SC4-Photon Systems-XTOD Physics Requirements

Communications/Coordination for Physics Requirements Development

- Physics Requirements Documents (PRDs): Status
- X-Ray Beam Line Layout (LCLS/LUSI/Users joint effort)
  - Preconditions/Features
  - Operational Overview
- Offset Mirror System (an update, and 2nd example of a joint effort)
  - Current Layout
  - Estimate of Mirror Effects
  - Other Factors

Acknowledgments:

X-Ray Beam Line Layout: John Arthur and Jerry Hastings

Offset Mirror System: Mike Pivovaroff and Peter Stefan

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XTOD Physics Requirements Documents (PRDs): Current Status

Instrument/Area	PRD Status
XTOD Mechanical/Vacuum	Completed
Gas/Solid Attenuator	Completed
Slits and Fixed Mask	Completed
Gas Detector	Completed
Total-Energy Calorimeter	Completed
Soft X-Ray Offset Mirrors	Draft completed/circulating
Hard X-Ray Offset Mirrors	In preparation
K and Low-Energy Spectrometer	In preparation
Direct Imager (FEE, NEH and FEH)	In preparation
Pop-In Monitors	Not started
Radiation Physics Collimators and Shielding (FEE, NEH and FEH)	(Now working with RP)

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Beam Line Layout preconditions/features:

All Experimental Hutches to be **accessible**, if not **in use.**

Enable multiple, simultaneous experiments.

Enable quick changeover from one experiment to another.

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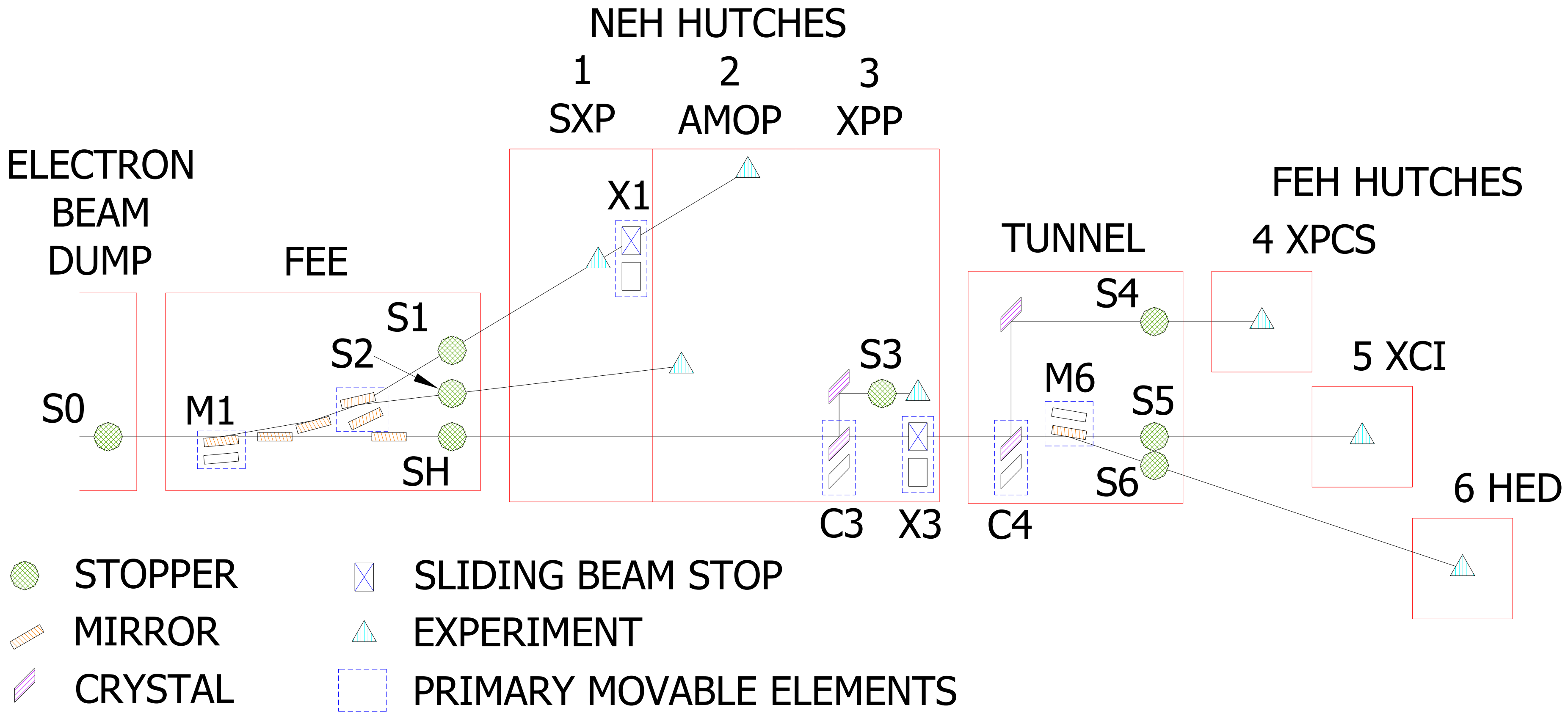
NEH HUTCHES
1
SXP
2
AMOP
3
XPP
ELECTRON BEAM DUMP
FEE
X1
FEH HUTCHES
TUNNEL
4 XPCS
S4
S1
S2
S3
M6
5 XCI
S5
S0
M1
SH
S6
6 HED
C3
X3
C4
STOPPER
MIRROR
CRYSTAL
SLIDING BEAM STOP
EXPERIMENT
PRIMARY MOVABLE ELEMENTS

