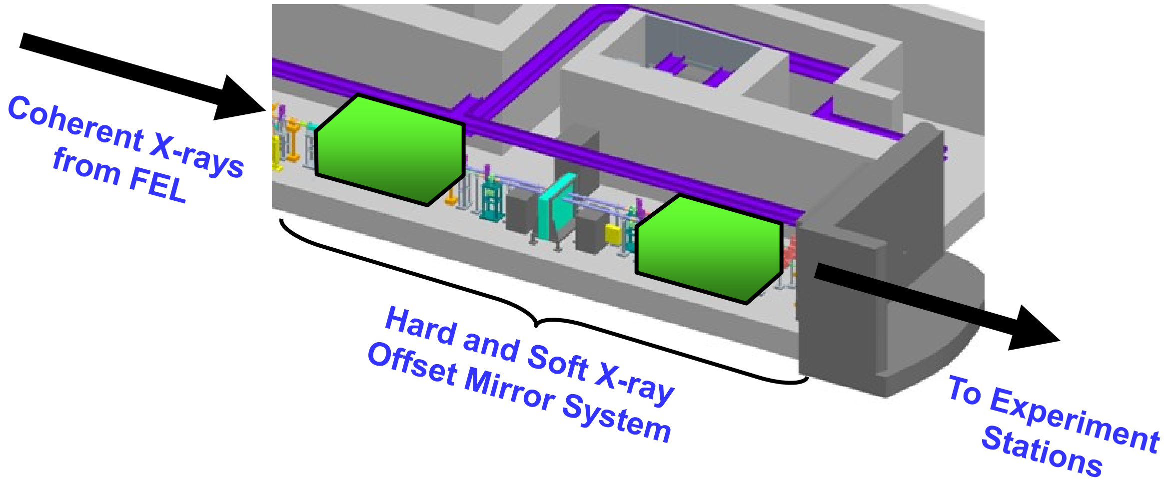
Opto-mechanical design considerations for the LCLS X-ray mirror system

T. J. McCarville[a], P. M. Stefan[b], B. Woods[a], R. M. Bionta[a], R. Soufli[a], M. J. Pivovaroff[a]
[a]Lawrence Livermore National Laboratory
[b]Stanford Linear Accelerator Center



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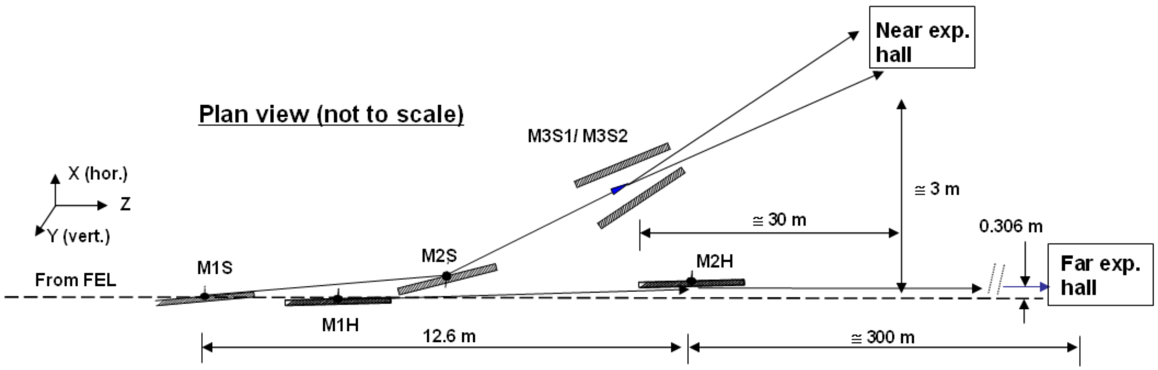
Tom McCarville
mccarville1@llnl.gov

The mirror system transports coherent X-Rays to experiment stations

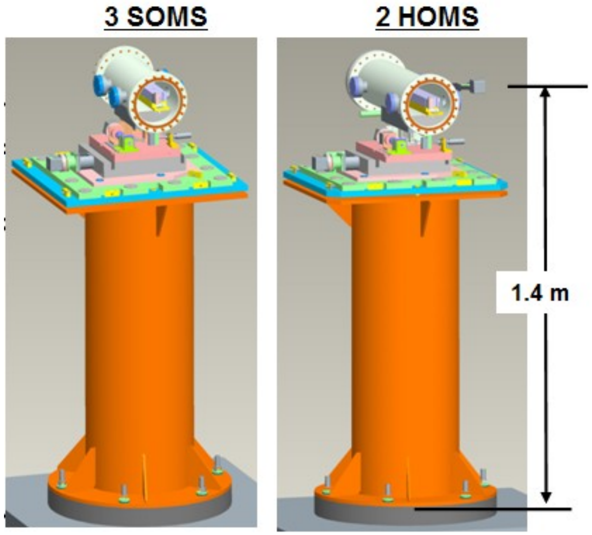
- **Soft Offset X-ray Mirrors (SOMS) deliver 0.827 – 2.0 keV X-Rays to the Near Experiment Hall**

- **Hard Offset X-ray Mirrors (HOMS) deliver 2.0-8.27 keV X-Rays to the Far Experiment Hall**



- **HOMS & SOMS designs are similar, but HOMS has tighter figure and pointing requirements:**

  < 9 nm (sphere) & 2 nm (aspheric) figure error (P-V)
  < 50 nano-radian pointing resolution & stability



