Cryogenic Active Mirror Technologies

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Cryo Active Mirrors (CAMs)

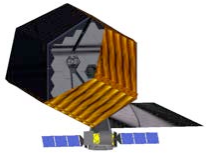
- **CAMs are large Silicon Carbide mirrors with embedded PZT actuators, for IR and Far IR space telescopes**
  - Technology proven for warm optics by successful development of Actuated Hybrid Mirrors for visible telescopes
  - Extension to cryo conditions is being pursued by JPL and AOA Xinetics under JPL R&D funding
- **CAMs use actuators to correct cool-down figure changes and other large optical aberrations**
  - To avoid expensive cryo-null figuring
  - To reduce mission risk from unexpected optical errors
- **CAMs can be tested in 1G, at room temperature *and* CAMs can be operated in 0G, at 4K**
  - To save on system testing

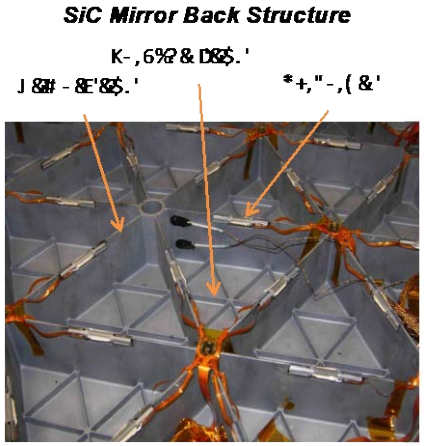
- ***CAM technology could provide low-cost primary mirrors or primary mirror segments for IR missions, such as FIRS***

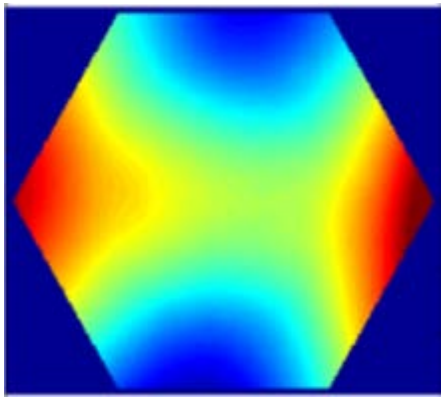
CAM Heritage: Actuated Hybrid Mirrors

Actuated Hybrid Mirrors (AHMs) demonstrate active mirror architecture

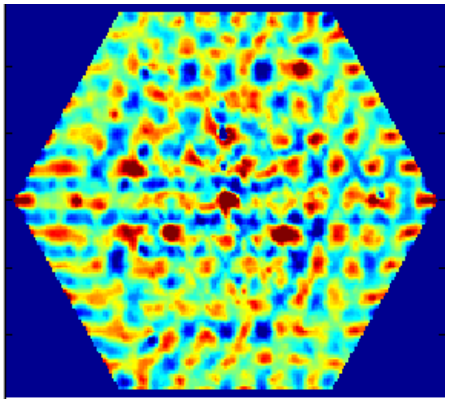
- Active mirror segments
  - 37 to 414 actuators
- 0.5 to 1.35 m size demonstrated
- <14 nm rms SFE demonstrated
- 10-15 kg/m^2 substrate
- <25 kg/m^2 total
- Tested in 1G to 0G specs