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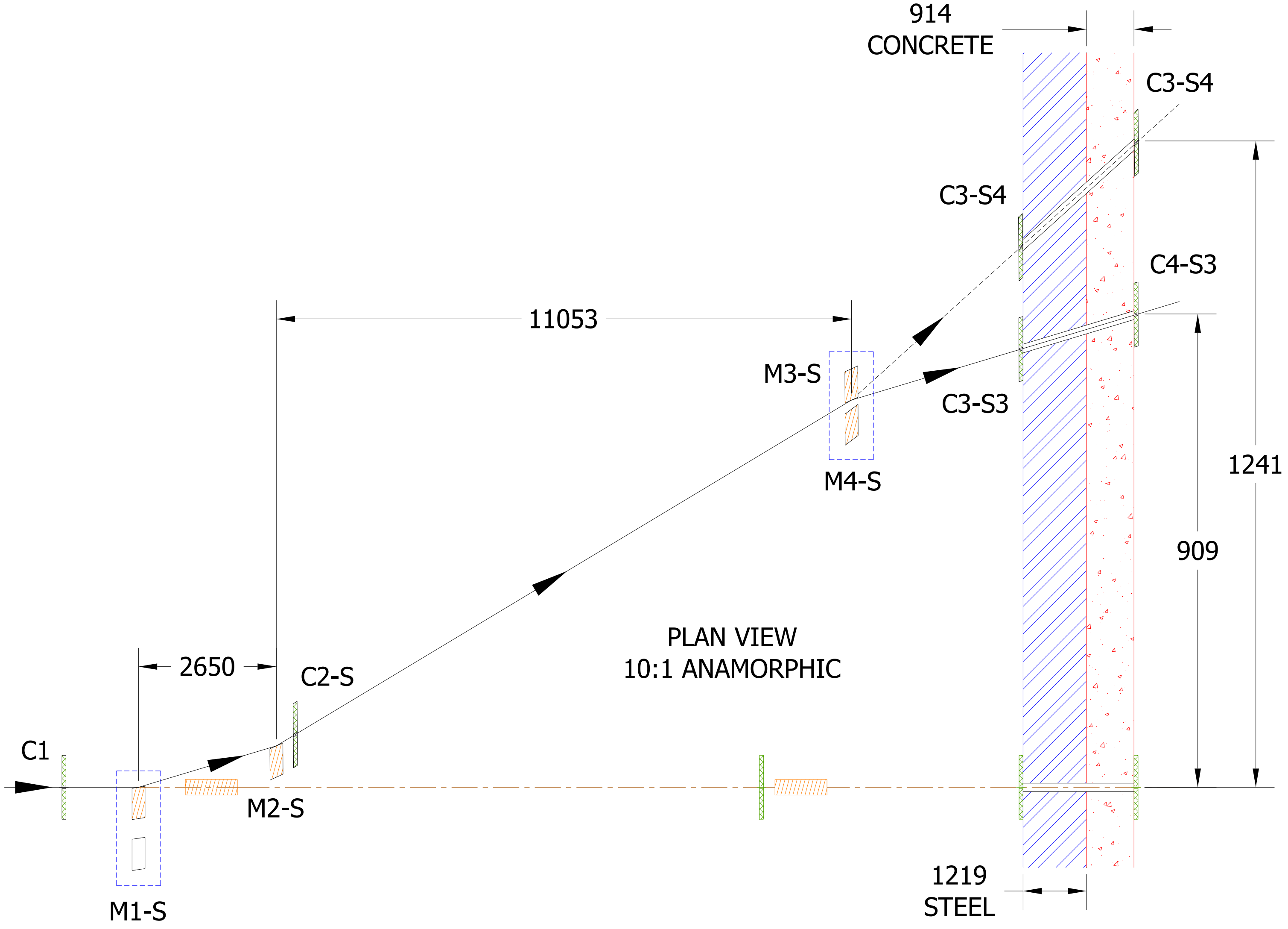
Soft X-Ray Offset Mirror System (SOMS):


914
CONCRETE
C3-S4
C3-S4
C4-S3
11053
M3-S
C3-S3
M4-S
1241
909
PLAN VIEW
10:1 ANAMORPHIC
2650
C2-S
C1
M2-S
M1-S
1219
STEEL