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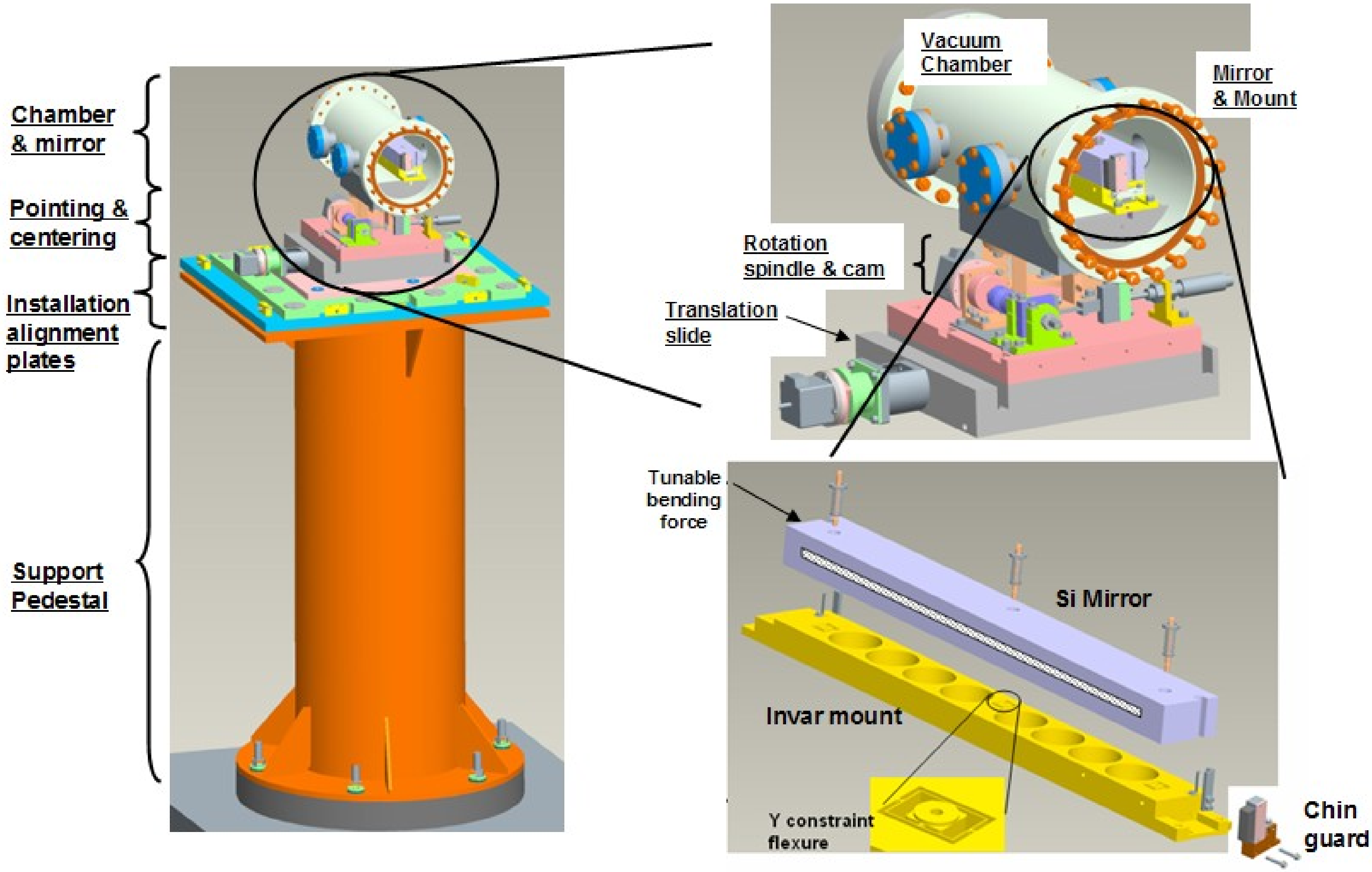
mccarville1@llnl.gov

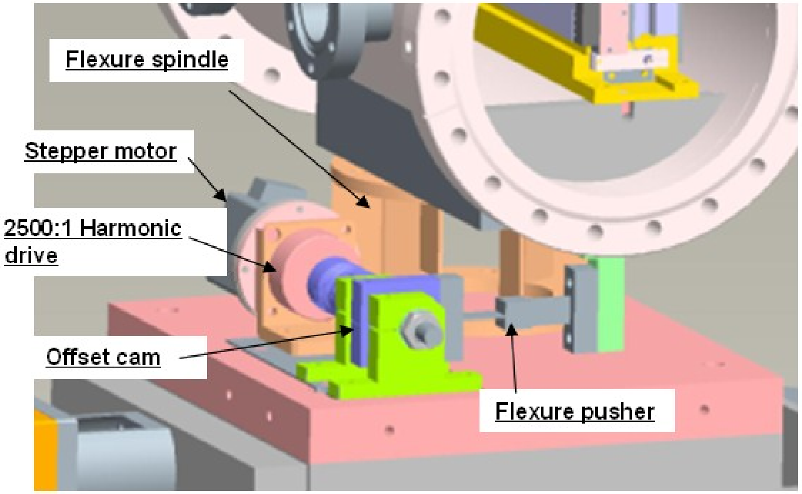
HOMS and SOMS assemblies have many functions and features in common

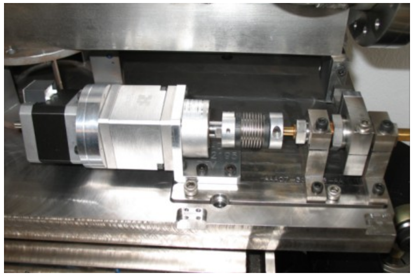


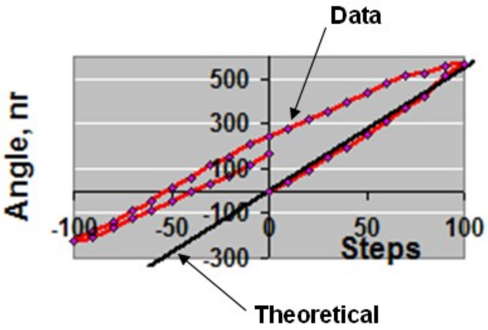
Tom McCarville
mccarville1@llnl.gov

The HOMS mirror pointing range is +/- 1 milli-radian, with 50 nano-radian resolution

