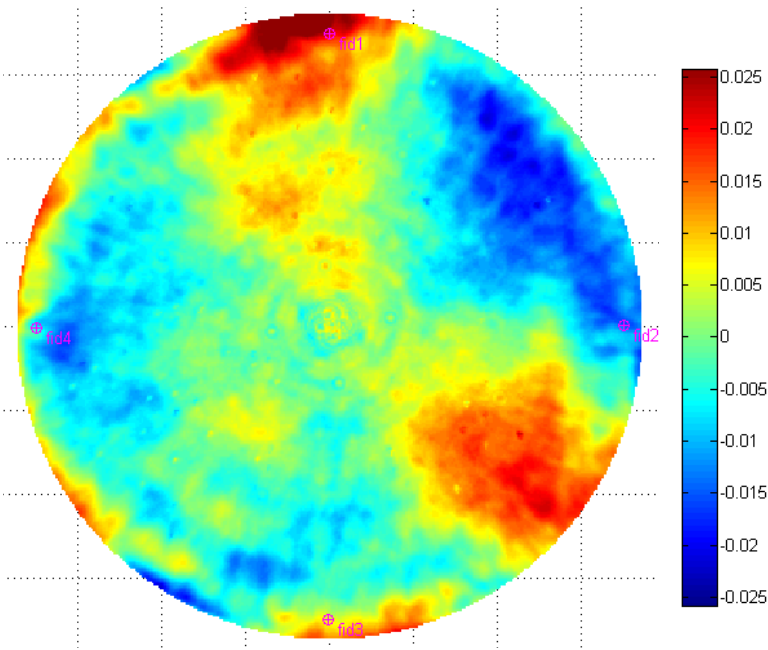
- Second ion cycle further reduced the errors by an additional 68%
- Pocket milled quilting becomes visible



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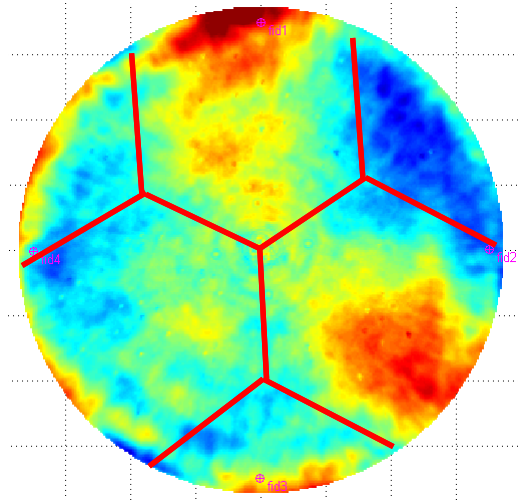
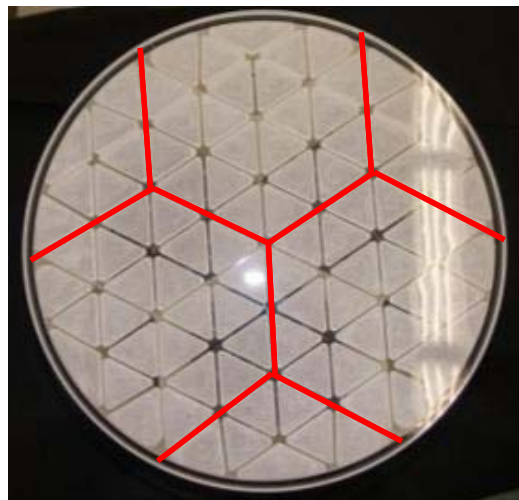
Post Ion Figuring #3

5.4nm RMS – 37nm P-V
Power Removed



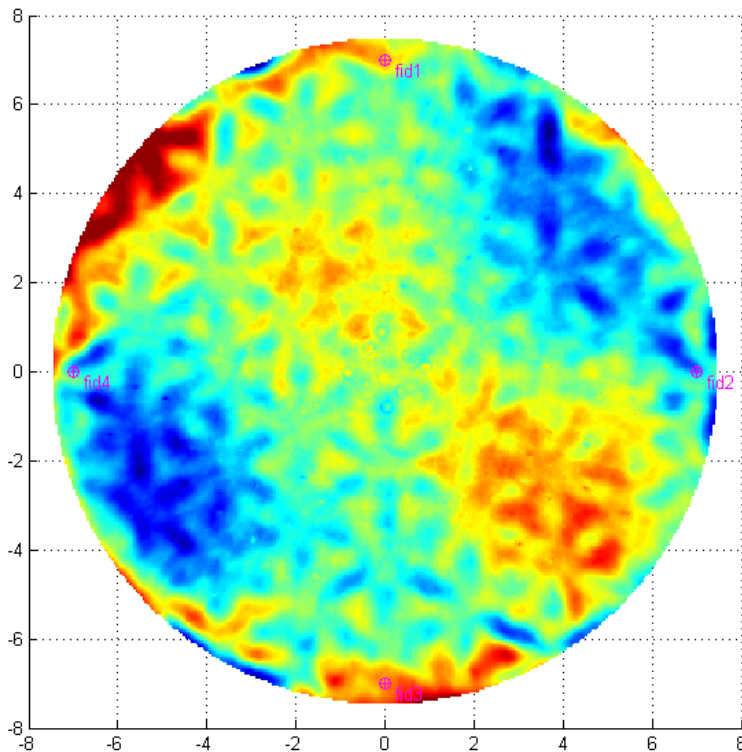
- Final ion figuring run reduces pocket quilting
- Mount repeatability limits overall surface quality

