10TH INTERNATIONAL CONFERENCE
MEDSI 2018
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION
CITÉ INTERNATIONALE UNIVERSITAIRE PARIS
25-29 JUNE

Mechanical Engineering Instrument Design and Development for LCLS-II

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SLAC National Accelerator Laboratory

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Introduction & Outline

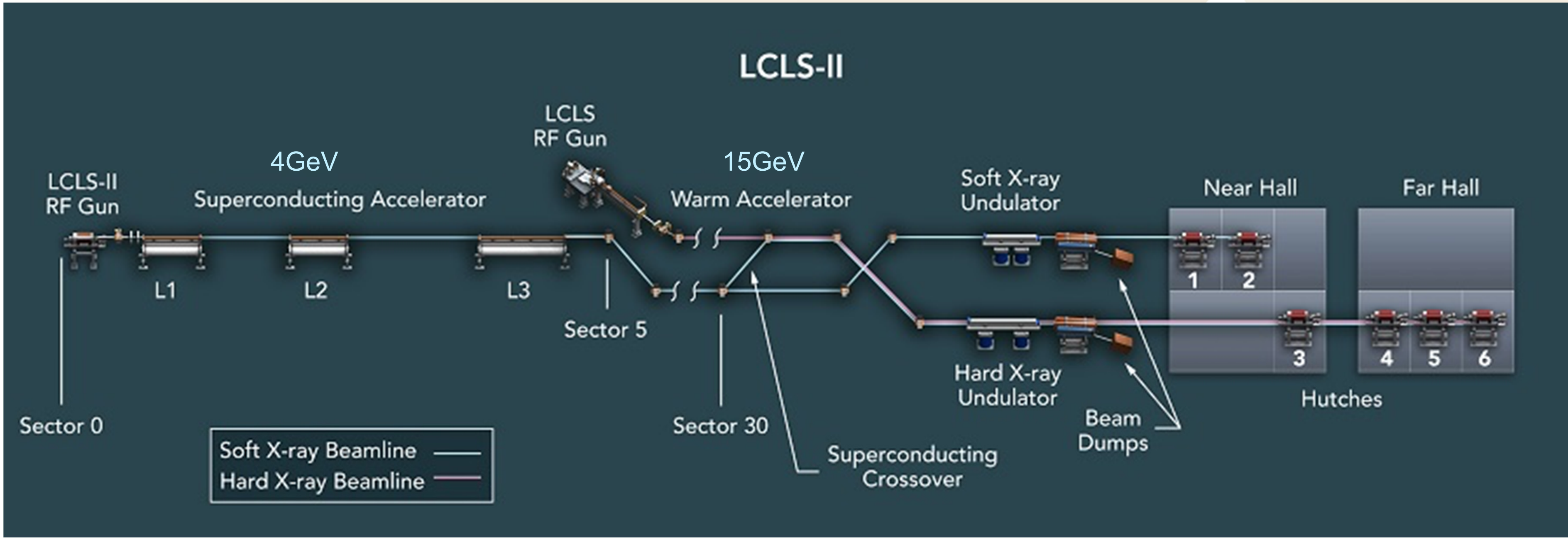
FEL versus Synchrotron Radiation

- **COMMONALITIES:** X-rays, photon energy, diffraction, absorption, scatting, spectroscopy, imaging, mirror, VLG monochromator, crystal monochromator, focusing optics (KB mirror, CRL transforcator,…), and many similar components (slits, diagnostics, detectors,...)
- **Specificities of FEL**
  - Extreme high peak power (intensity) → single short damage, more gas/liquid sample
  - Fully coherence → wavefront preservation
  - Short pulse, time structure → time resolved, pump-probe experiments

