

Breakout Session 3: Mirror Update

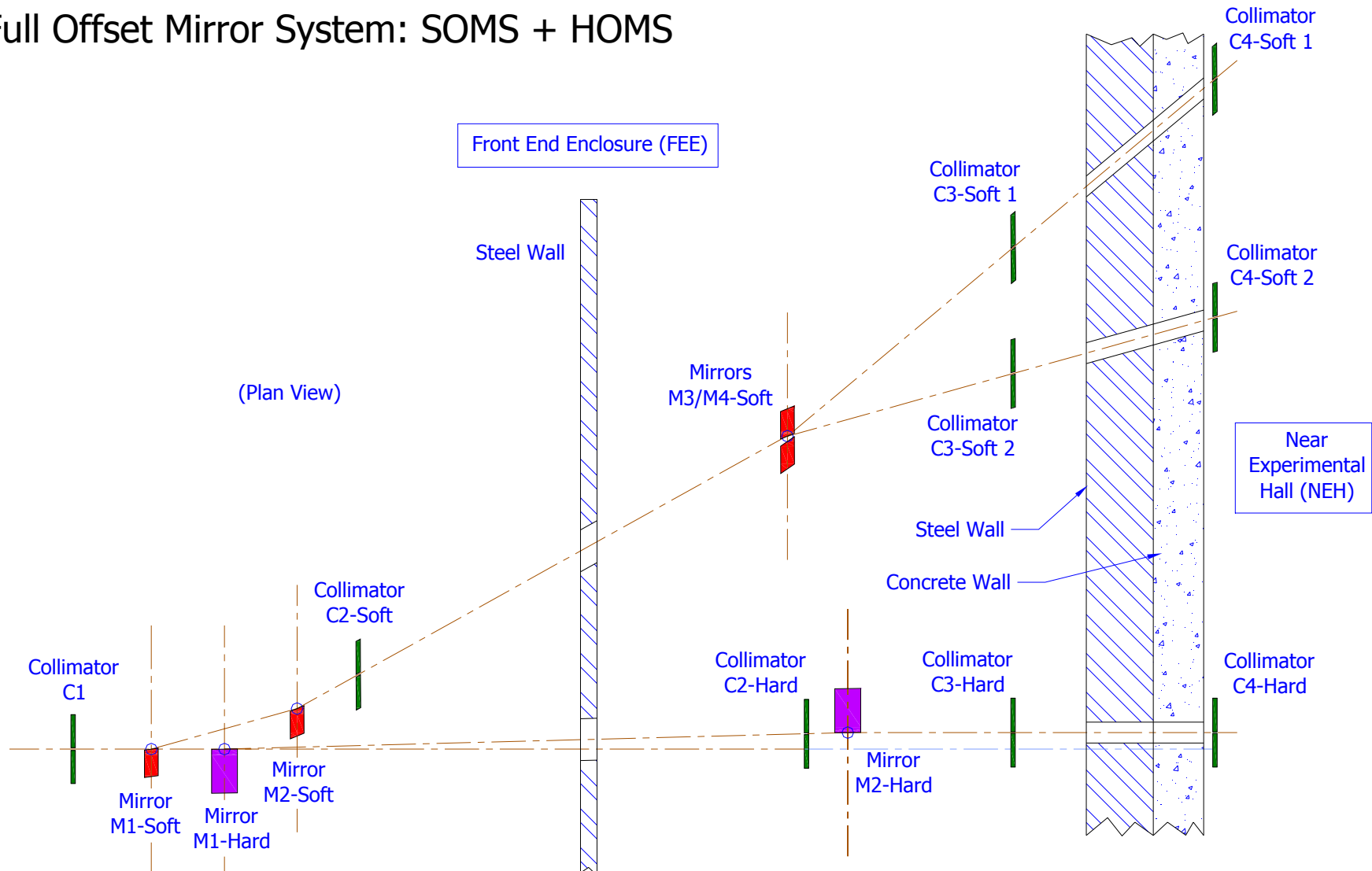
Breakout Session 3: Mirror Update

- Overall Offset Mirror System (OMS) Changes
- Soft X-Ray Offset Mirror System (SOMS) Progress
- Hard X-Ray Offset Mirror System (HOMS) Progress

Acknowledgment: Primary contributors to this work include Tom McCarville, Mike Pivovarov, Regina Soufli, and John Trent.