- Rapid convergence to final surface quality
- Deterministic processes reduce schedule time

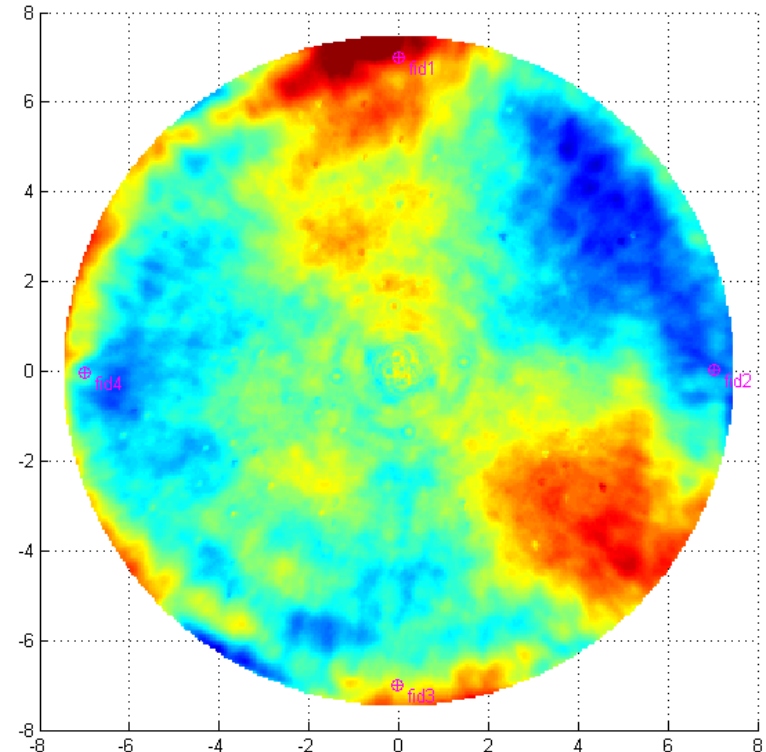


AMTD PSD Testing Summary

- > Data collected using Zygo Verifire and White Light Interferometer
- > Results show no significant PSD change due to ion figuring in spatial periods smaller than 20mm.