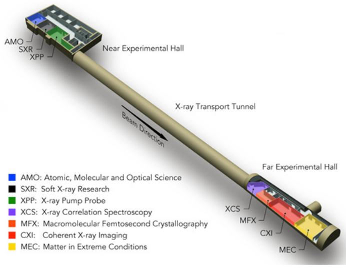
Outline of this presentation

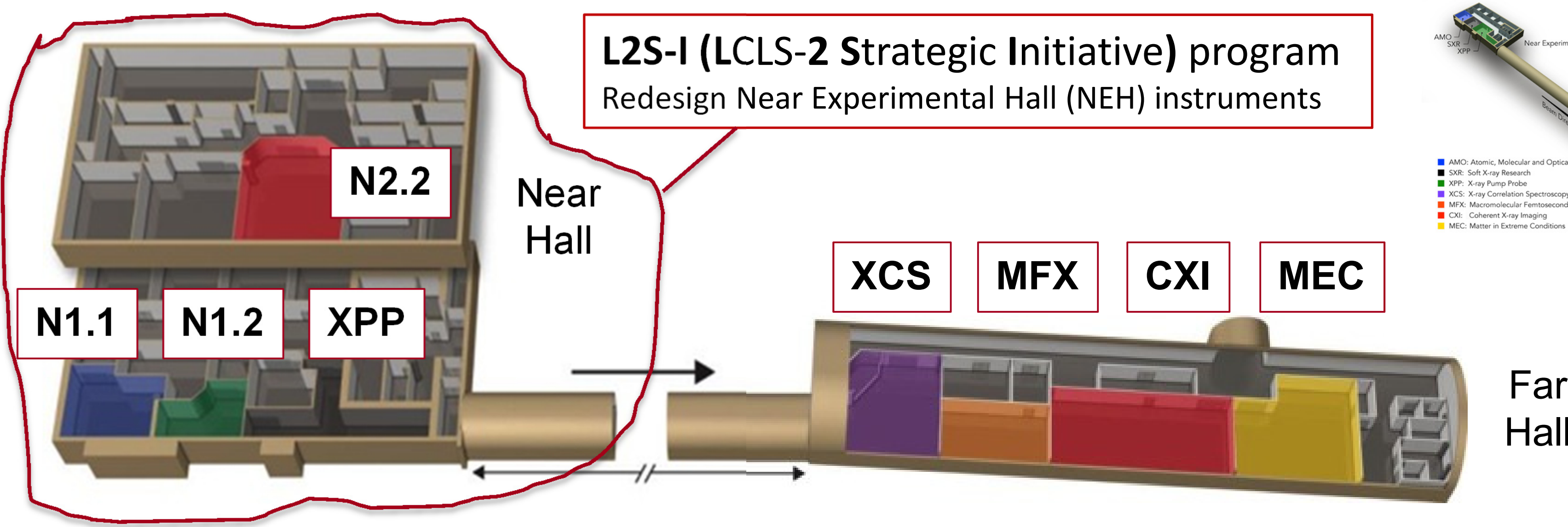
- **Short presentation of LCLS-II, L2S-I, LCLS-II-HE**
- **Some examples of ME Instrumentation development**

LCLS-II, L2S-I

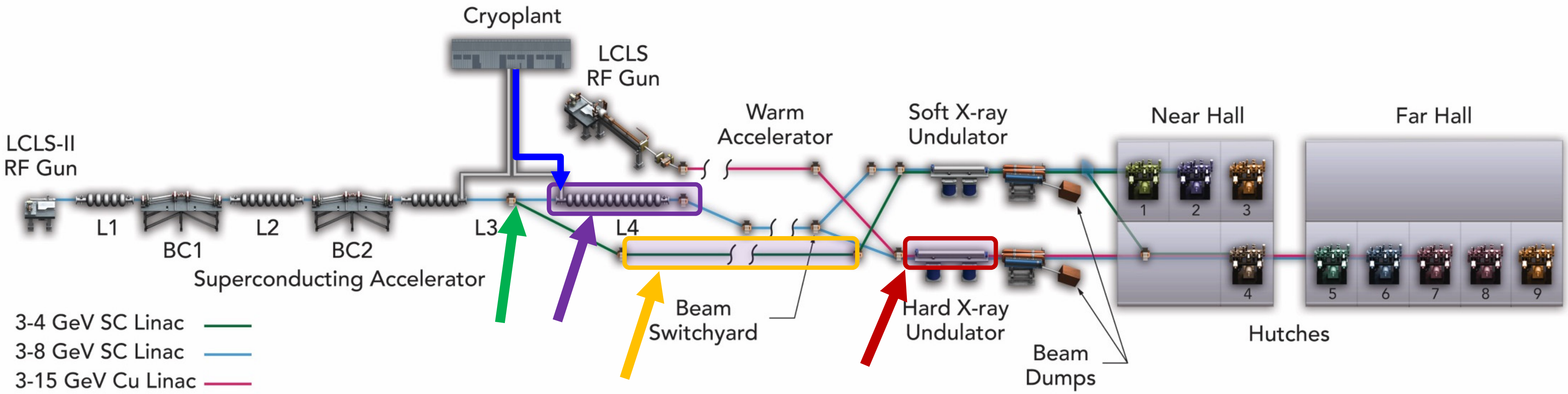


L2S-I (LCLS-2 Strategic Initiative) program
Redesign Near Experimental Hall (NEH) instruments