- Accomplished by rotating the chamber with a gear reduced offset cam







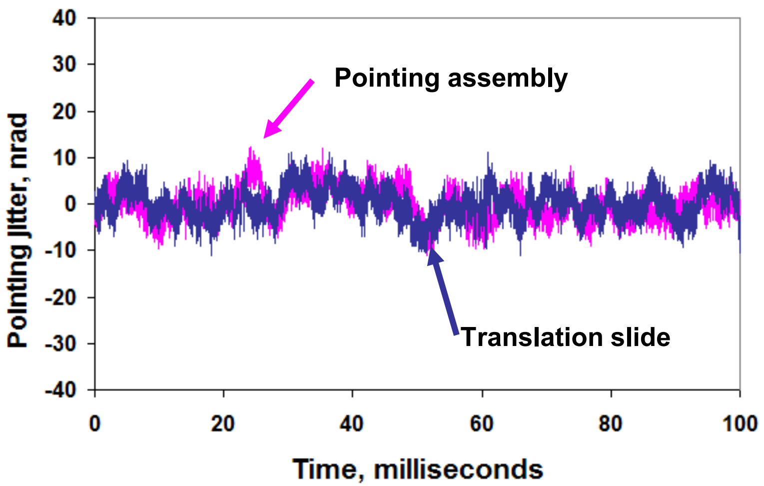
- Threats to pointing stability during an experiment include:

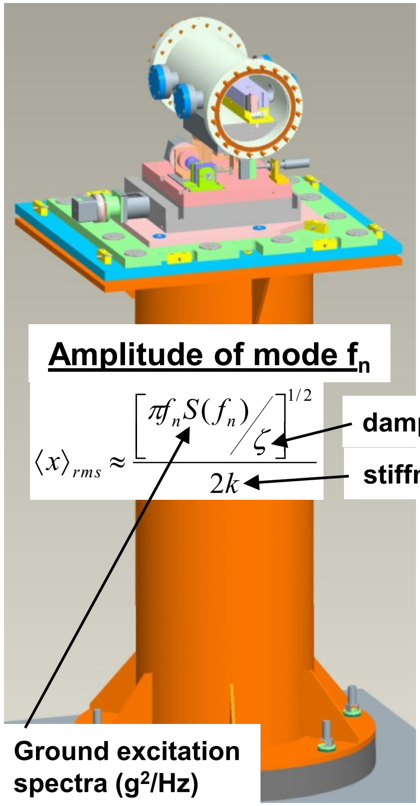
  - pointing jitter (> 1 Hz) from amplified ground vibration
  - temperature dependent pointing drifts (<1 Hz)

Tom McCarville
mccarville1@llnl.gov

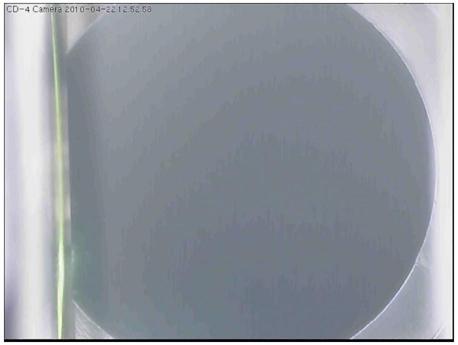
Pointing jitter from ground vibration was limited by stiffening the structures and mechanisms

• Pointing jitter in the rotation & translation mechanisms measured with a capacitance sensor pair





• Hard x-ray beam pointing sweep at experiment station



Tom McCarville
mccarville1@llnl.gov

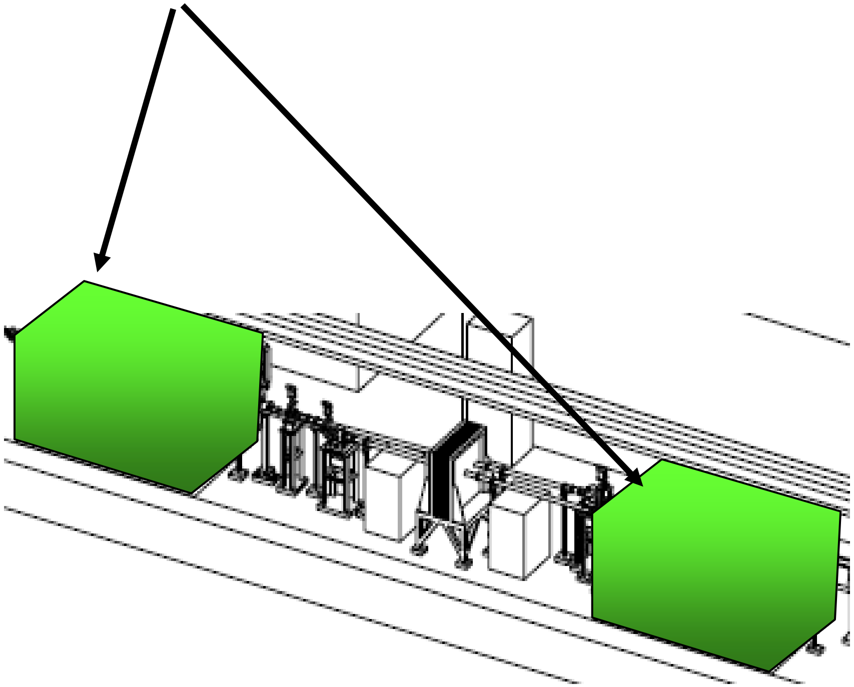
Thermally induced pointing drifts are controlled with local temperature control

- Pointing & centering drift of mechanisms was measured: $d\theta/dT \cong 3\ \mu rad/^{o}C$

  $\therefore$ dT < 0.01ºC required to limit pointing drift < 30 nano-radians

- Local insulating enclosures are constructed around the mirror assemblies

- Closed loop thermal control maintains internal temperatures stable within < 0.01C