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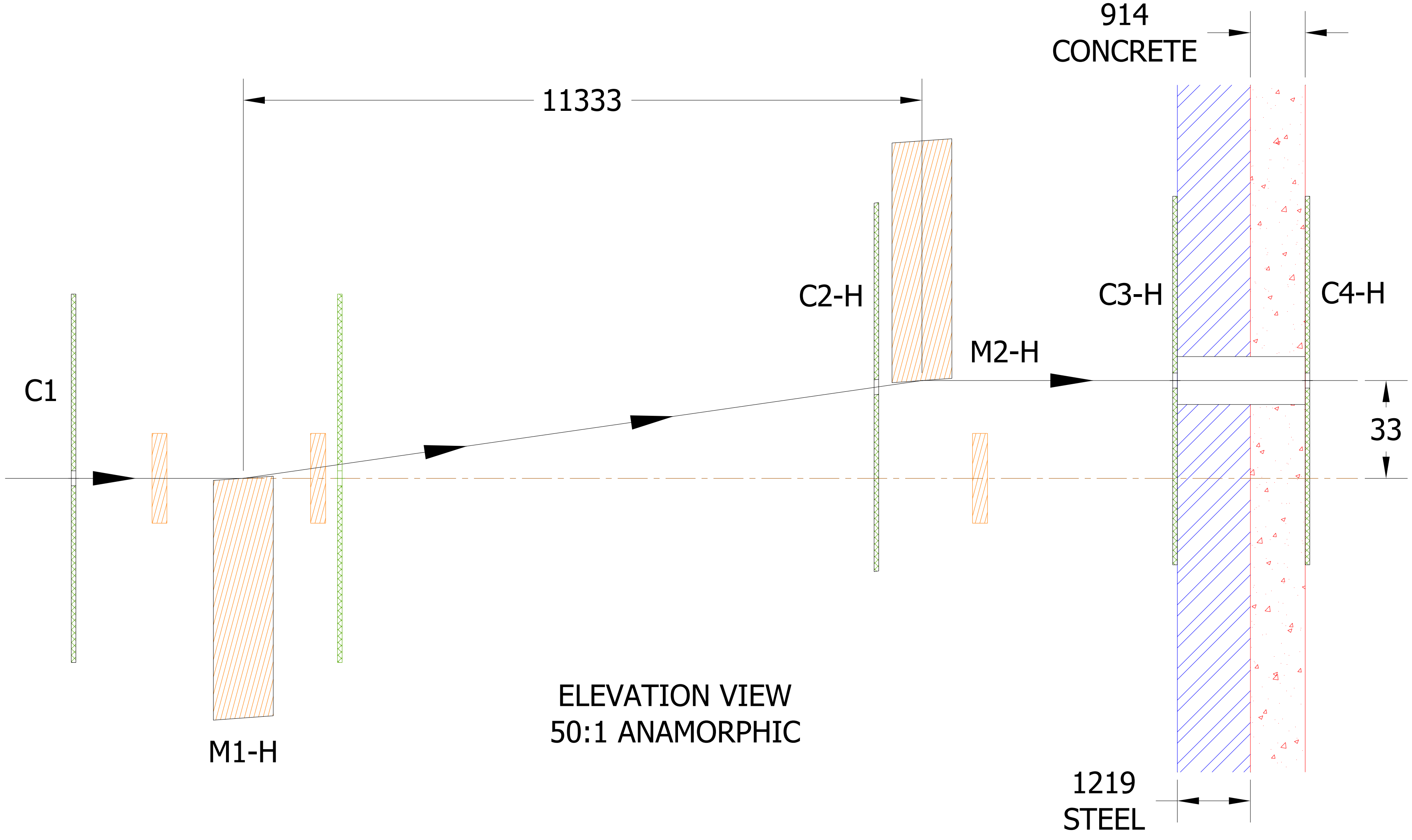
Hard X-Ray Offset Mirror System (HOMS):


914
CONCRETE
11333
C2-H
C3-H
C4-H
M2-H
C1
33
M1-H
ELEVATION VIEW
50:1 ANAMORPHIC
1219
STEEL

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Estimate of Mirror Effects:

divergence degradation and scattered photon generation

Use formalism by Gene Church and Peter Takacs:

Specification of Glancing- and Normal-Incidence X-Ray Mirrors, Optical Engineering Vol. 34 No. 2, pp 353-360, 1995.

Prediction of Mirror Performance from Laboratory Measurements, SPIE Vol.1160, pp. 323-336, 1989.

Fractal Surface Finish, Applied Optics Vol. 27 No. 8, pp1518-1526, 1988.

The Optimal Estimation of Finish Parameters, SPIE Vol. 1530, pp. 71-85, 1991.

Specification of Surface Figure and Finish in Terms of System Performance, Applied Optics Vol. 32 No. 19, pp. 3344-3353, 1993.