LCLS-II-HE

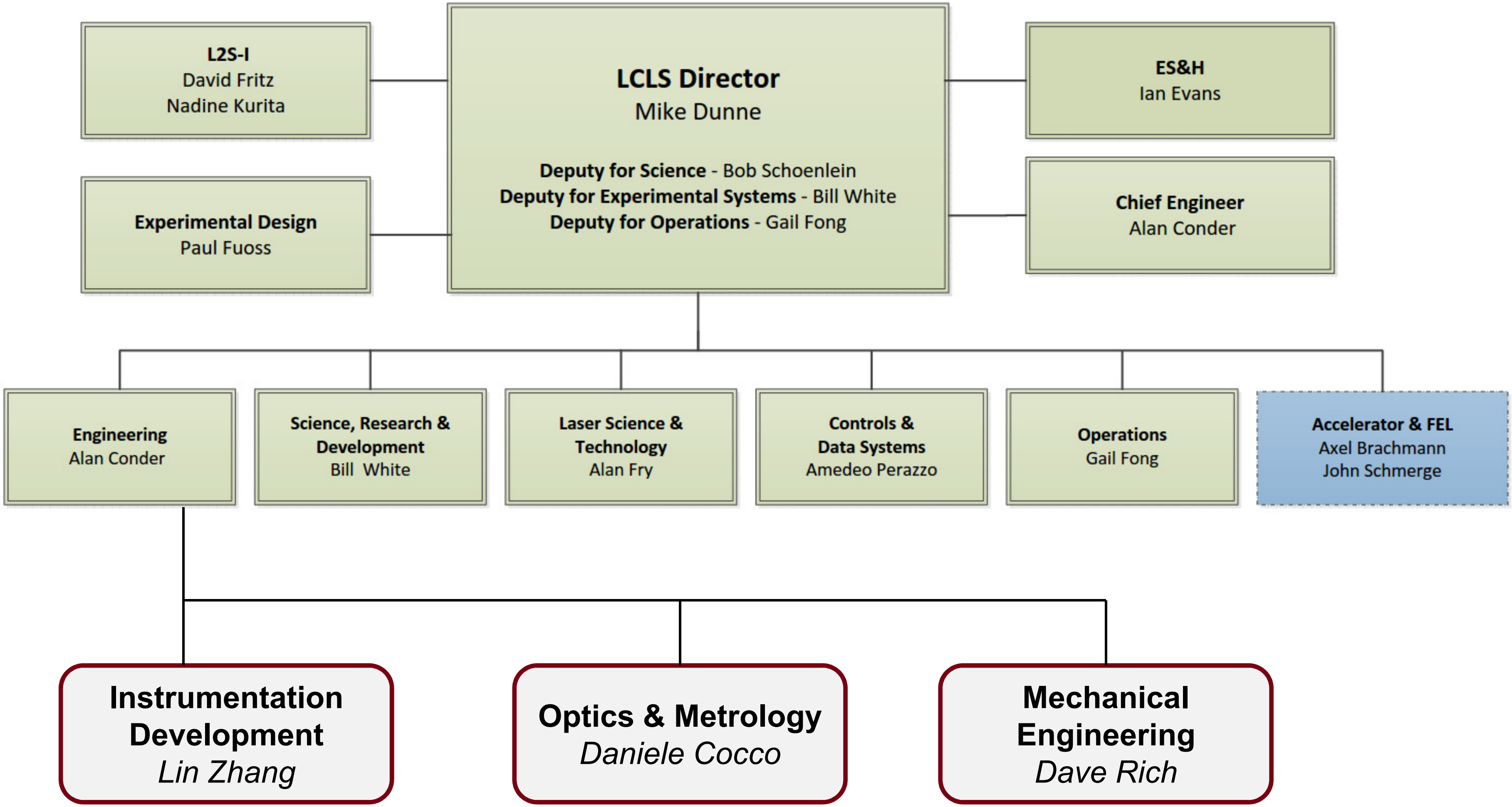


1. Upgrading the LCLS-II superconducting linac to 8 GeV
2. Installing a new cryoplant and transfer line
3. Addition of a pulsed low-energy extraction point at 3.8 GeV
4. Beam swithyard
5. Installation of a Hard X-ray Self Seeding (HXSS)