Tom McCarville
mccarville1@llnl.gov

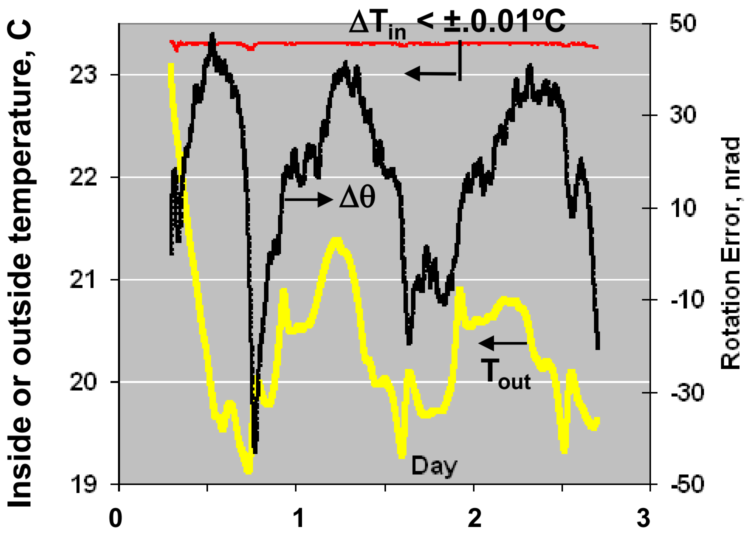
1” vacuum insulation panels are equivalent to 6” thick fiber insulation

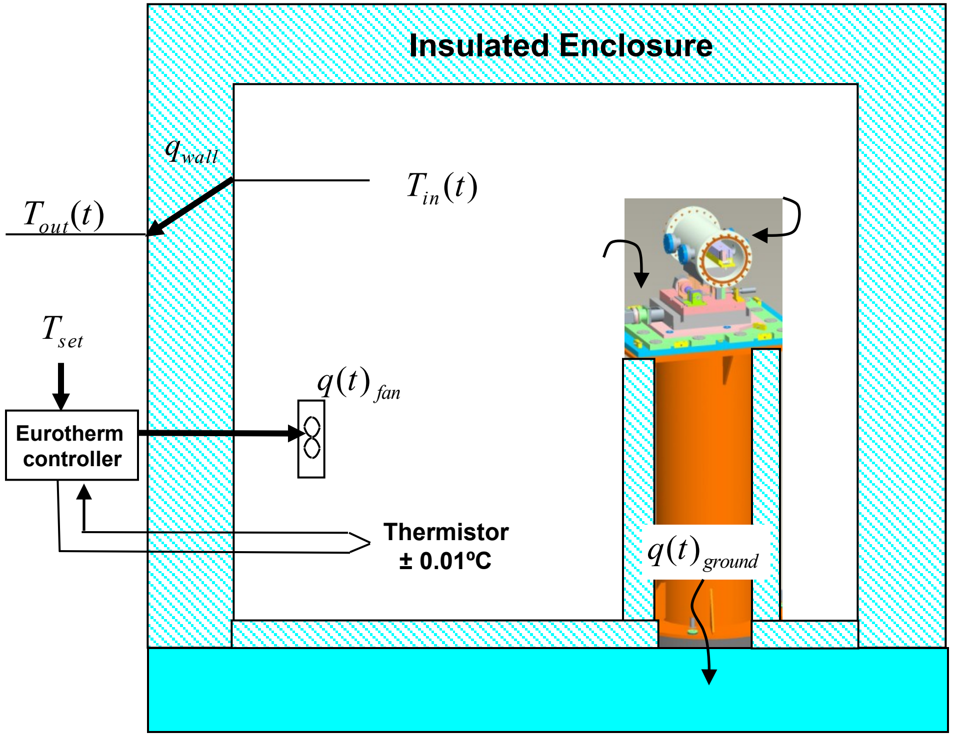
Tom McCarville
mccarville1@llnl.gov

Pointing stability within +/- 30 nano-radians has been demonstrated for a prototype mirror assembly

- The internal temperature set point is slightly higher than maximum room temperature