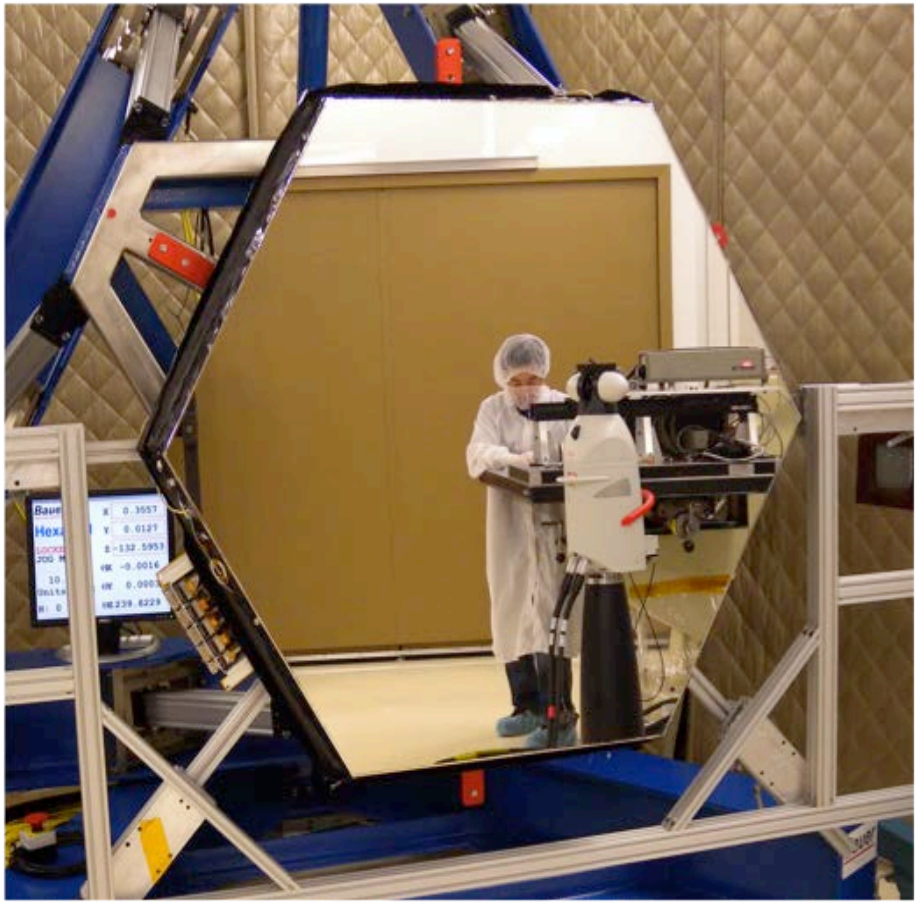




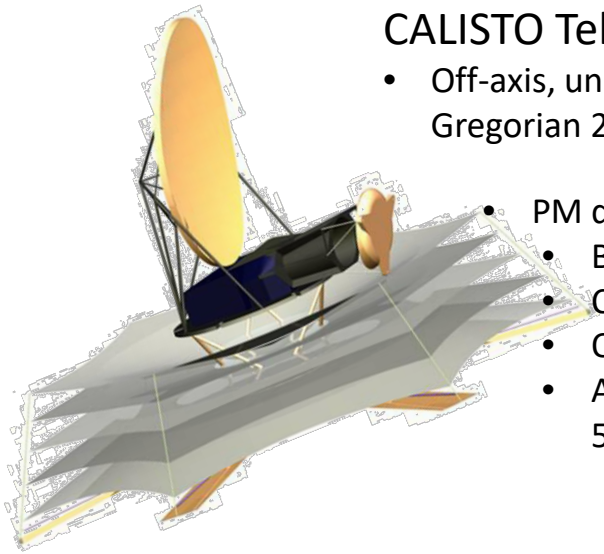
EM-4a Uncorrected
SFE = 1.88 µm RMS



EM-4a Corrected
SFE = 0.014 µm RMS

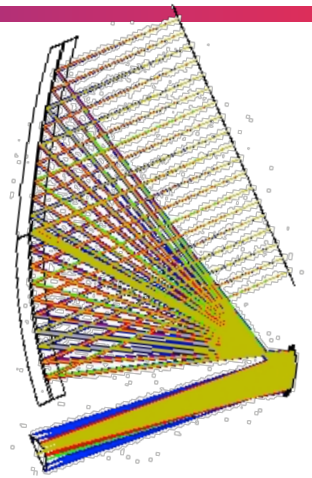


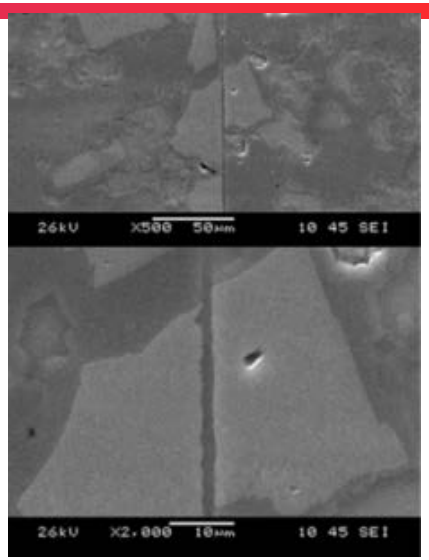
CAM Design Study: CALISTO Primary



CALISTO Telescope PM

- Off-axis, unobscured, Gregorian 2-mirror system
- PM design:
  - Base radius = 8 m
  - Conic = –0.98654
  - Off-axis = 3.8 m
  - Aperture = 3.7 by 5.7 m





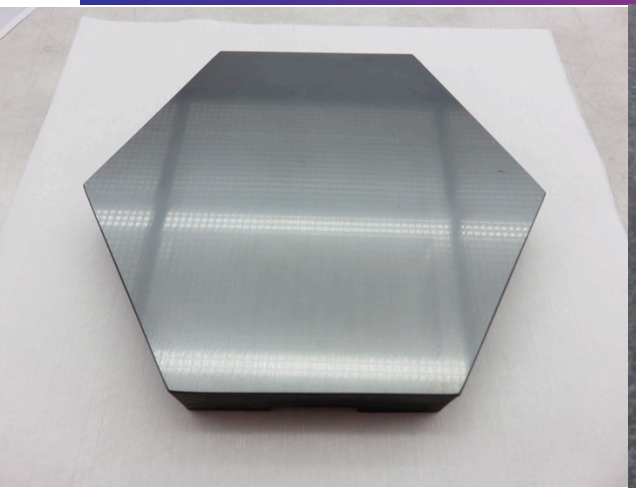