Physics Requirements for the XTOD Soft X-Ray Offset Mirror System (SOMS)

Full Offset Mirror System: SOMS + HOMS



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Overall Offset Mirror System (OMS) Changes

- HOMS now Horizontally-Deflecting: minimize gravity sag distortion
- Steel Wall, 300 mm thick, now required by Radiation Physics
- SOMS M3/M4 relocated upstream:
 - Still accommodates future soft x-ray monochromator grating chamber
 - Provides additional space for branch line collimators and stoppers

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Soft X-Ray Offset Mirror System (SOMS) Progress

SOMS PRD signed in November:

Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

LCLS Physics Requirements Document #	1.5-004	X-Ray Transport and Diagnostics	Revision 0
Physics Requirements for the XTOD Soft X-Ray Offset Mirror System			
Peter Stefan Author		Signatures	2006/11/1 Date
Michael Pivovarovoff Author		Signature	13 NOV 2006 Date
Richard Bionta XTOD Manager		Signature	11/3/06 Date
John Arthur Photon Systems Manager		Signature	11-1-06 Date
Paul Emma Accelerator Physics Team Leader		Signature	11/1/06 Date
Darren Marsh Quality Assurance Manager		Signature	11/2/06 Date
John Galayda Project Director		Signature	11/10/06 Date

Brief Summary
This document provides general physics requirements for the XTOD Soft X-Ray Offset Mirror System (SOMS), an optical system designed to substantially reduce the levels of high-energy spontaneous radiation, Bremsstrahlung γ -rays and their secondary radiations within the LCLS Experimental Halls. At the same time, this System strives to minimally degrade the intrinsic characteristics of the LCLS FEL beam.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000	2006/11/1	All	Initial Version

PRD 1.5-004-r0 Check the LCLS Project website to verify that this is the correct version prior to use.
 1 of 6

Physics Requirements for the XTOD Soft X-Ray Offset Mirror System (SOMS)

3. Optical Requirements

3.1. Basic Mirror Geometry: Flat, planar reflecting surfaces. Minimum tangential radii in the tens-of-kilometer range.

3.2. Mirror Surface Specifications:

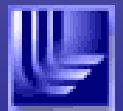
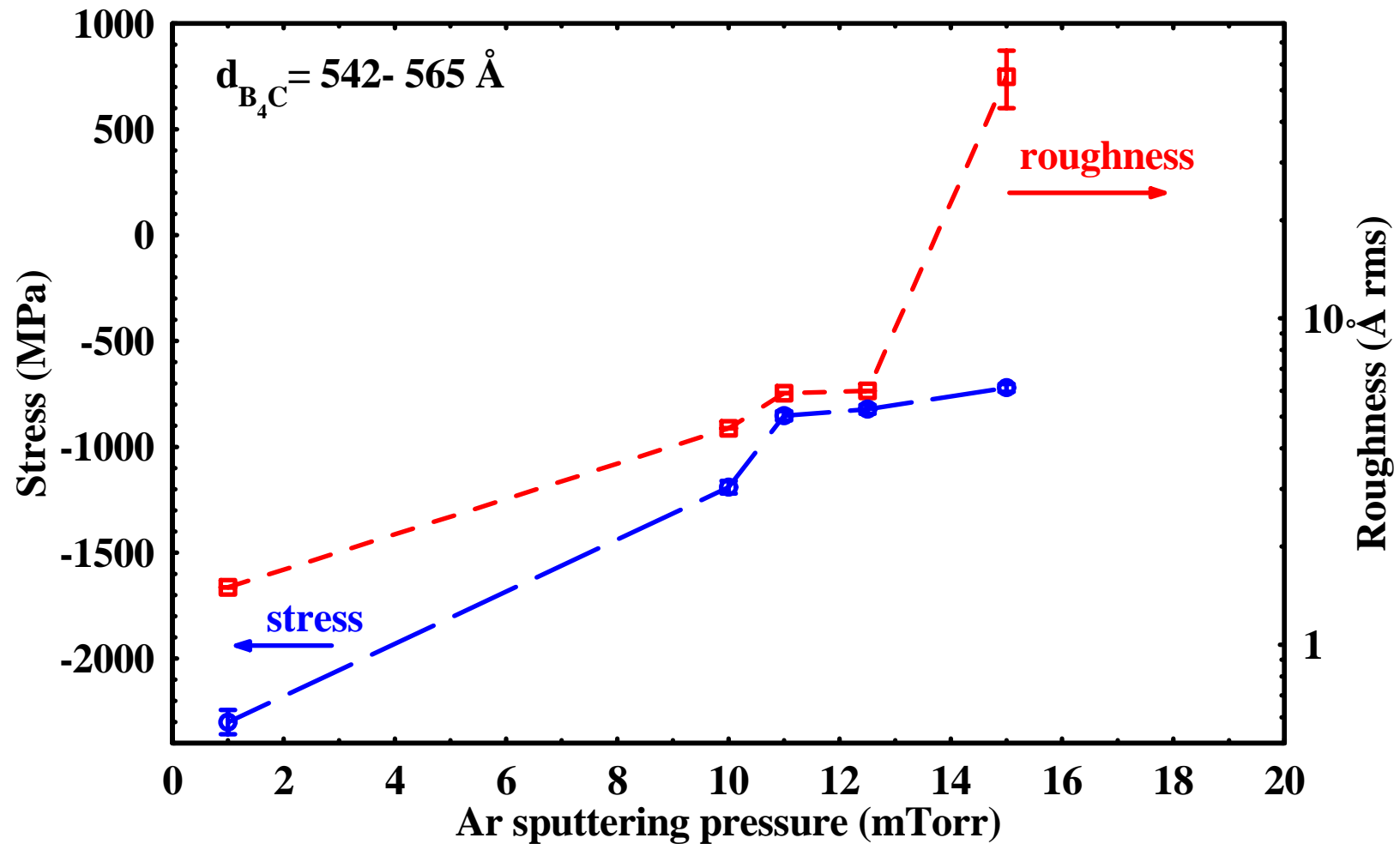
Error Category	Spatial Frequency Range	Roughness Wavelengths	Specification
High-Spatial Roughness	$0.5 \mu\text{m}^{-1}$ to $50 \mu\text{m}^{-1}$	20 nm to 2 μm	≤ 0.4 nm rms
Mid-Spatial Roughness	$10^{-3} \mu\text{m}^{-1}$ to $0.5 \mu\text{m}^{-1}$	2 μm to 1 mm	≤ 0.25 nm rms
Figure (slope errors)	$(\text{mirror size})^{-1}$ to $10^{-3} \mu\text{m}^{-1}$	mirror size to 1 mm	≤ 0.25 μrad rms