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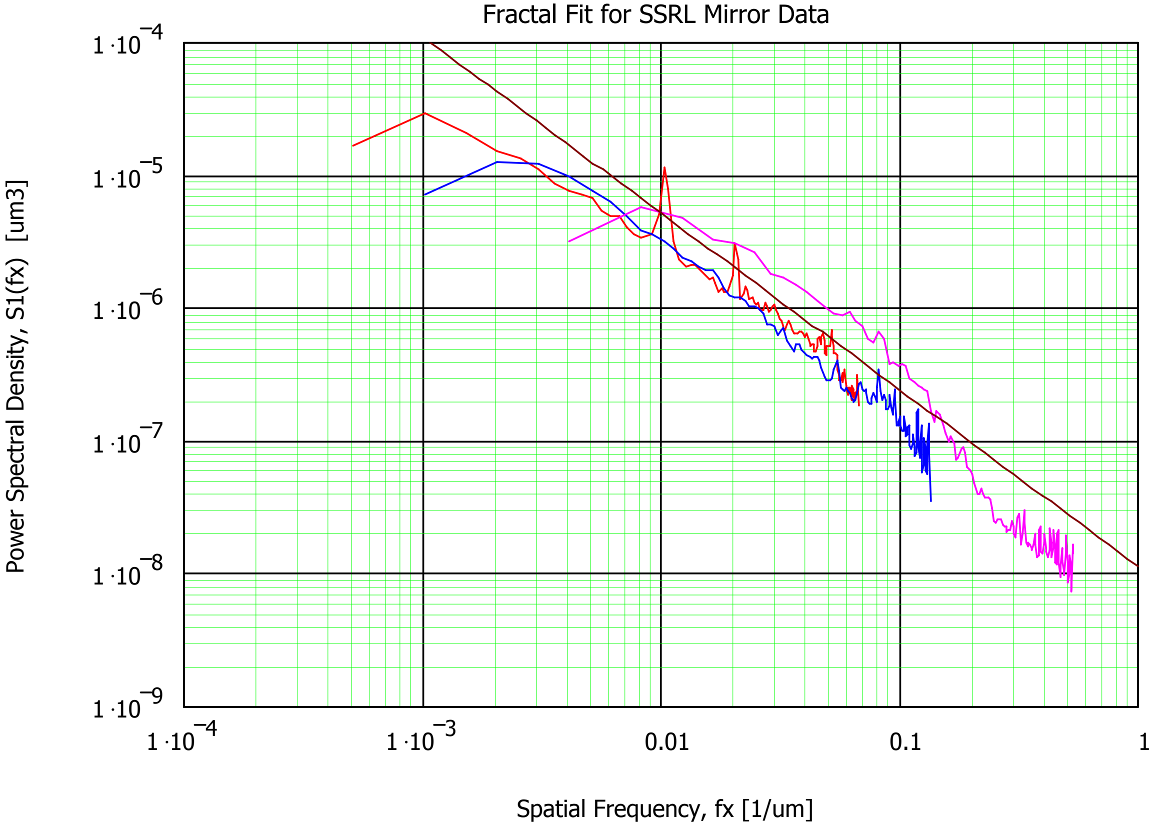
Estimate of Mirror Effects:

Use conservative, fractal, power spectral density (PSD) for mirror errors, based on data from delivered SSRL mirrors:



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Estimate of Mirror Effects:

Assume highly-idealized FEL beam profile, based on Ming Xie description and the diffraction limit:

FEL Condition		FWHM Source Parameters	
λ (nm)	hν (eV)	Size (μm)	Divergence (μrad)
1.5	830	81.6	8.11
0.62	2000	76.0	3.60
0.15	8300	60.0	1.10

A more realistic beam profile is now being calculated by Sven Reiche. Larger effective divergence is likely.

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Estimate of Mirror Effects:

Attainable mirror Figure errors (slope errors):

From informal vendor conversations:

≤ 0.25 µrad recently delivered for three, 350 mm silicon mirrors.

A 1 m mirror, with a central sub-region figure error of ≤ 0.25 µrad should be readily achievable.

But recall: ≤ 0.1 µrad will become available for mirrors of the dimensions we require, through deterministic polishing/correction, in the next several years.

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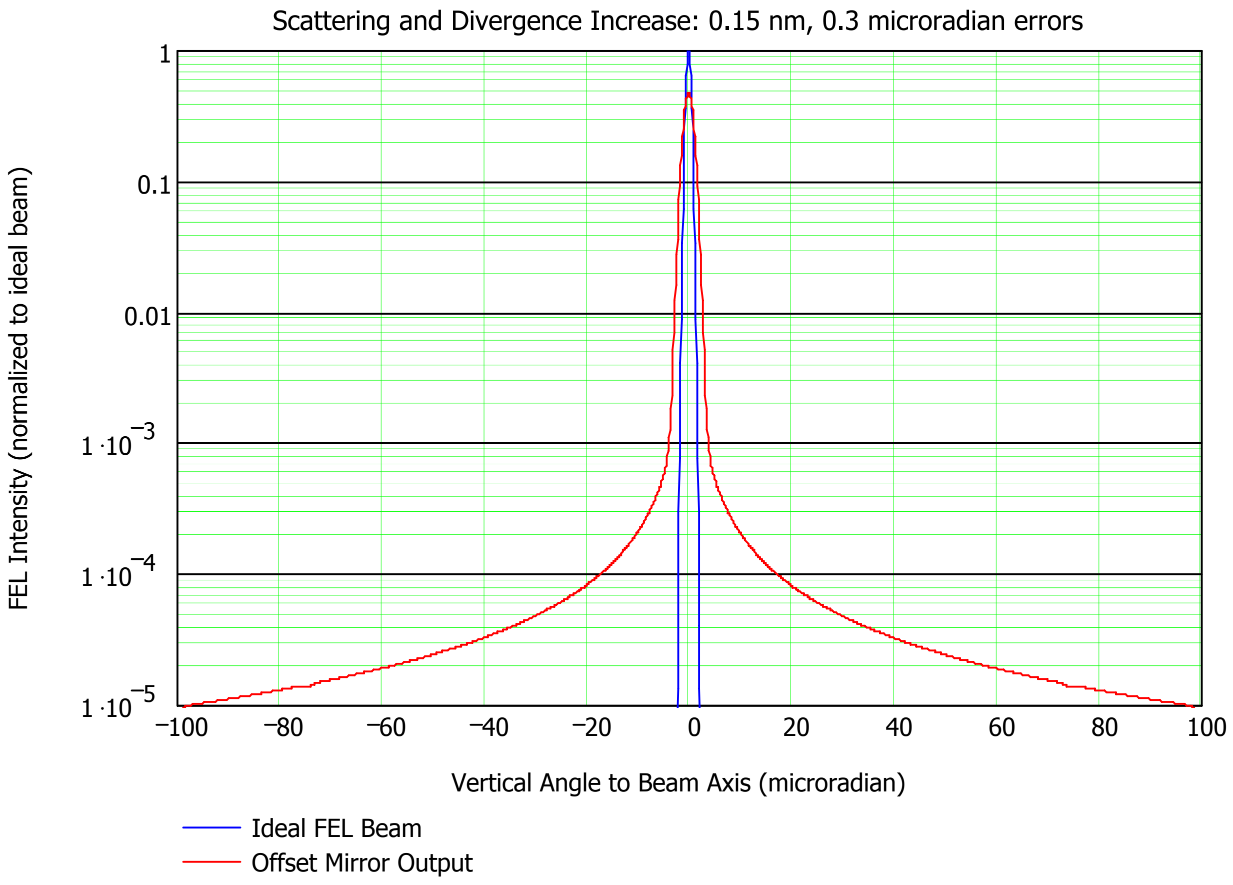
Estimate of Mirror Effects:

A summary of the results: Scattering and Divergence Increase



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Estimate of Mirror Effects:

A summary of the results: worst-case, FEH Hutch 6

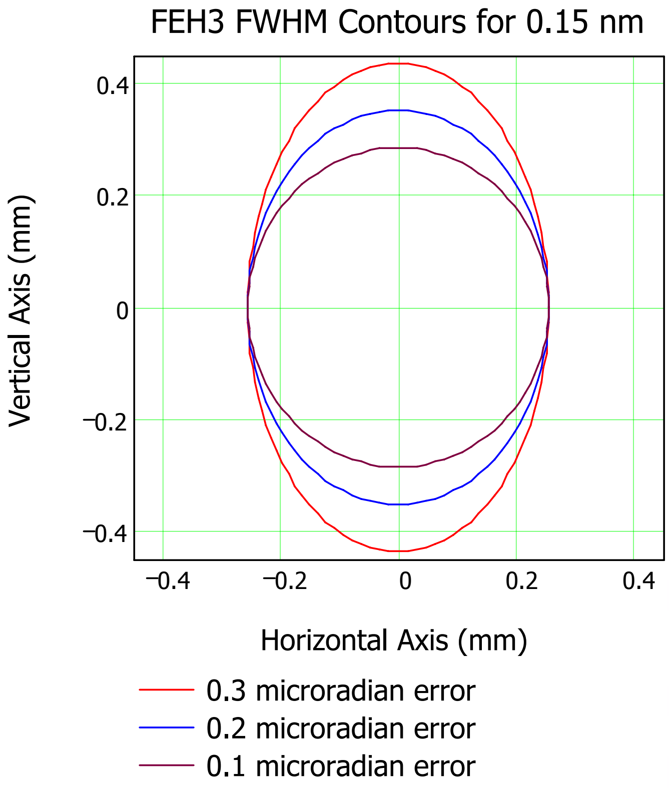
FEH6: z = 406.1 m from downstream end of the LCLS Undulator
λ_{min} = 0.15 nm (8.265 keV)
λ_{max} = 0.62 nm (2.0 keV)

Parameters "Independent" of Offset Mirror System:

Horizontal Axis	λ_{min}	λ_{max}
Source Distance (m)	460.4	427.2
FWHM Source Size (µm)	59.94	76.03
FWHM Source Divergence (µrad)	1.10	3.60
FWHM Beam Size in Hutch (µm)	511.8	1539.0

Parameters Dependent on Offset Mirror System:

Vertical Axis	0.3 µrad Slope Errors		0.2 µrad Slope Errors		0.1 µrad Slope Errors	
	λ_{min}	λ_{max}	λ_{min}	λ_{max}	λ_{min}	λ_{max}
Effective Source Distance (m)	379.7	411.8	403.6	419.6	437.3	425.1
FWHM Source Divergence (µrad)	2.29	4.12	1.74	3.84	1.30	3.66
FWHM Beam Size in Hutch (µm)	873.2	1697.1	704.4	1612.1	570.3	1558.2