Polishing Quilting



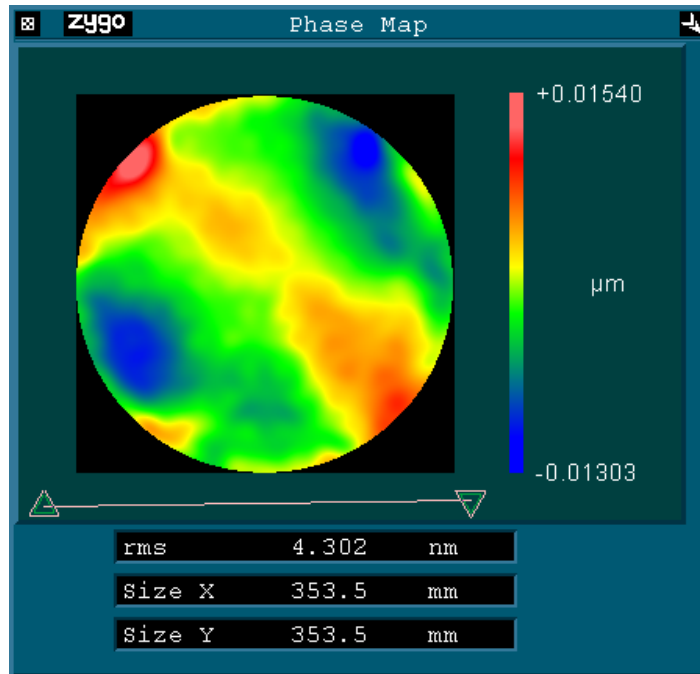
Finished



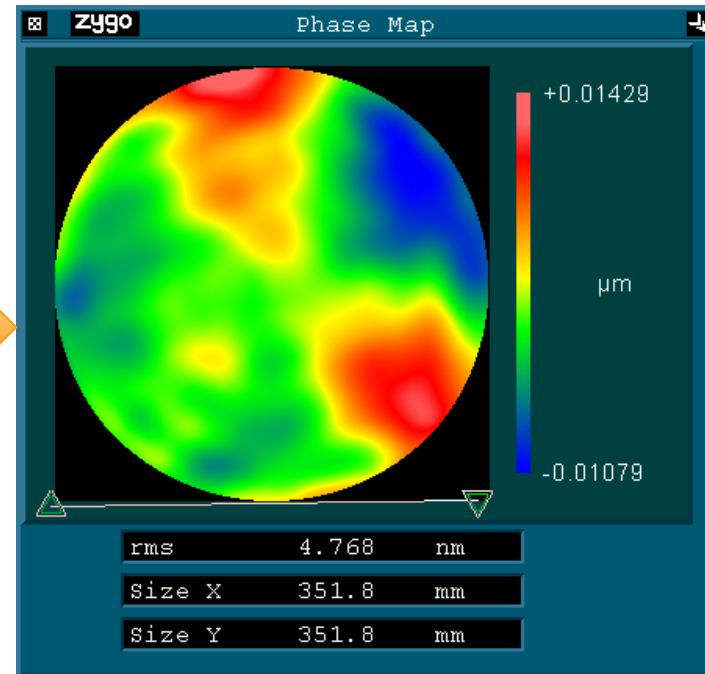
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50mm FFT Low Pass Filter

Before Ion Figuring



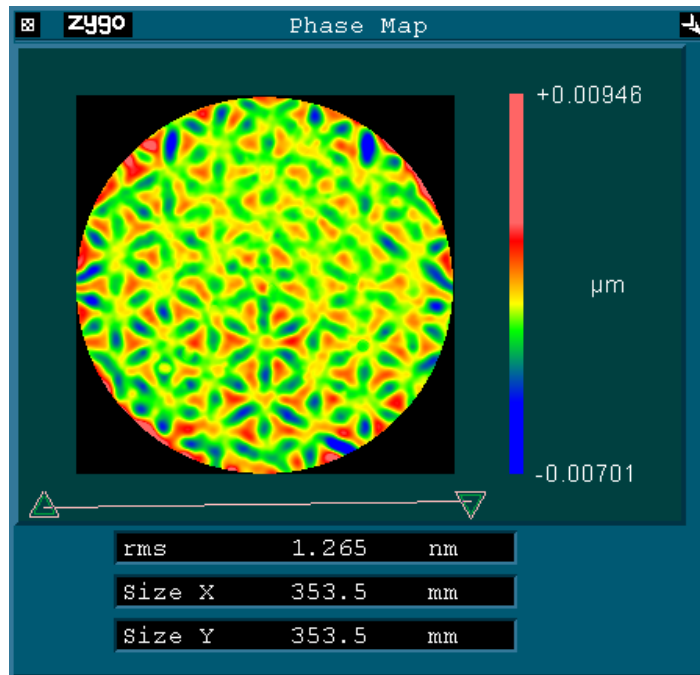
After Ion Figuring



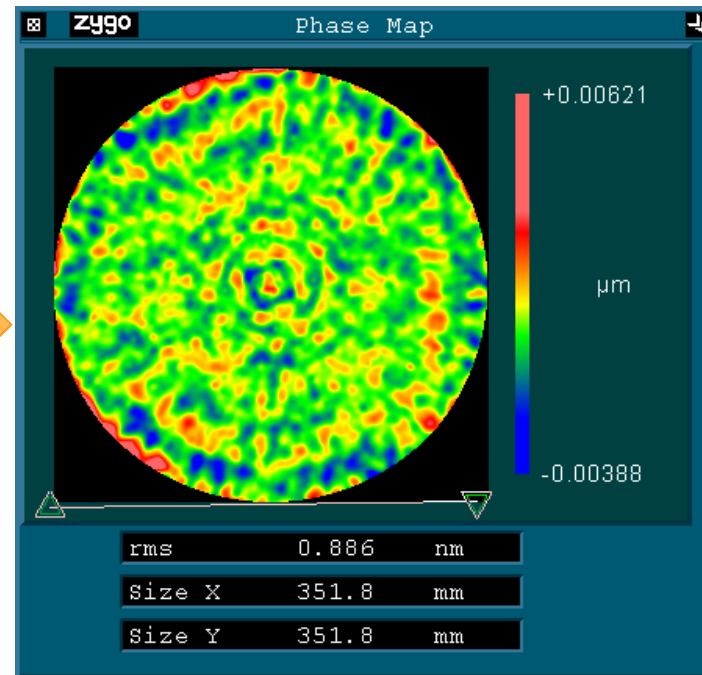
- > Low order figure error has reached the current metrology reproducibility limit in the current configuration leading to no improvement in figure errors with spatial periods longer than 50mm
- > Low order figure error present in the measurement after ion figuring is driven by mount reproducibility
- > Metrology reproducibility and accuracy could be improved with optimize mount design and additional part rotations