Table 3 – Level 1 Milestones

Level 1 Baseline Milestones	Schedule
CD-0 - Approve Mission Need	December 5, 2016
CD-1 - Approve Alt. Select. & Cost Range	September 2018
CD-3A - Approve Long Lead Procurement (LLP)	September 2019
CD-2 – Approve Performance Baseline	January 2023
CD-3 – Approve Construction Start	January 2023
CD-4 - Project Complete/Start of Operations	June 2028

LCLS ME Instrumentation Development



LCLS ME Instrumentation Development

Instrumentation Development
Lin Zhang

Cheng, Xianchao
Morton, Daniel
Schafer, Donald
Shi, Hongliang
Wang, Hengzi

Lee, Lance *
Janowitz, Jiya **

- Opto-mechanics
- Optics design & engineering
- Precision Mechanics
- High-heat load engineering
- Engineering Physics R&D
- Multiphysics & ME analysis
- Vibration measurement and analysis

LCLS

LCLS-II
L2S-I
LCLS-II-HE

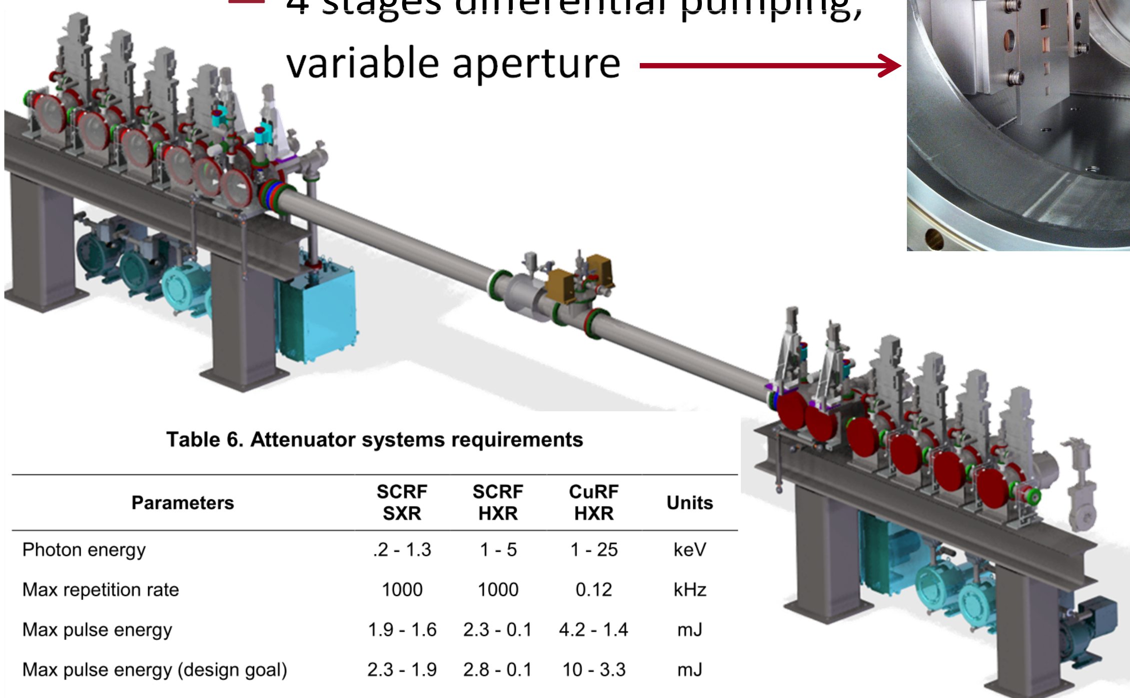
Diego Huyke Villanueva (?)
2nd PhD student