Braze example. Mirror to be made in 1.2 m segments that are joined in a brazing process.

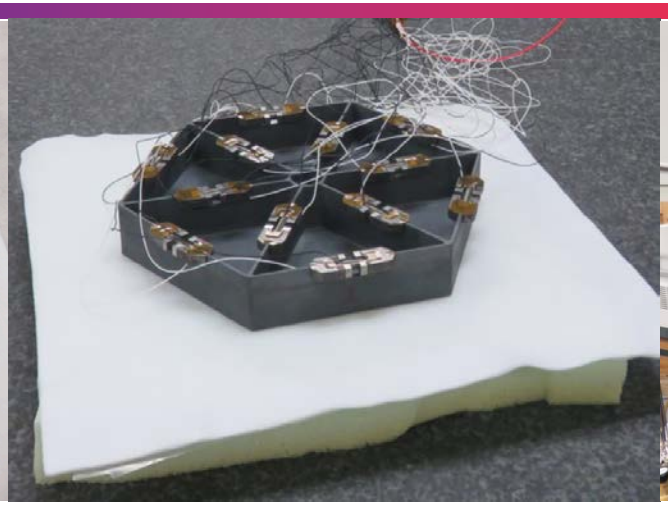
- **Large Cryo Active Primary Mirror design study**
  - Made in segments that are joined together by brazing
  - Mirror facesheet is supported by ribs for stiffness and light weight
  - Actuators will be embedded in ribs and oriented parallel to the facesheet
  - Actuator tabs provide an athermalizing interface, to preserve full actuation range at 290K and at 4K
  - SiC can be clad with amorphous Si for ease of polishing (and higher quality final surface)