  - a 15 W resistor provides adequate heat





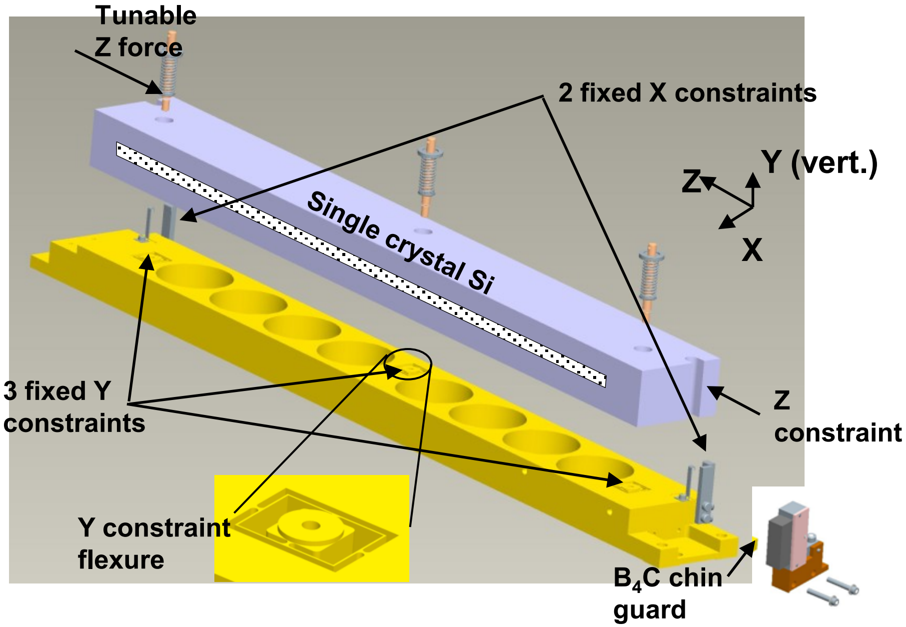
Tom McCarville
mccarville1@llnl.gov

Single crystalline Si mirrors are supported on a kinematic mount

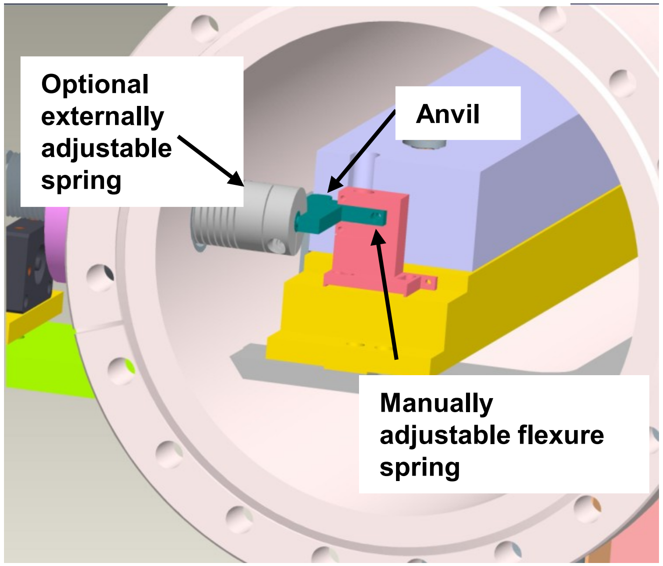
• Spherical curvature is manually adjusted to < 10 nm (P-V) in front of an interferometer
  - Each mirror is bent by about 150 nm (P-V)

• Aspheric curvature is limited to +/- 2 nm (P-V) at fabrication, and limited to this level during coating and installation

<u>Mirror is supported at 6 points of contact</u>

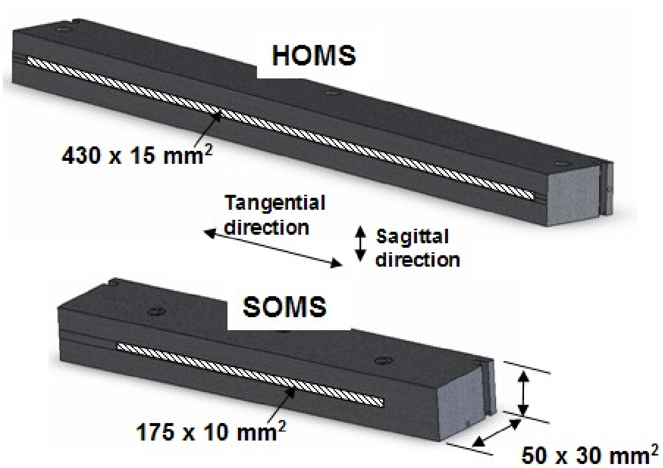


<u>Mirror bending mechanism</u>

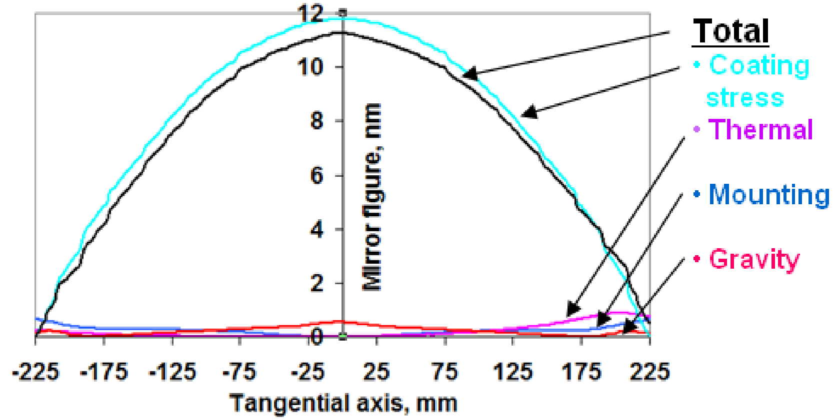


Tom McCarville
mccarville1@llnl.gov

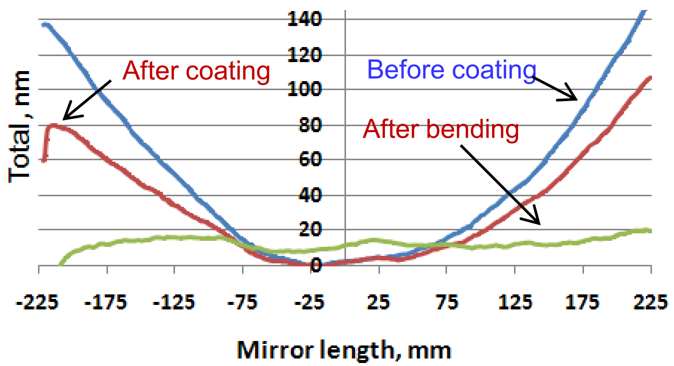
Curvature contributions were calculated during design, and verified during final assembly



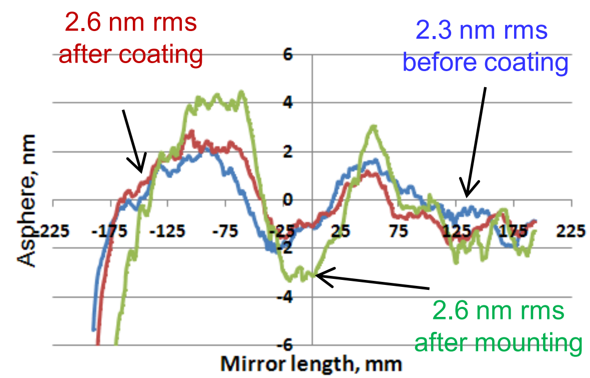
- Analysis of a mounted HOMS mirror, Included all constraints & holding forces



