



AMTD thermal characterization and model correlation

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Mirror tech days

10-1-2013







Objectives:

- Demonstrate feasibility of stack core mirror technology for 4-m class mirror
- Validate thermal deformation models.

Operational temp: 275K (2°C). Test temp: 293 to 253K (RT to -20°C).

Status:

- Fabricated at ITT Exelis.
- Delivered to MSFC in Dec 2012.
- Cryo tested at MSFC in Jan-Feb 2012.







43	cm	diameter
1.6	cm	face sheet
33.4	cm	3 core layers
1.7	cm	back sheet
36.7	′ cm	total edge thickness

Mass: 6.7 kg

- 7% of equivalent solid ULE
- 93% lightweighting

2.5 m radius of curvature



1x3 m optical test chamber





Vacuum Chamber: 1x3 m cylinder with helium shroud. Optical View Ports: BK7 window; 150 mm dia. clear aperture. Precision stage to provide interferometer pointing and alignment. Operational Pressure: < 5 E-6 Torr Temperature Range: 300 to 12K Typical cryo optical test: 290, 200, 100, 70, 50, 30K, 2 cycles; 3 weeks duration.









Side view of cryogenic chamber







Front view of cryogenic chamber



















Temperature sensor locations







LK6_1





Sensors	Locations			
LK6_1	Front Face 5:00			
LK6_2	North Side West End			
LK6_3	North Side Center			
LK6_4	North Side East End			
LK6_5	Back Face 11:00			
LK6_8	Back Face 9:00			
LK7_1	Back Face Center 9:00			
LK7_2	Back Face Center			
LK7_3	Back Face 7:00			
LK7_4	Back Face 5:00			
LK7_5	Back Face 3:00			
LK7_6	Back Face 1:00			
LK7_7	Cold Plate			
LK7_8	Test Stand NW Leg			

Silicon diodes: Lake Shore DT-670 ~1°accuracy

12 diodes on mirror12 diodes on test stand & chamber

Controller: Lake Shore LK218 0.25°accuracy



Thermal IR image





- FLIR SC655 640x480 16-bit uncooled microbolometer
- 7.5–14 µm spectral range.
- A 130mm clear aperture ZnSe window.
- IR image recorded on 1st cryo cycle @ ~285K during warmup







PhaseCam 5010 interferometer

- 1954 x 1967 pixels
- Effective array: 977 x 983 pixels
- diverger: f/6; R/6.25 mirror
- PV uncalibrated accuracy: 15 nm
- RMS uncalibrated accuracy: 3 nm
- PV repeatability: 0.24 nm
- RMS repeatability: 0.05 nm
- PV precision: 2.64 nm
- RMS precision: 0.51 nm





- Evacuate chamber with roughing pump to 5x10⁻² Torr.
- Turbomolecular pump to 10⁻⁵ Torr.
- Helium refrigerator to drive the cryo shroud to ~200K.
- Mirror temperature stabilize overnight for minimum gradient.
- Optical measurements at 255K, 265K, 275K, 285K and ambient.
- 3 cryo cycles.







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Cycle 3, 293K, 8.8 nm rms



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253K 8.5 nm rms

253-293K 4.0 nm rms







273K 8.0 nm rms

273-293K 3.7 nm rms







286K 7.9 nm rms

286-293K 3.6 nm rms







287K 10.6 nm rms

287-293K 7.2 nm rms







288K 11.5 nm rms

288-293K 7.9 nm rms







289.5K 7.9 nm rms

289.5-293K 4.0 nm rms







292K 7.8 nm rms

292-293K 4.0 nm rms













AMTD Cycle 3







Arnold Lightweight Mirror Modeler (ALWMM)

- Expedites modeling for complex lightweighted mirror design
- Model any type of mirror of any configuration
- Store load cases directly and calculate bending modes
- Common mirror substrates includes: ULE, Zerodur, SiC
- Hexapod and bond pads design
- Perform parametric trade studies
- Determine thermal diode locations
- ANSYS thermal model
- Validate cryo test results
- Predict gravity sag



Thermal diode locations





Diodes on side











- During cycle 3, heat was introduced after 286K measurements to induce thermal gradient, resulting in higher residual rms values for 287K and 288K.
- Thermal-elastic expansion generates unwanted surface deformation.
- Non-linear FEA analysis to compute thermal-elastic response as the system changes temperature.
- Minimal surface deformation seen during steady state thermal transition.





- Qualify a 1/3 scale of 4-m class, 1.2-m, 400 mm thick, lightweight Zerodur mirror from ambient to 250K.
- Qualify a 1.5-m AMSD ULE mirror.
- Perform modal test with cryo shaker and interferometer to relevant vibro-acoustic level.
- Improve IR thermal capability to record face sheet temperature.
- Enhance ALWMM capabilities.



X-ray cryogenic facility (XRCF)





History

Testing grazing-incidence x-ray telescopes (Chandra, Solar X-ray Imager, Solar B) since 1992.

Cryogenic optical interferometric testing of normal incidence, visible & IR telescope optics & components since 1999.

Capabilities

Thermal vacuum test chamber:

7.3 x 22.9 m (O.D. x L) horizontal cylinder

6 x 18.3 m (I.D. x L) test volume

527 m: x-ray guide tube

5 x 9.4 m (I.D x L) Helium shroud

Cryo shroud enclosure: 20K to 320K

Refrigeration system: 2 gaseous helium refrigerators; each capable of ~1 kW at 20K.

Vacuum systems: 10⁻⁸ Torr

Clean Rooms:

6000 sq. ft. Class 2,000

2000 sq. ft. Class 10,000

Onsite machine shop









XRCF clean room













JWST composite hardware cryo tests





Backplane stability test article (BSTA)

Integrated science instrument module (ISIM)





JWST mirror backplane center section at ATK













Unloading off C-5







Backplane center section/support frame installation















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