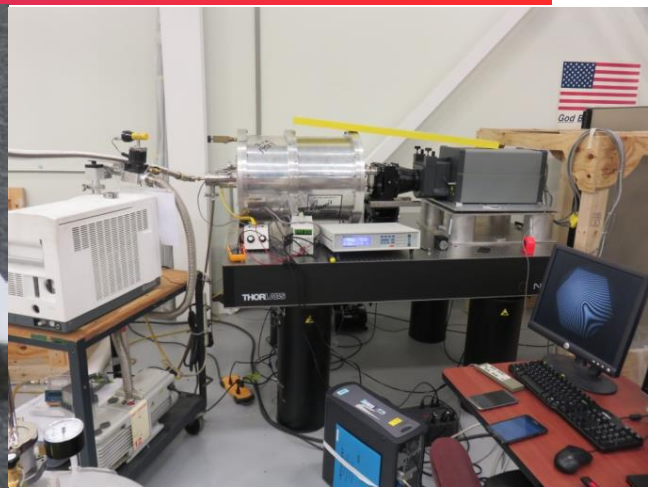
Design	Light	Medium	Heavy
Core Height	4.0 in	8.0 in	12.0 in
First mode	19 Hz	41 Hz	61 Hz
Weight	1163 Lb	1826 Lb	2489 Lb
Figure (1G)	136 nm	42 nm	24 nm
Figure (4K)	80 nm	50 nm	56 nm

Key mirror performance results.

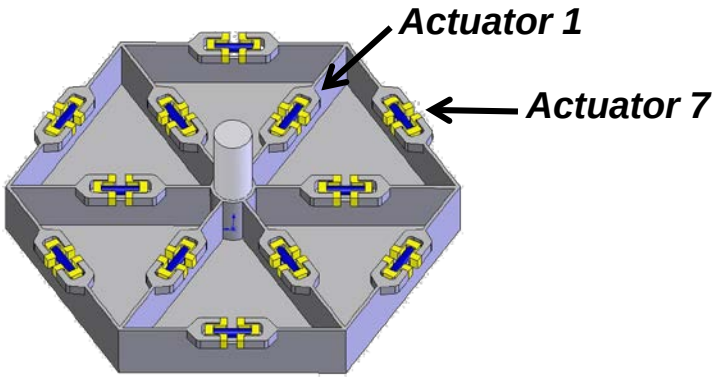
Demonstrator CAM Fabrication and Test



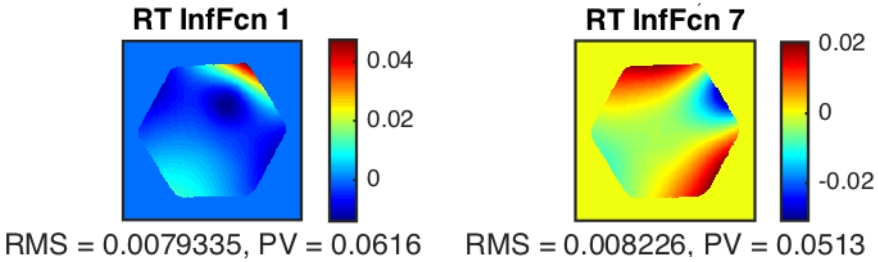




- **CAM Demonstrator mirror**
  - 150 mm size, with 12 actuators
- **Substrate polished for testing**

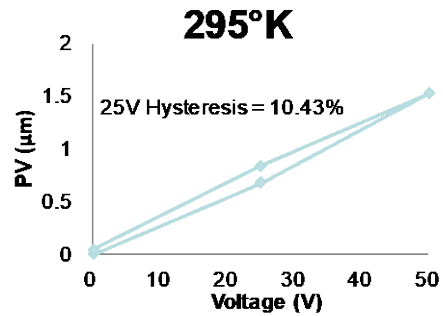


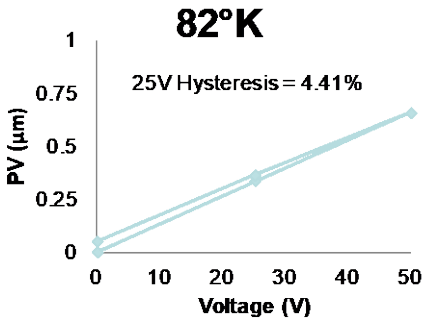
- **Preliminary testing completed, with 331 measurements**
  - Room temperature (295K) and cryo temperatures (82K and 26K)
  - All actuators characterized