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Soft X-Ray Offset Mirror System (SOMS) Progress

- Two key decisions for all SOMS mirrors:
 - Single-crystal silicon substrates with B₄C coating applied at LLNL
 - Independent substrate metrology required

The thickness, roughness and stress properties of B₄C coatings for the LCLS SOMS mirrors are being optimized at LLNL

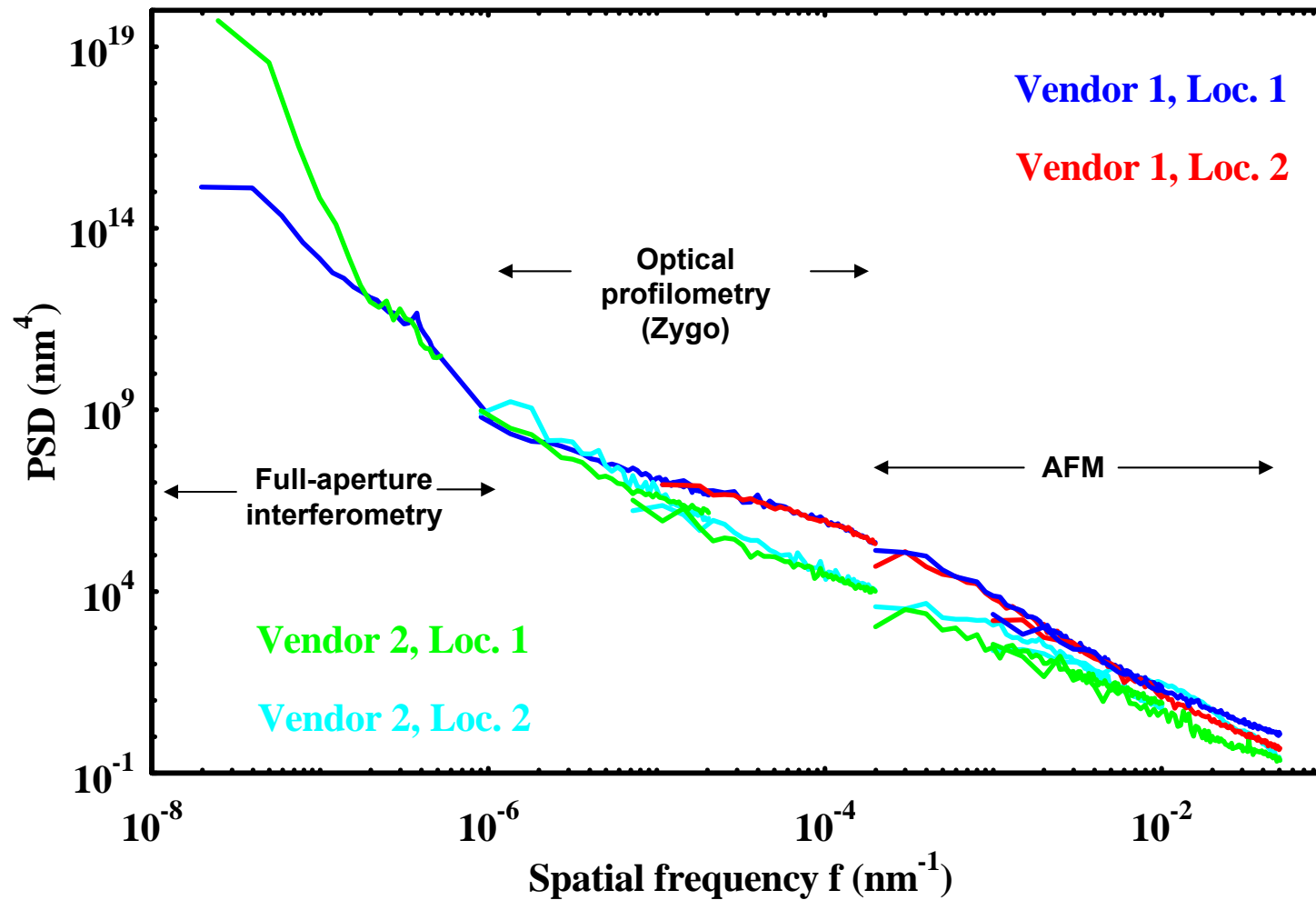


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Soft X-Ray Offset Mirror System (SOMS) Progress

- LLNL also has the required metrology capabilities:

PSD analysis of LLNL surface metrology data on Si test substrates by two vendors



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Soft X-Ray Offset Mirror System (SOMS) Progress

- Initiate communication with mirror vendors, to enable vendor selection
 - Generate one page mirror specification summary:

Mirror Specification Summary: LLNL "Soft X-Ray Offset Mirror System (SOMS)"

2007/2/2 Regina Soufli and Peter Stefan

Parameter	Value
Quantity	4 each
Type	Mirror
Basic Dimensions (length x width x depth)	250 mm x 30 mm x 50 mm * ¹