- HOMS #1 figure measured as received, then after coating, and bending



- HOMS #1 with sphere subtracted

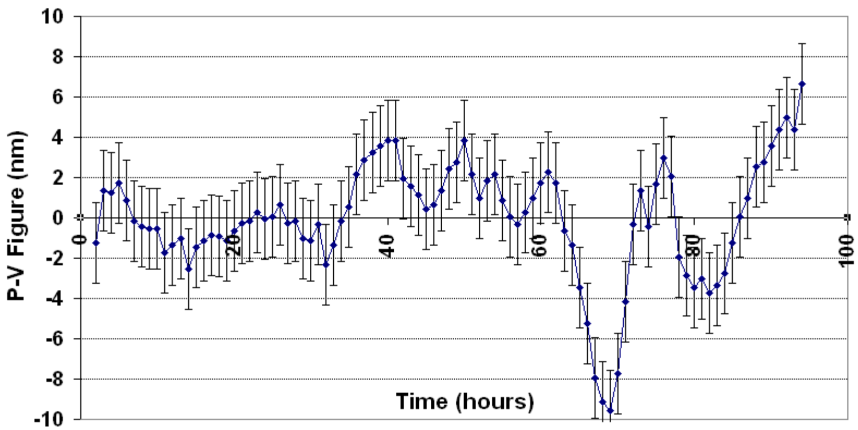


- Mirror coatings are described in a companion paper by Regina Soufli

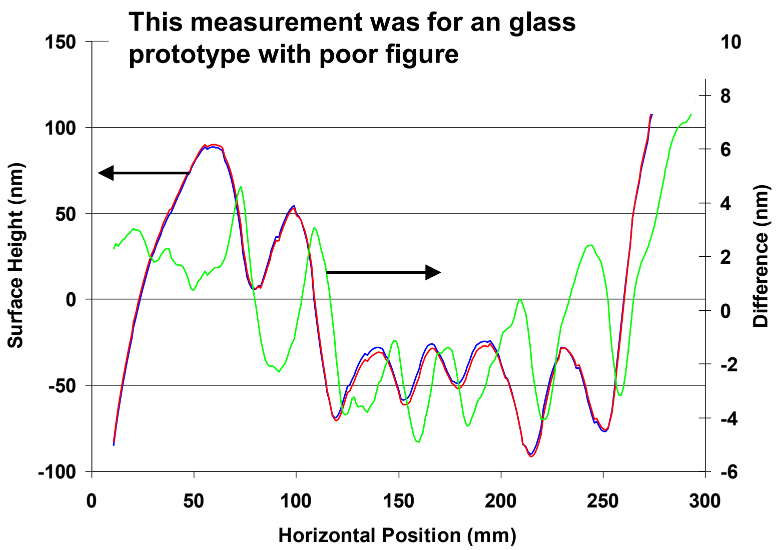
Tom McCarville
mccarville1@llnl.gov

HOMS mirror figure does not vary significantly with time, temperature, & transportation

- Figure stability measured after bending
  - sphere varies by 10 nm/ºC
  - aspheric component is stable



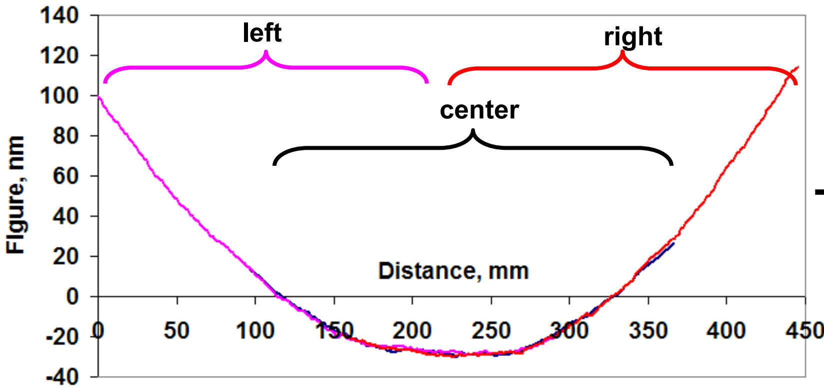
- Surface figure change before & after transport:
  - measured on Friday
  - transported 60 miles
  - re-measured following Tuesday