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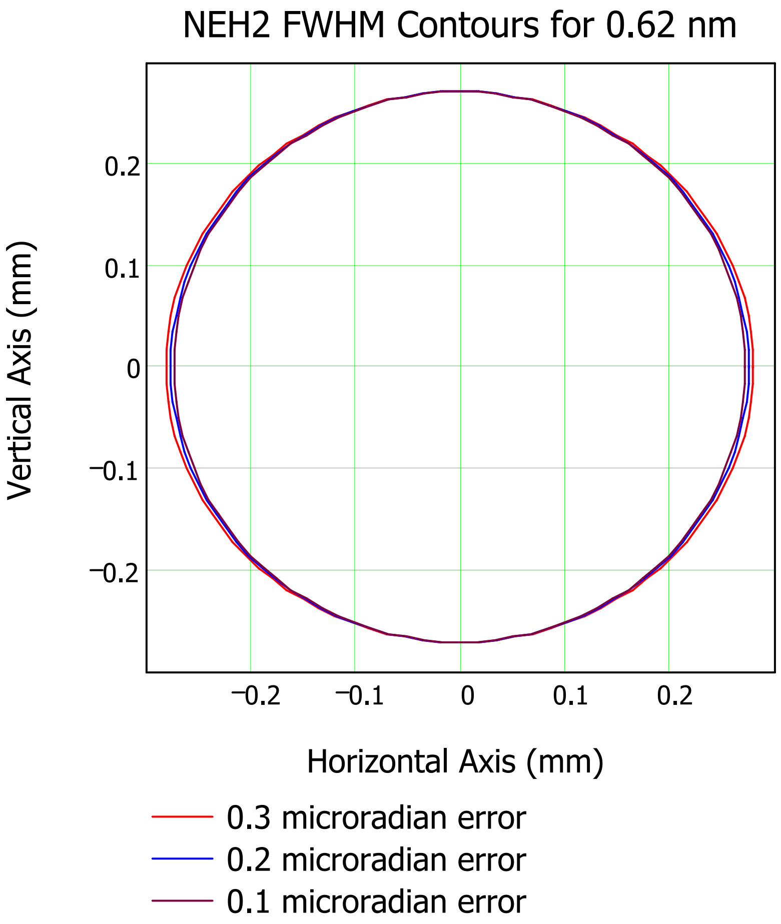
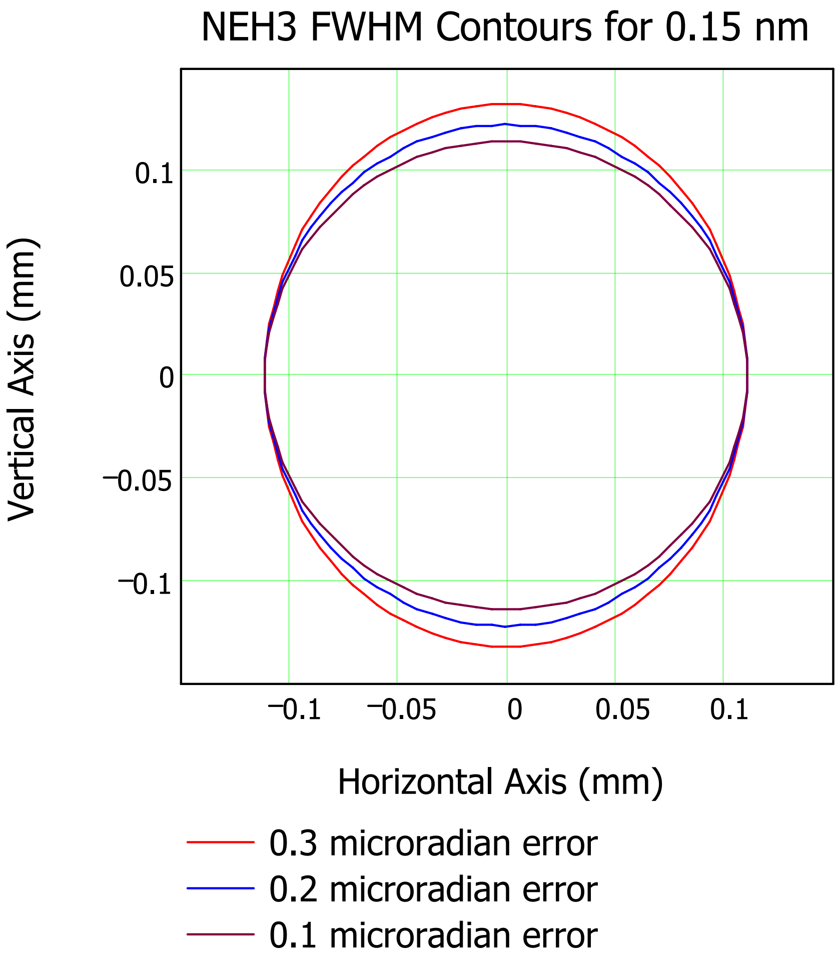
Estimate of Mirror Effects:

A summary of the results: in the NEH


NEH2 FWHM Contours for 0.62 nm


NEH3 FWHM Contours for 0.15 nm

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Other important factors in the Offset Mirror Systems design:

Pointing Error/Stabilization: ≤ 0.1 μrad may be required, to limit motion to less than 1/10 beam size.