50mm-10mm FFT Band Pass Filter

Before Ion Figuring



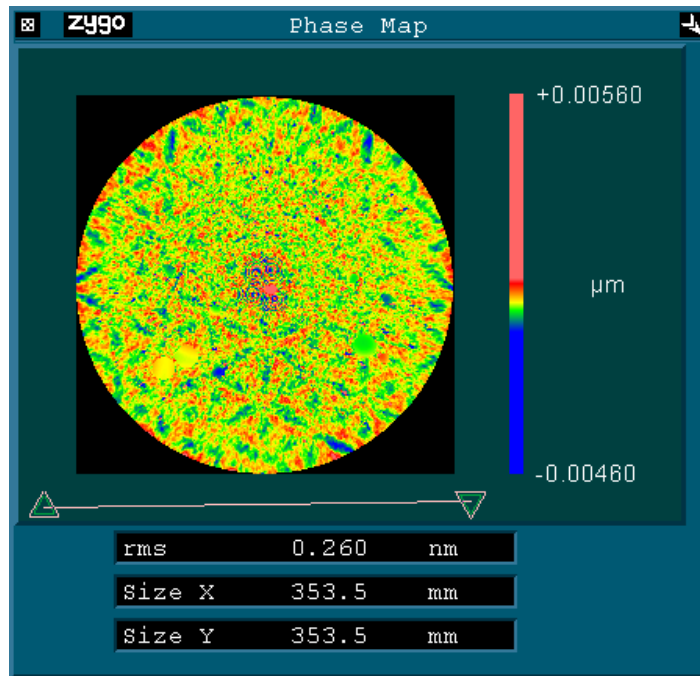
After Ion Figuring



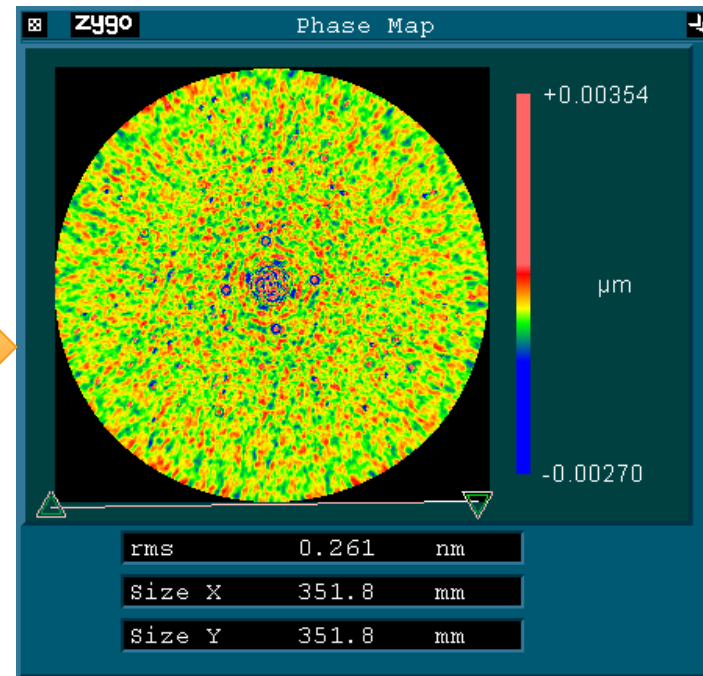
- > The quilting period appears at $\sim 30\text{mm}$ spatial periods before ion figuring
- > Ion figuring improved the rms in the 50-10mm spatial period band eliminating most of the quilting structure