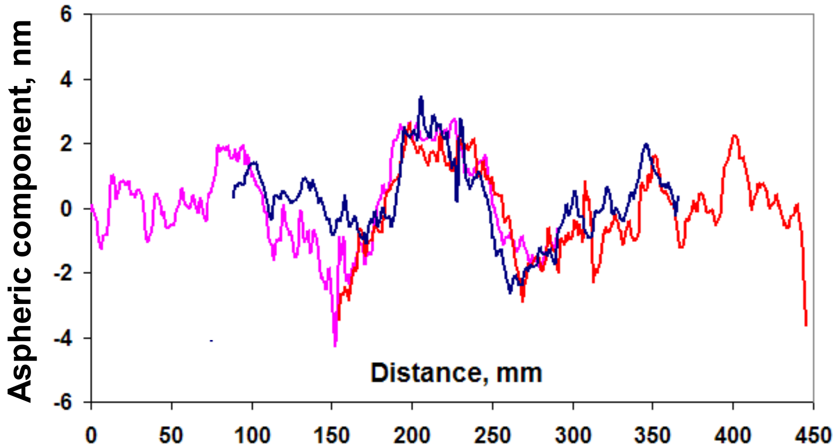
Tom McCarville
mccarville1@llnl.gov

Figure is measured by stitching three files from our 12' Zygo Mark II

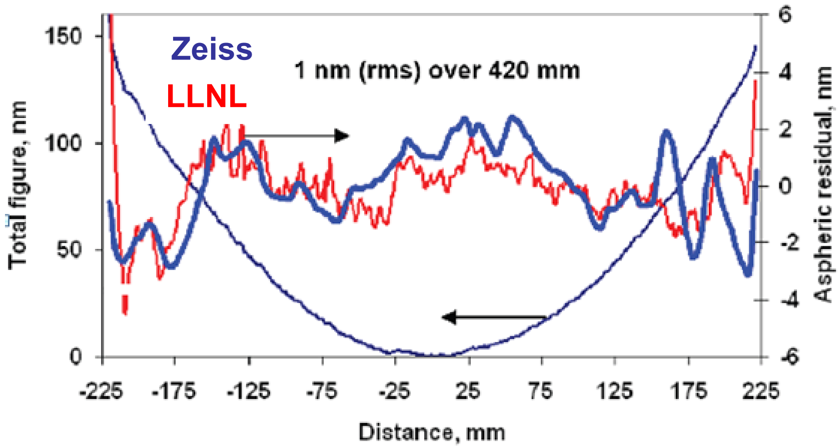
• Stitched by matching slopes & average value of overlap regions



• Reference flat calibration and low noise are verified by overlap of aspheric component



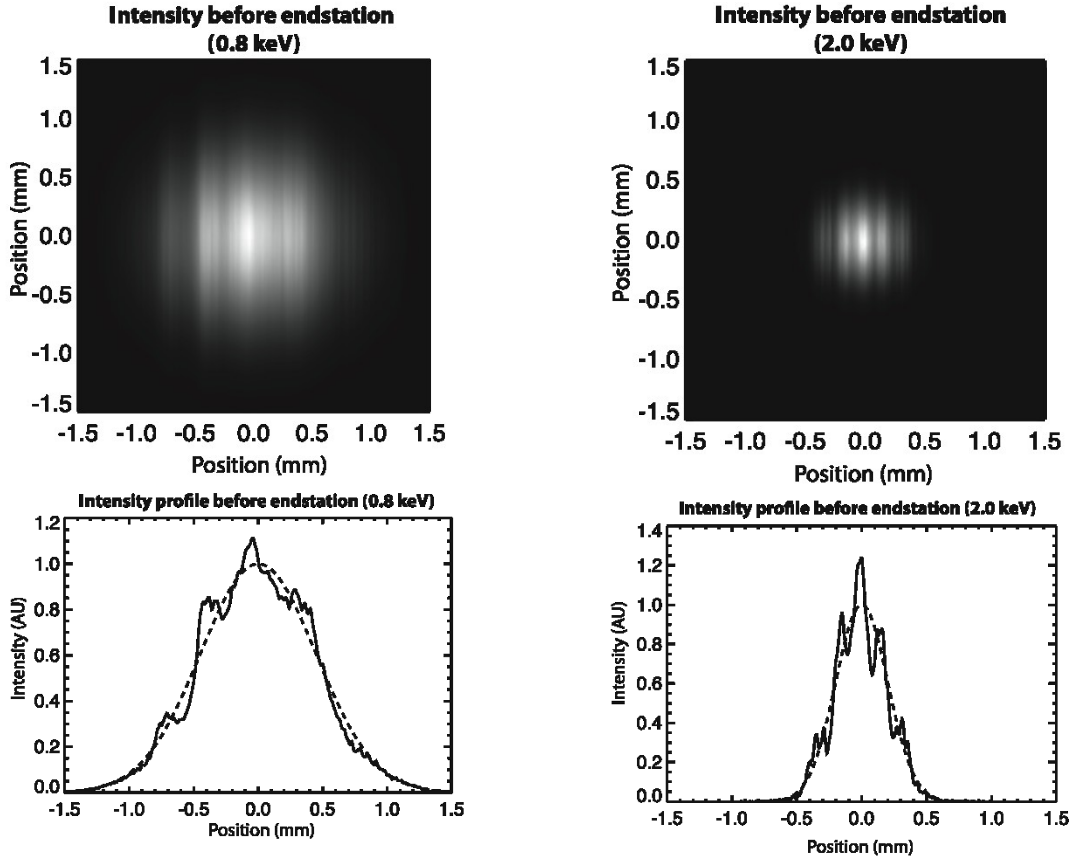
• Zeiss & LLNL figure measurements agree within +/- 1 nm



Tom McCarville
mccarville1@llnl.gov

LLNL metrology data on SOMS and HOMS mirrors were used to predict LCLS coherent wave-front propagation and focal spot structure

- Scalar diffraction model was employed
- The same methodology was used to select order of SOMS and HOMS elements for optimum performance



SOMS branch line, before AMO end station

A. Barty, R. Soufli, T. McCarville, S. L. Baker, M. J. Pivovaroff, P. Stefan, and R. Bionta, “Predicting the coherent X-ray wavefront focal properties at the Linac Coherence Light Source (LCLS) X-ray free electron laser”, Optics Express 17, 15508-15519 (2009).

Summary

- HOMS mirror figure and pointing requirements presented "high risk" challenges

    - The design evolved significantly as a result of prototype testing
    - Testing required state of the art metrology methods

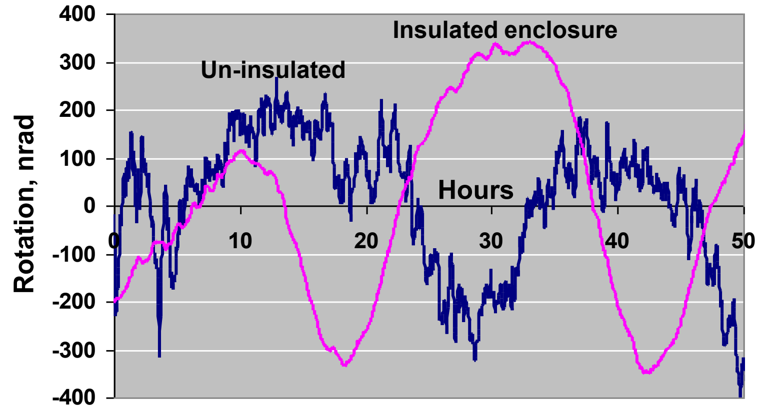
- Three more HOMS mirrors are presently being mounted and installed in vacuum tanks