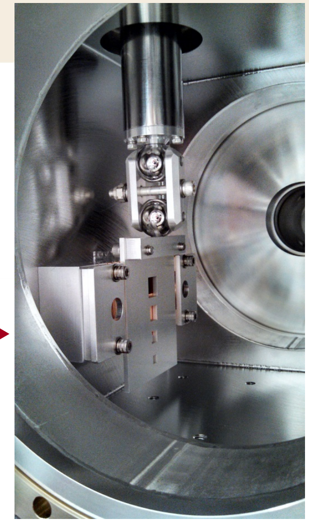
Some examples

Gas attenuator for LCLS-II

SLAC

- Pwr_{max} = 200 W
- Attenuation coef. = 1 ~ 10^{-5}
- $P_{ar\ or\ N2}$ = 0.3 ~ 40 torr
- Vacuum pressure: *10^{-9} Torr*
- 4 stages differential pumping, variable aperture →





pressure wave

hot core

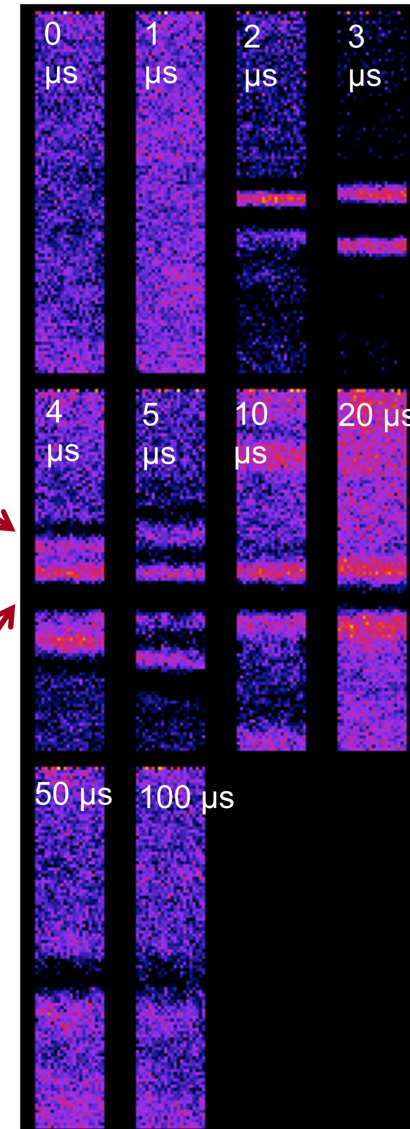


Table 6. Attenuator systems requirements

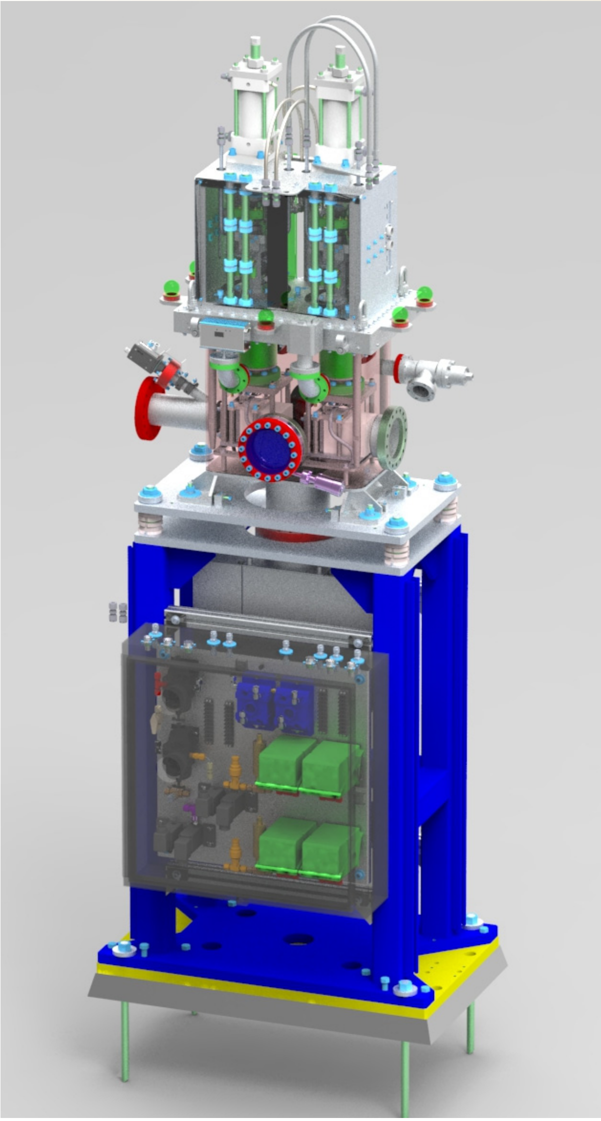
Parameters	SCRF SXR	SCRF HXR	CuRF HXR	Units
Photon energy	.2 - 1.3	1 - 5	1 - 25	keV
Max repetition rate	1000	1000	0.12	kHz
Max pulse energy	1.9 - 1.6	2.3 - 0.1	4.2 - 1.4	mJ
Max pulse energy (design goal)	2.3 - 1.9	2.8 - 0.1	10 - 3.3	mJ
Max average power	200	200	1.2 - 0.4	W
Attenuation coefficient	1 - 10^{-5}	1 - 10^{-3}	1 - 10^{-3}	-
Coefficient granularity	3 per	3 per	3 per	decade
Relative stability of attenuation coeff.	10	10	10	%