10mm FFT High Pass Filter

Before Ion Figuring



After Ion Figuring

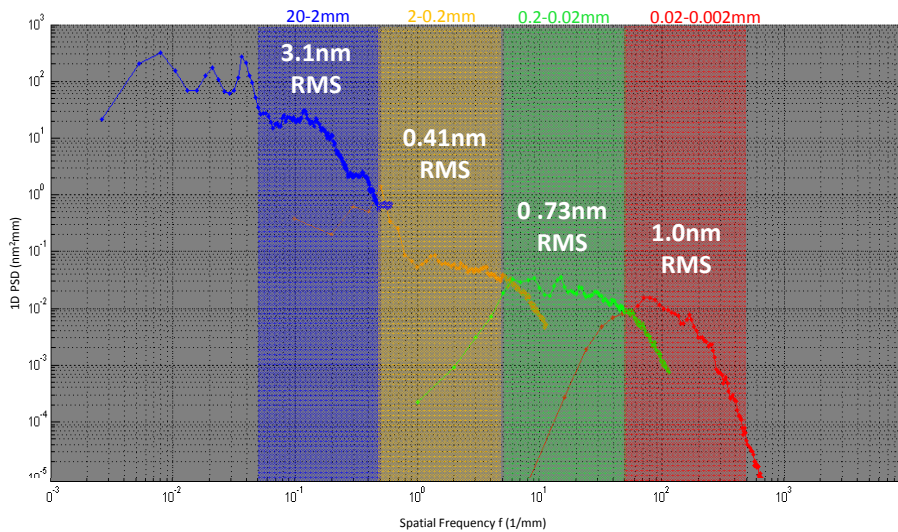


> The shorter spatial periods, <10mm, were negligibly affected by ion figuring

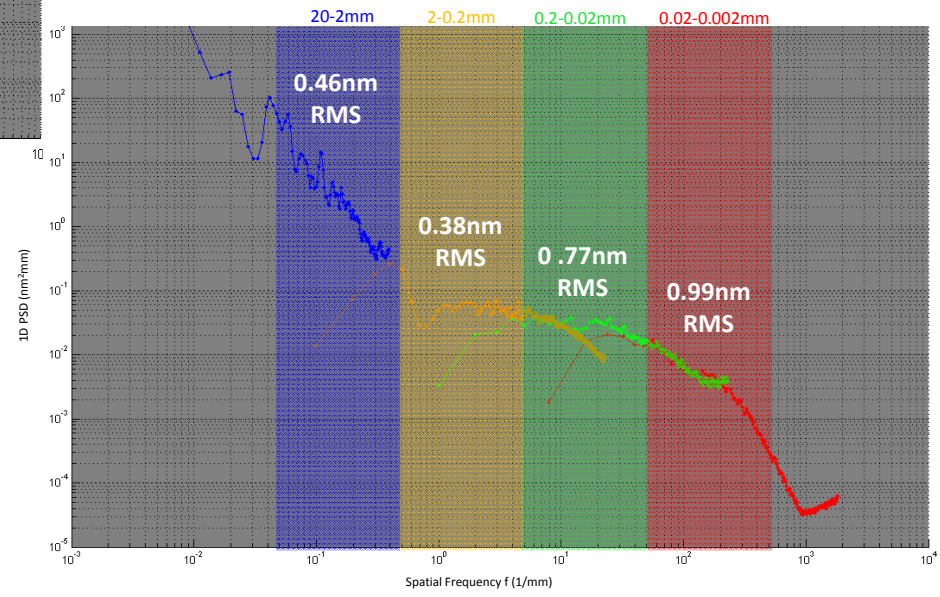
MSFC sphere tested on 12/3/12- PSD (Post Polish)

- Zygo Verifire
- Zygo NewView
- Zygo NewView
- Zygo NewView
- Full Aperature
- 1X Objective; 0.5X relay
- 5X Objective; 1X relay
- 20X Objective; 2X relay
- 10 mm aperture; 22um pixel
- 1 mm aperture; 2um pixel
- 0.13mm aperture; 0.23um pixel

Before Ion Figuring



After Ion Figuring



- > Bands were analyzed at >5X above Nyquist limit with ~5 cycles per test aperture
- > Hanning window used for PSD analysis with magnitude re-scale

> Spatial periods smaller than 20mm were negligibly affected by ion figuring as evident in the PSD plot



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AMTD Testing Summary

- Processing of the stacked core mirror converged very quickly using ion figuring
- Results show no significant PSD change due to ion figuring in spatial periods smaller than 20mm.
- Global surface figure limited by mount repeatability

- All work performed under NASA contract XXXXXXXX
 - COTR: Michael R. Effinger
- Related Papers at this conference
 - Cryogenic optical performance of a lightweighted mirror assembly for future space astronomical telescopes: optical test results and thermal optical model (8837-11)
 - The development of stacked core technology for the fabrication of deep lightweight UV-quality space mirrors (8838-23)