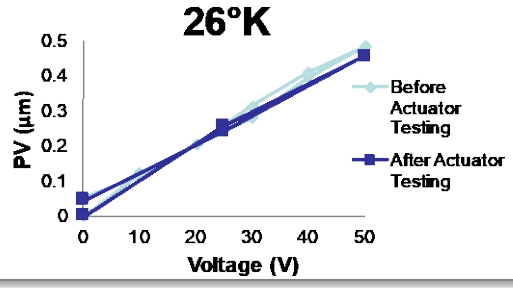


CAM Athermalization and Stroke

- **CAM demonstrator mirror preliminary testing verified cryo actuation and passive athermalization of the actuator interface**

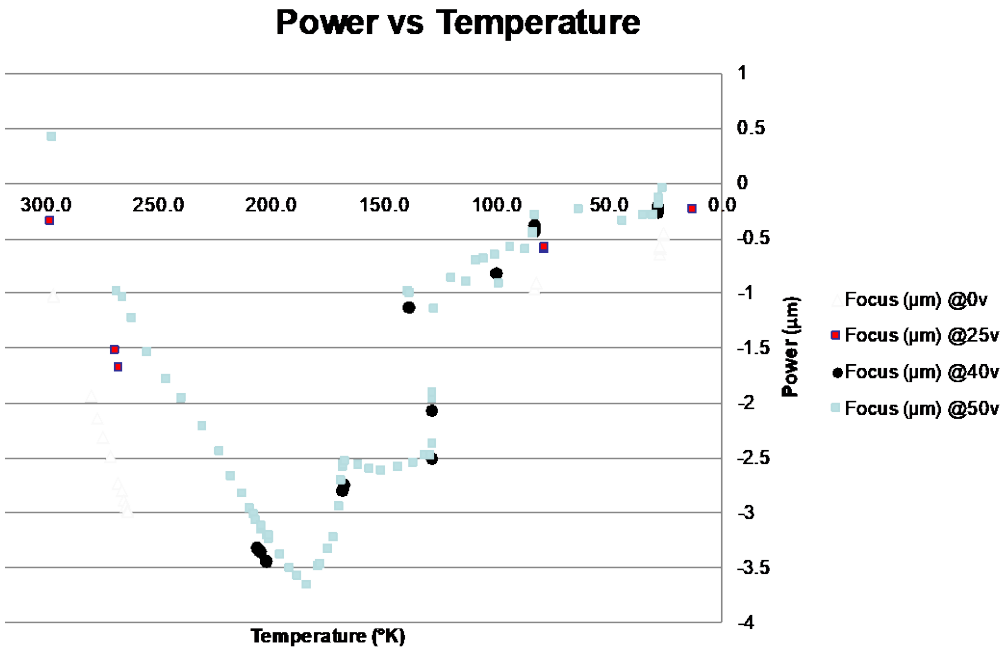






Actuator hysteresis was shown to be small in the 0-50 V range.

Stroke decreased 4x from 295K to 26K. This can be compensated by increasing the voltage applied, without violating strain limits.



Difference in focus between 300K and 26K was <0.1 um, with all actuators at 25V (the designed bias condition). This compares to 8 um expected without athermalization.

CAM design preserves full controllability across 300K – 26K temperature range.

CAM Technology Checklist

CAM Technology	Status for 1.2 m PM segments	Status for 4x6 m monolithic PM	Plan forward
SiC substrate	Mature	Brazing of active large mirror not demonstrated	Propose large demonstrator mirror to next SAT
Testable in 1G to VIS specs	Mature for 300K, not demonstrated at cryo	Not demonstrated at large size or at cryo	
Si cladding (for UV to IR)	Demonstrated by ZeCoat SBIR	Not demonstrated at large size	
Athermal SiC-to-actuator interface	Demonstrated		
Cryo actuation to IR specs	Demonstration in progress		Continue R&D-level activities
Zero-volt hold actuation	Developmental		