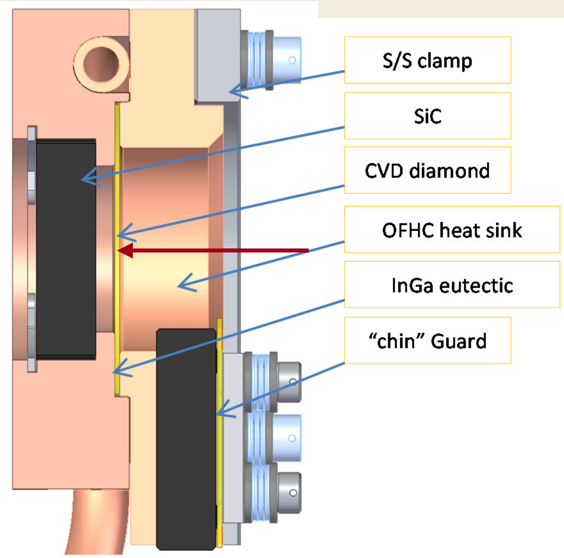
Donald Schafer *et al.*

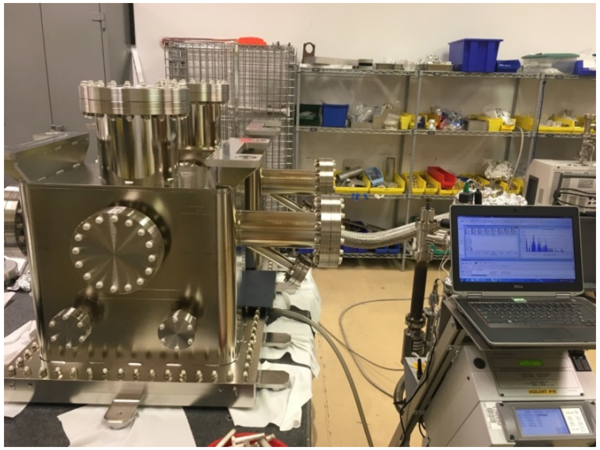
LCLS-II photon beam stop (PPS)

Hangzi Wang *et al.*

TUPH39







	SXR	HXR
Photon energy (eV)	250 - 1300	1000 - 5000
Beam divergence (µrad)	3 - 18	1.4 - 4
Beam size (mm, rms)	0.5 – 1.9	0.15 – 0.4
Max. power (W)	**880**	**519**
Max. power density (W/mm^2)	**500**	**700**
Max. single pulse (mJ)	**8.8**	**4.6**
Max. repetition rates (MHz)	1.0	1.0