Substrate Material	Silicon Single Crystal
Polished Shape	Flat
Optically-Active Area (Clear Aperture)	175 mm x 10 mm * ¹

*¹ Tolerance: ± 0.50 mm for these dimensions

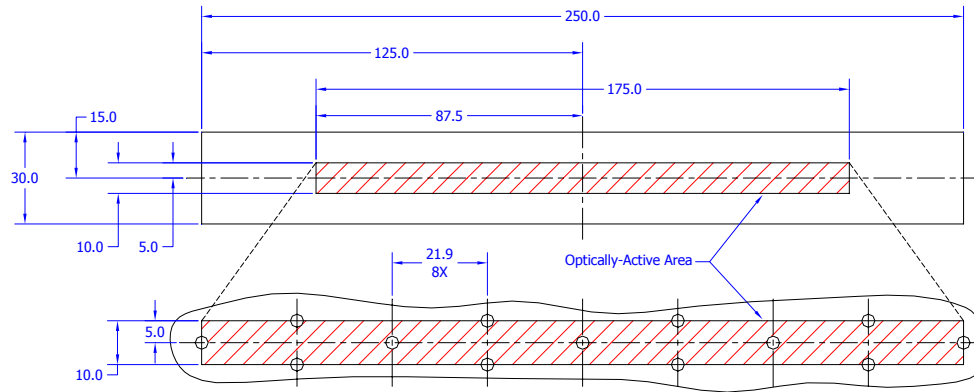
Parameter	Value
Tangential Radius	> 50 km
Sagittal Radius	> 1 km
Tangential Slope Error (error wavelength range)	$\leq 0.25 \mu\text{rad RMS}$ (1 mm to 175 mm) * ²
Tangential Slope Error (error wavelength range)	$\leq 0.25 \mu\text{rad RMS}$ (10 mm to 175 mm) * ² * ⁵
Sagittal Slope Error (error wavelength range)	$\leq 10 \mu\text{rad RMS}$ (1 mm to 10 mm) * ²
Roughness Over Optically-Active Area (error wavelength range)	$\leq 0.4 \text{ nm RMS}$ (20 nm to 2 μm) * ² * ³
	$\leq 0.25 \text{ nm RMS}$ (2 μm to 1 mm) * ²
Number of Roughness Sites and Location	13 points, uniformly-distributed * ⁴

*² Machine-readable raw data sets required from the vendor for these measurements

*³ Atomic Force Microscope (AFM) measurements. If AFM not available to the vendor, advise LLNL.

*⁴ See Figure below for roughness measurement sites:

*⁵ Wavelength error range causing wavefront distortion. Expect special requirement in this or another form.