Thermal loads and "thermal grounding": thermal drift

Ground/floor vibrations and settling: an intrinsic limit

Beam position feedback stabilization: likely required on HOMS

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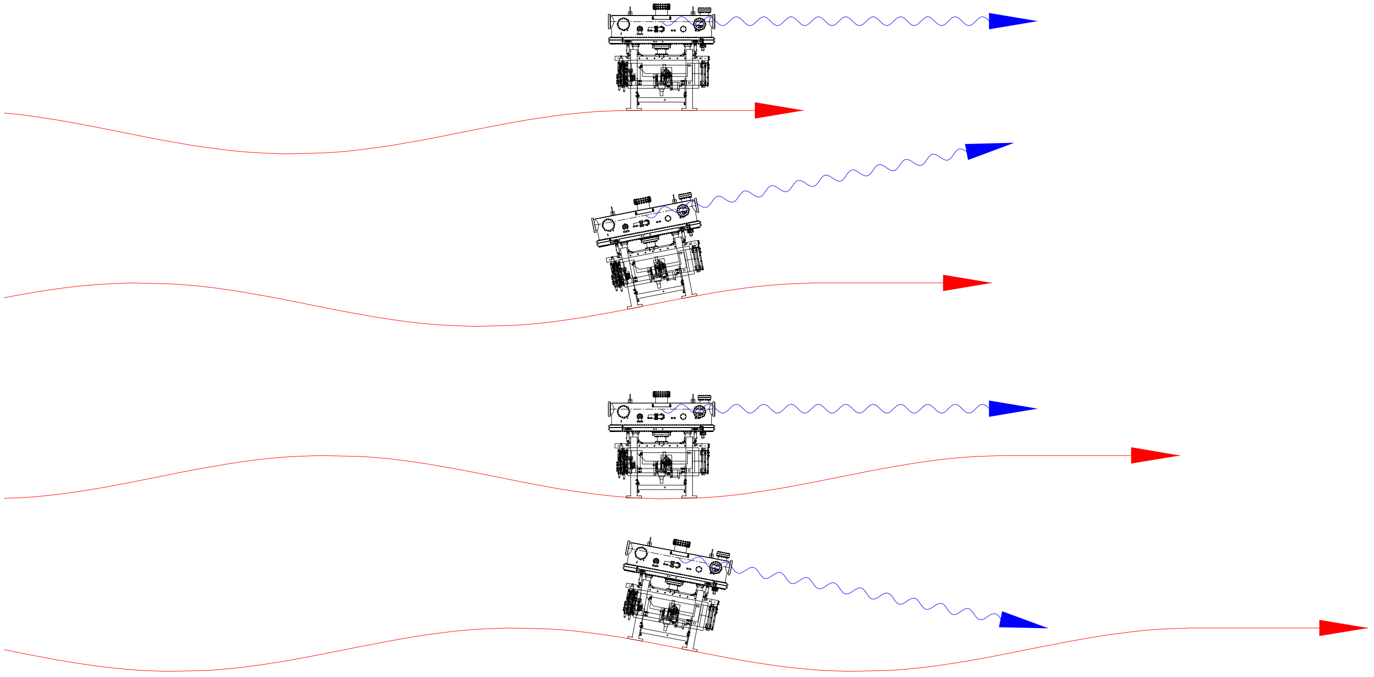
Other important factors in the Offset Mirror Systems design:

Pointing Error/Stabilization:

Ground/floor vibrations and settling: an intrinsic limit

A Traveling Seismic Shear Wave: generates pointing error



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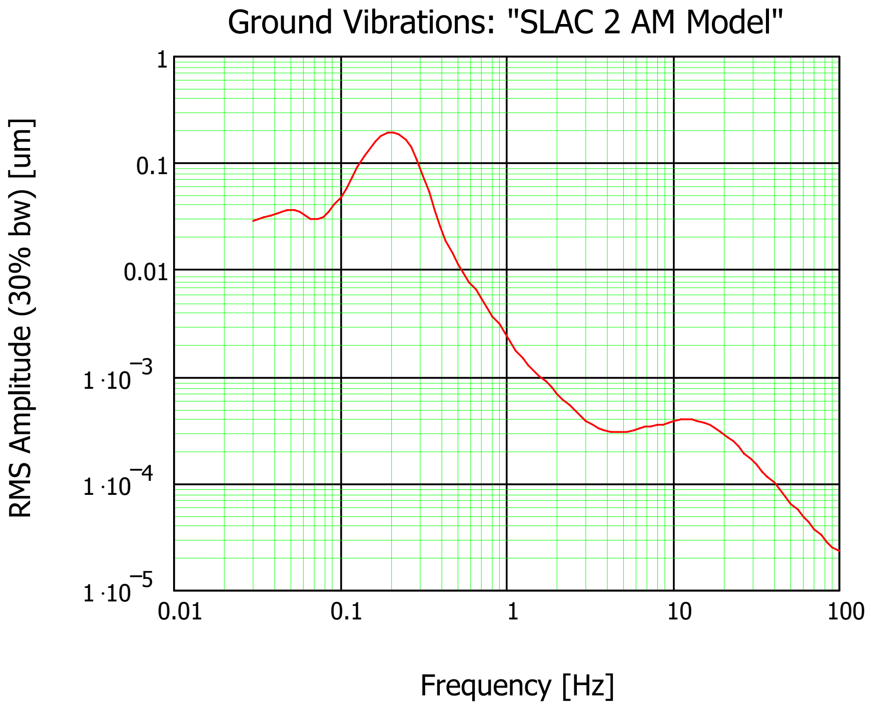
Other important factors in the Offset Mirror Systems design:

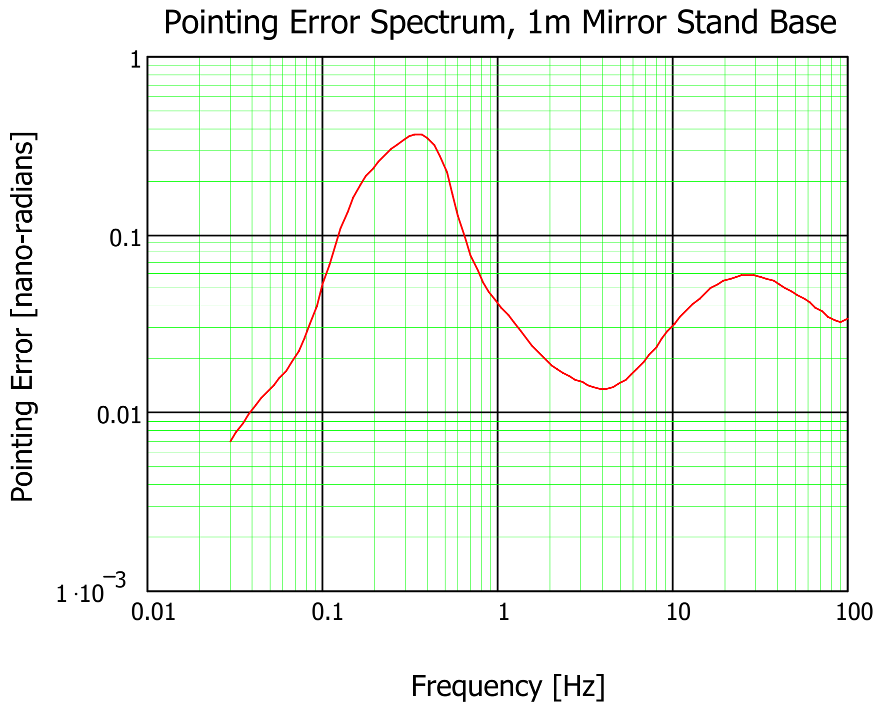
Pointing Error/Stabilization:

Ground/floor vibrations and settling: an intrinsic limit

RMS Integrated Pointing Error < 1 nano-radian (our limit 100 nano-radians)



Ground Vibrations: "SLAC 2 AM Model"



Pointing Error Spectrum, 1m Mirror Stand Base

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Other important factors in the Offset Mirror Systems design:

HOMS tangential radius will require active control:

"Focusing" radius too large to be controlled statically.

The parameters, for 0.15 nm setting:

$L_{Rayleigh} := 54.3m$

$L_{eou\_mir} := 105.4 \cdot m$ (end-of-undulator to mid-point of downstream mirror)

$L_{eou\_FEH6} := 406.1 \cdot m$ (end-of-undulator to center of FEH Hutch 6)

Source-to-mirror distance:

$F_1 := L_{eou\_mir} + L_{Rayleigh}$ $F_1 = 159.7\ m$

Mirror-to-experiment distance:

$F_2 := L_{eou\_FEH6} + L_{Rayleigh} - F_1$ $F_2 = 300.7\ m$

$\theta := 1.44 \cdot mrad$ (mirror grazing angle-of-incidence)

To re-image the source at the experiment:

Mirror minor, saggittal radius:

$$R_1 := \frac{2 \cdot F_1 \cdot F_2}{F_1 + F_2} \sin(\theta)$$ $R_1 = 300.4\ mm$

Mirror major, tangential radius:

$$R_2 := \frac{R_1}{(\sin(\theta))^2}$$ $R_2 = 144.9\ km$

J.A. HOWELL AND P. HOROWITZ

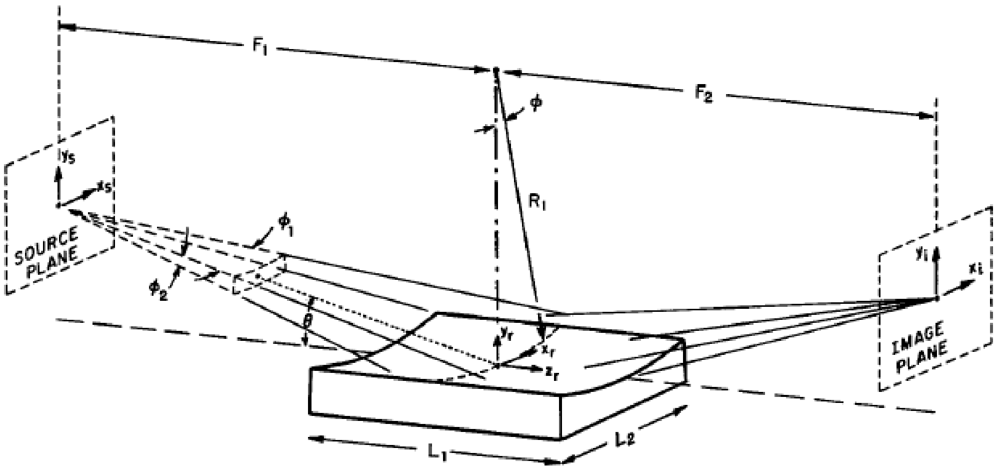

Fig. 1. X-ray condensing-mirror geometry.

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Other important factors in the Offset Mirror Systems design:

Is adequate time available/scheduled to procure the mirrors?

Historically, SSRL silicon mirrors in the 1 m length class have required 8 to 12 months to produce.

A very recent, informal conversation with a qualified mirror vendor suggested that our mirrors might be produced in substantially less time than this.

The present XTOD schedule could allow approximately 12 to 15 months between the completion of an optical element FDR and the installation of the mirror systems. This should allow adequate time for mirror procurement.

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Thank you!

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