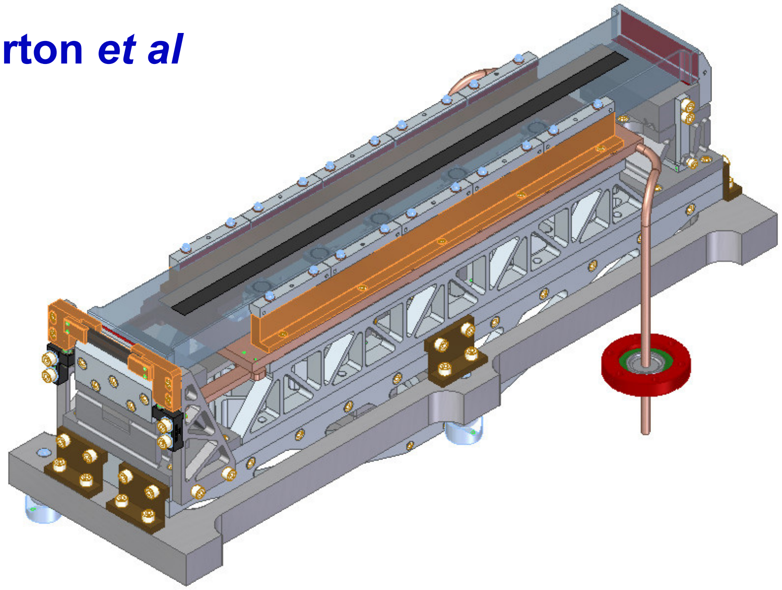
L2S-I Bendable Mirrors

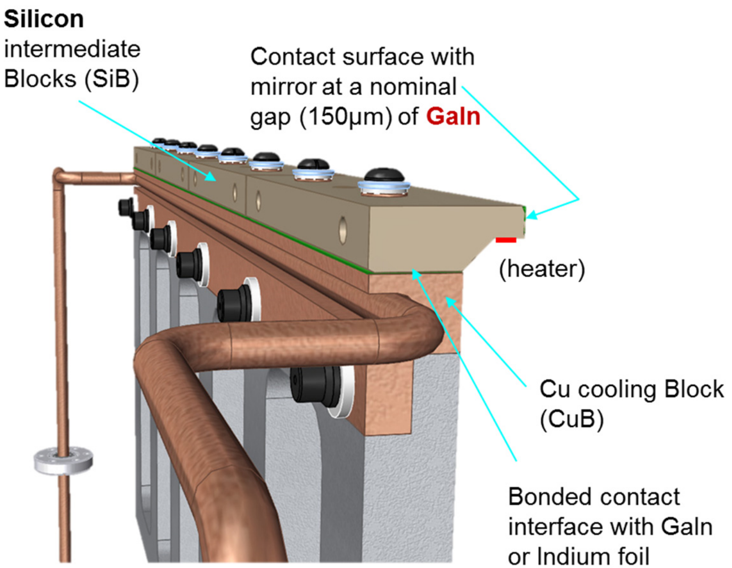
Some key figures:

Daniel Morton *et al*

THPH34

- **Sub-nm height error**
- **Water cooled**
  - — P_{FEL} = 20 W (200 W)
- **Dynamically bendable**
  - — Large bending (R~200 m)
  - — 2-blocks flexor bender
  - — Twist correction
  - — In-vacuum actuator
  - — Capacitive sensor for mirror shape monitoring
- **Eutectic GaIn interface**
  - — Good thermal contact
  - — Weak mechanical coupling