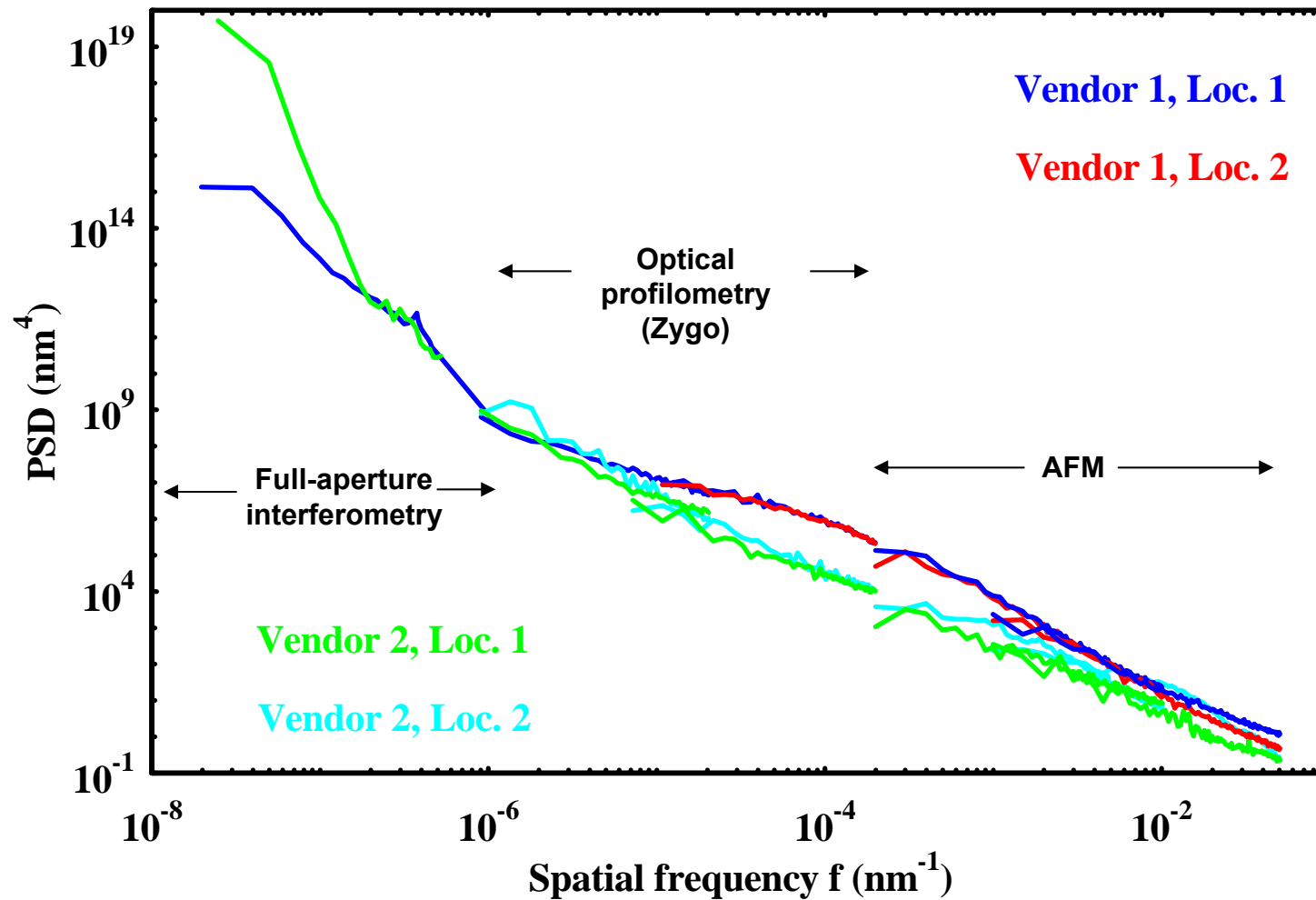
Parameter	Value
Surface Finish on Non-Polished Surfaces	ground and wet-chemical etched
Edge Bevels	Chamfer 0.5 mm to 1 mm, 45°
Coating	None
Cleaning and Handling	Full UHV practice required
Packaging and Shipping	Best protection against contamination and shock/vibration desirable. All-metal, dust-free interior-most enclosure desirable.
Special Features	TBD: several through-holes for mounting likely.