Tom McCarville
mccarville1@llnl.gov

Lessons learned from pointing stability measurements

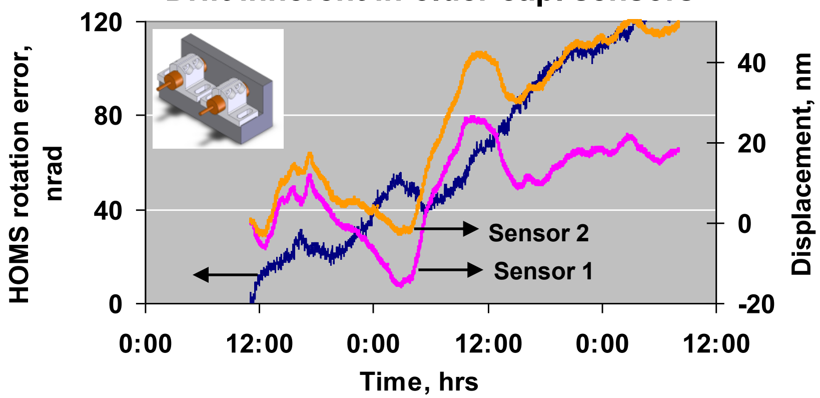
- Air temperature fluctuations cause “rapid” (< 1 min.) pointing error fluctuations
  - insulation filters out periods < 1 hr
  - active temperature control is required for periods > 1 hr

Rotation error without temperature control



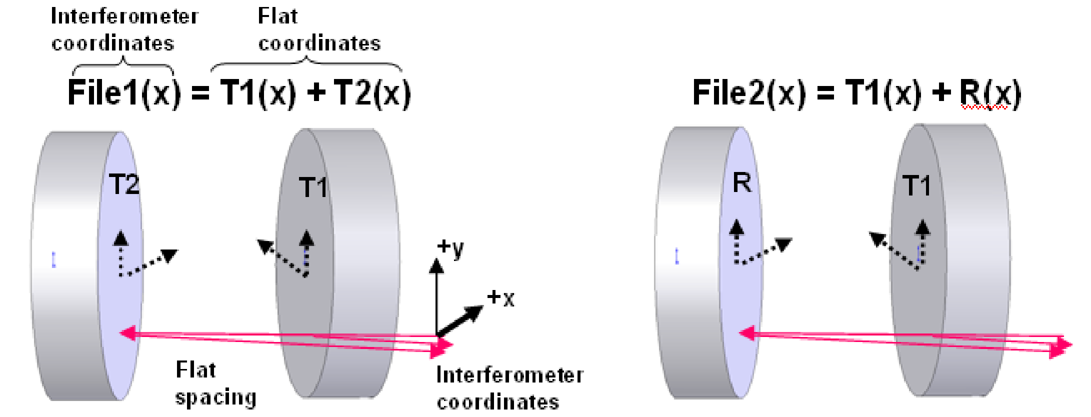
- Stability measurements were initially compromised by long term drift in older (5 yrs) cap. sensors
  - drift is measured with a calibration block
  - new generation sensors solved this problem

Drift inherent in older cap. sensors

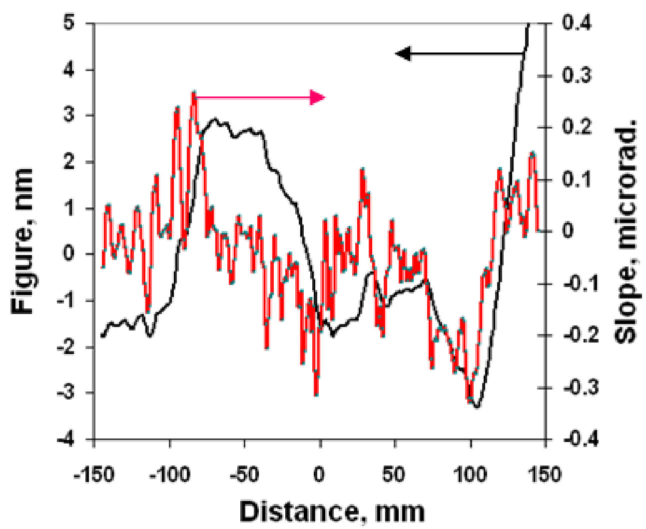


Tom McCarville
mccarville1@llnl.gov

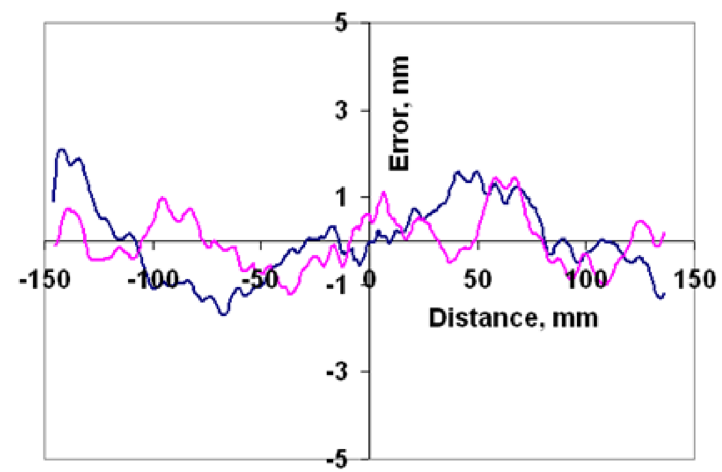
Geometry for calibrating transmission flat horizontal axis



- Figure error and slope of our TF



- Calibration measurement error is < +/2 nm



Tom McCarville
mccarville1@llnl.gov