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Soft X-Ray Offset Mirror System (SOMS) Progress

- Initiate communication with mirror vendors, to enable vendor selection
 - Generate one page mirror specification summary
 - Solicit engineering feasibility evaluation from:
 - InSync
 - Sagem/REOSC
 - Schaffer-not interested
 - SESO
 - Tinsley-not interested
 - Zeiss
 - Solicit test substrates for evaluation from responsive vendors

PSD analysis of LLNL surface metrology data on Si test substrates by two vendors



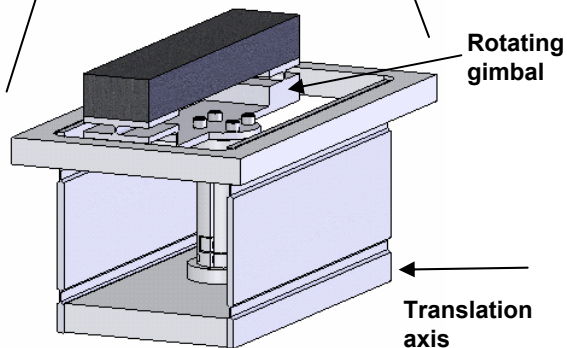
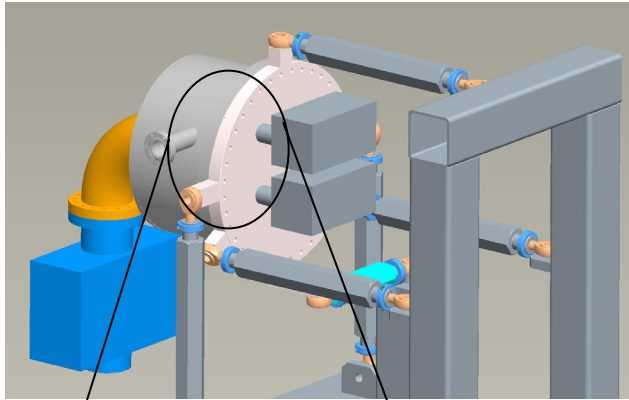
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Soft X-Ray Offset Mirror System (SOMS) Progress

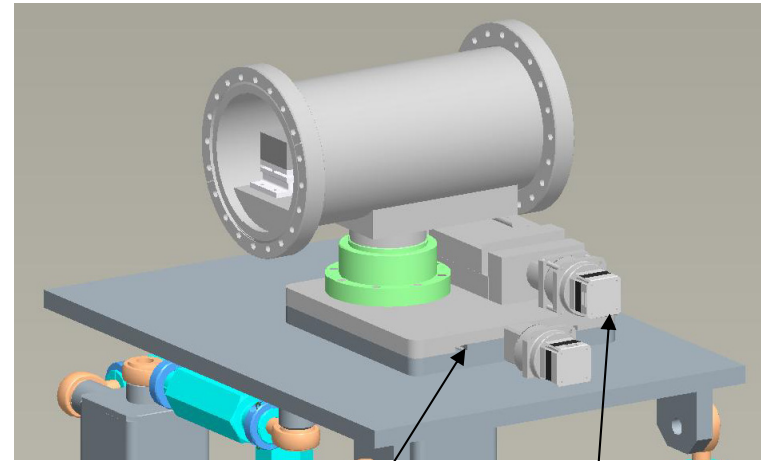
- SOMS Mechanical Systems:
 - Added Tom McCarville to the engineering team in January, 2007
 - Held a System Concept Review (SCR) 2007/4/5
 - Proposed Mechanical Concept:

Two configurations were considered in detail

Movable mirror in a fixed chamber



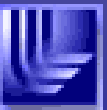
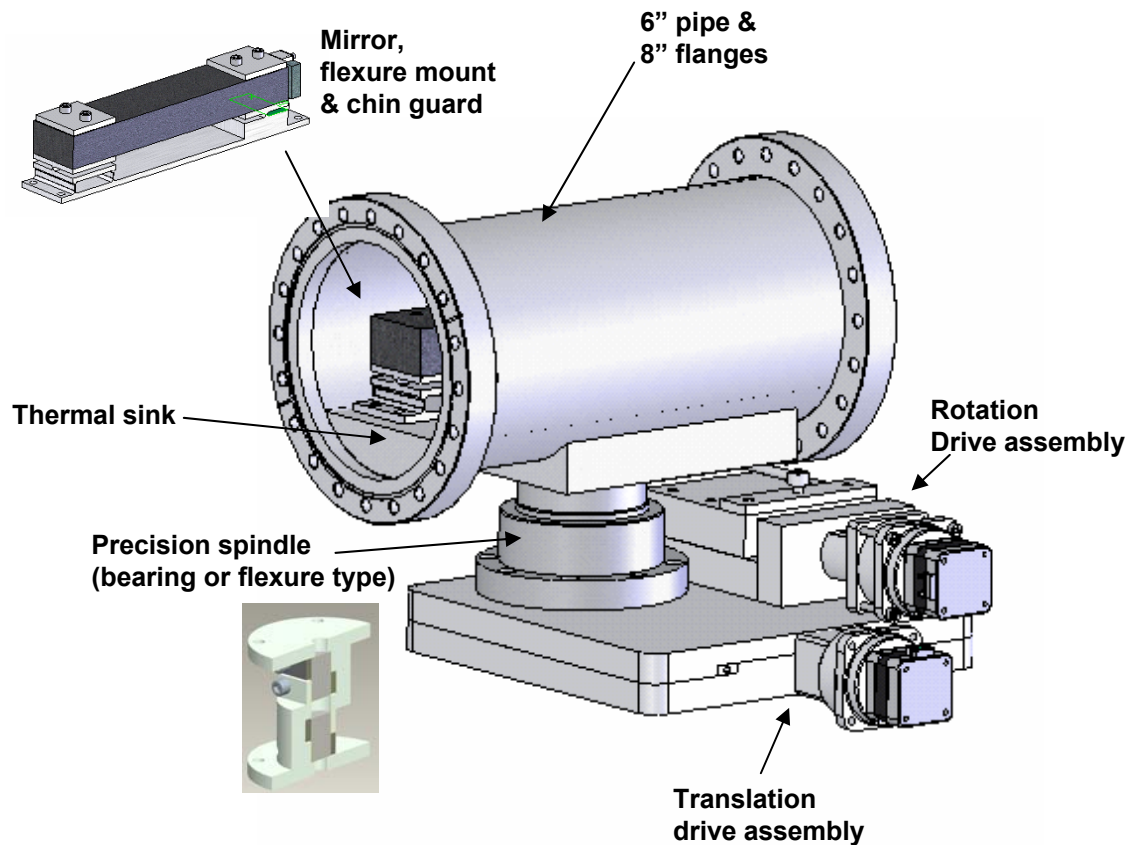
Preferred: Move chamber/mirror



- Same motion mechanisms for either approach
- Either could be designed to meet requirements
- Preferred configuration is simpler and more compact



Key subassemblies

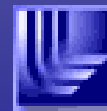
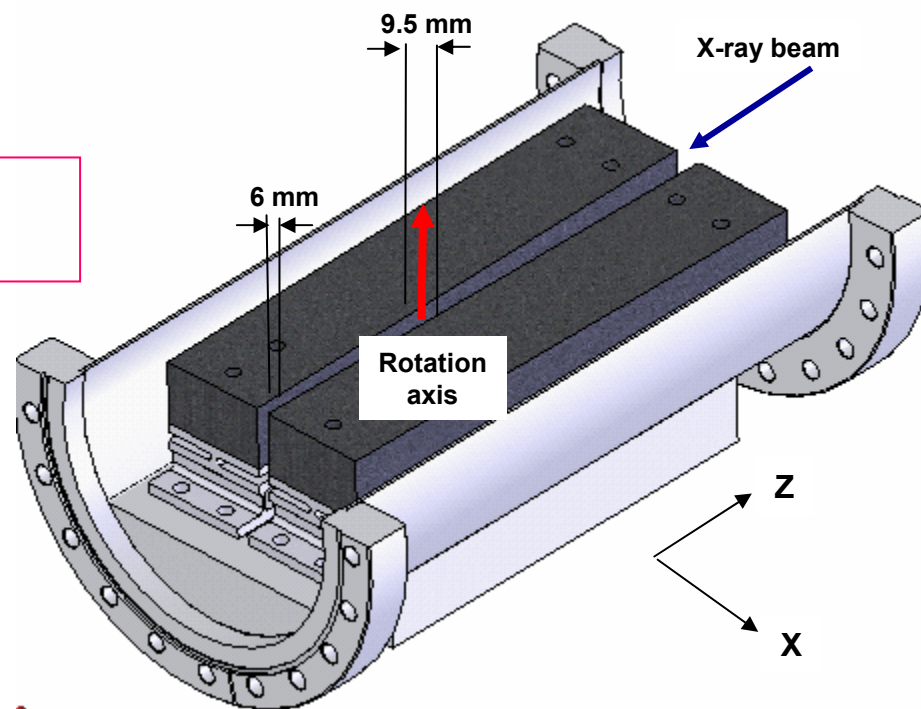


The M3/M4 rotation axis is offset, but the cross coupling between rotation & translation is small

- A rotation $\Delta\theta$ walks the beam by ΔZ along the mirror:

$$\Delta Z \cong 2 \mu\text{m per milliradian}$$

∴ This parasitic motion is small enough to ignore (or compensate)



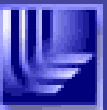
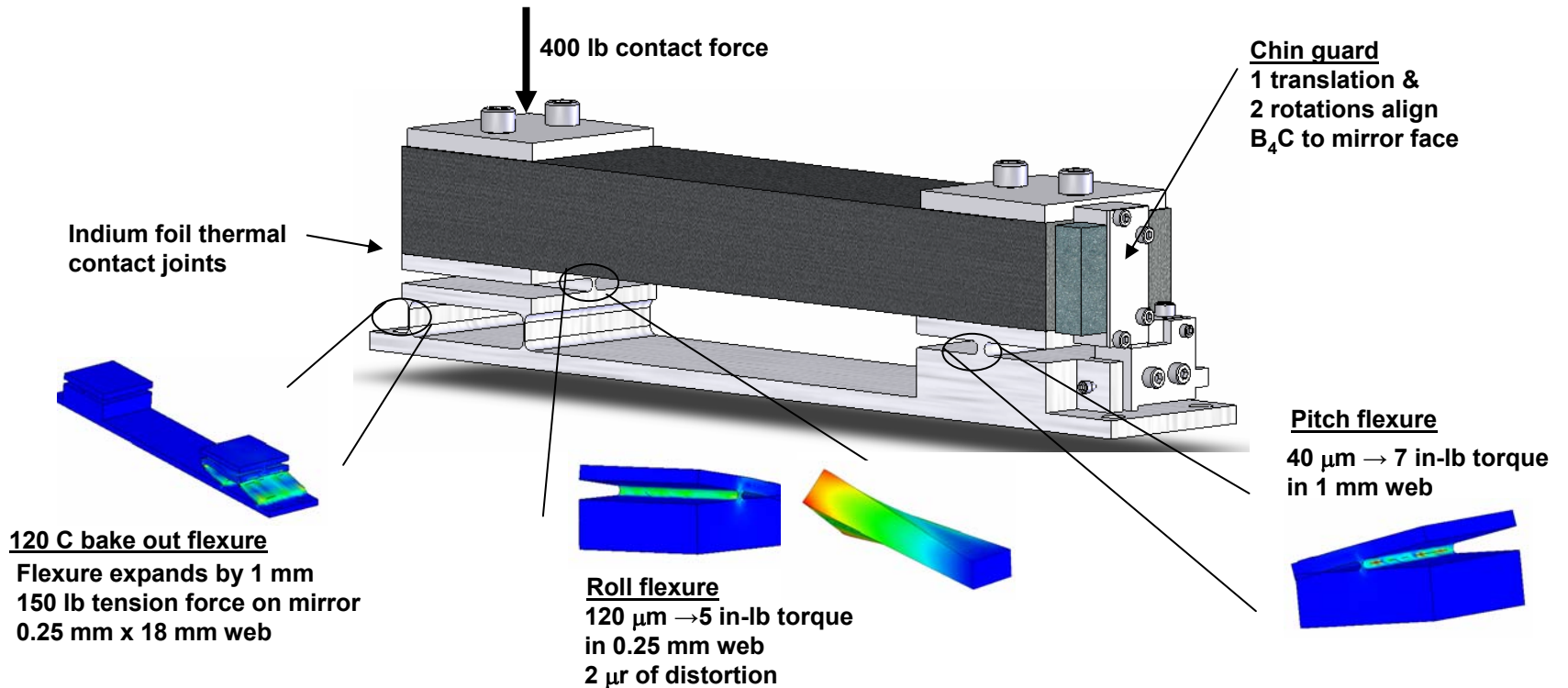
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Soft X-Ray Offset Mirror System (SOMS) Progress

- SOMS Mechanical Systems:
 - Work-in-Progress:
 - Drive system component selection and evaluation
 - Mirror mounting-thermal/stabilization design
 - Mirror distortion from mounting
 - Misalignment through bake out
 - Thermal conduction path/thermal time constant
 - Pulse-to-pulse and "equilibrium" thermal distortion

The mirror is mounted on flexures to reduce mounting stress & distortion

- Mirror mounting stress is < 0.1 ksi
 - mirror fracture stress is ≈ 10 ksi
- Roll flexure induces < $2 \mu\text{m}$ distortion of mirror face
 - negligible effect on intensity profile at the experiment stations



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Hard X-Ray Offset Mirror System (HOMS) Progress

- HOMS offset changed to Horizontal Plane
- Want LLNL to deposit mirror coatings: limits substrate to ~ 450 mm long
- Considering two-stripe coating: B_4C and SiC
- Mirror bender to correct tangential radius still appears necessary

Physics Requirements for the XTOD Soft X-Ray Offset Mirror System (SOMS)

Thank You!