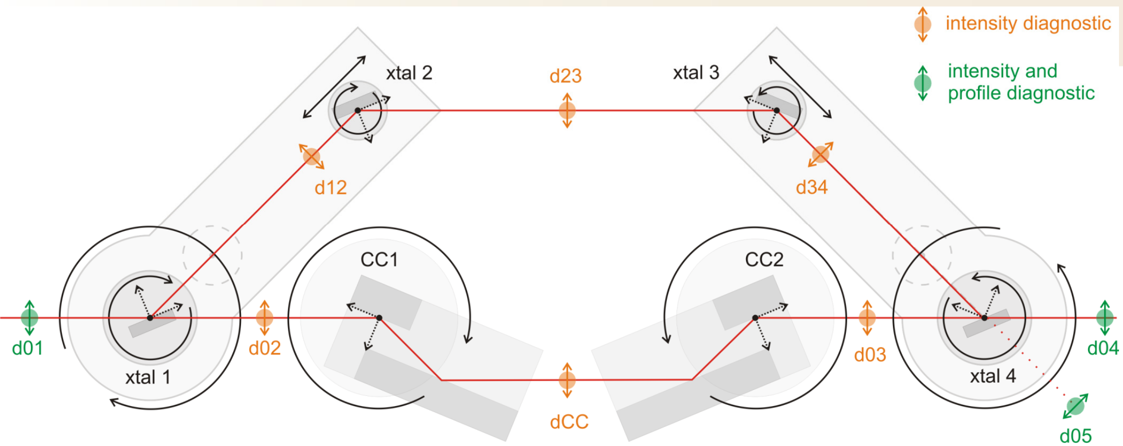


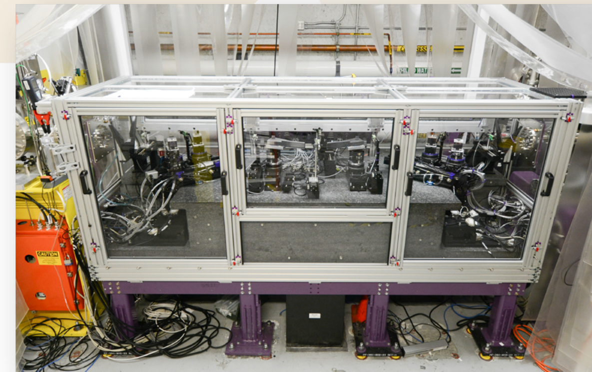


For L2S-I, 9 bendable mirrors:

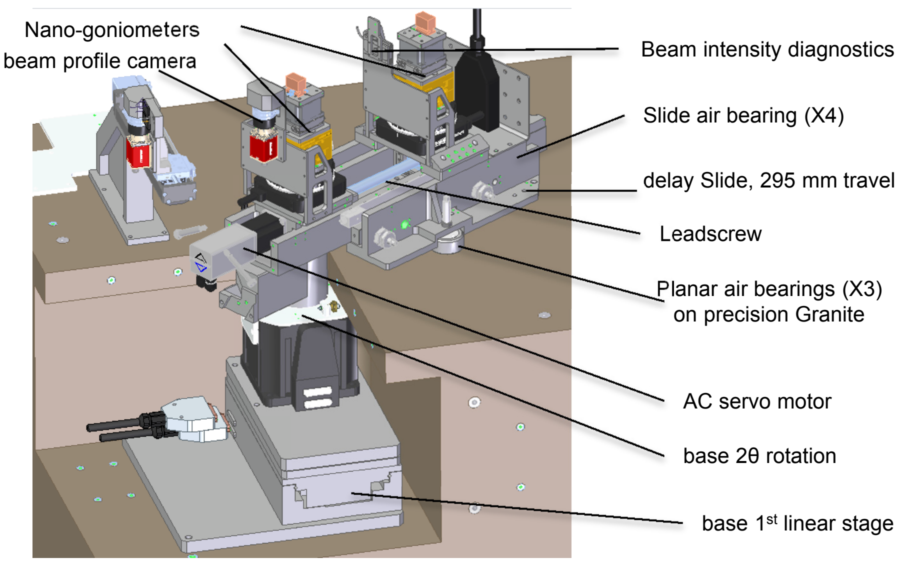
- — 4 pairs bendable KB systems
- — 1 VFM for VLS gratings mono

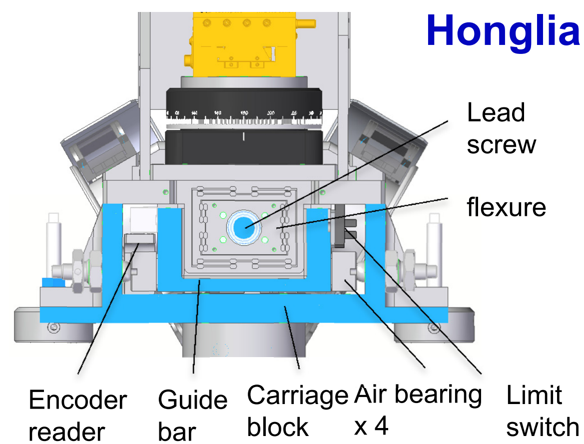
Split and Delay System





Delay range	-5 to 500 ps at 8 keV
Energy range	6.5-26 keV
Focal spot size	Down to 1-2 um spot
Overlap precision	10% of beam size at IP
Stability	20% of beam size at IP



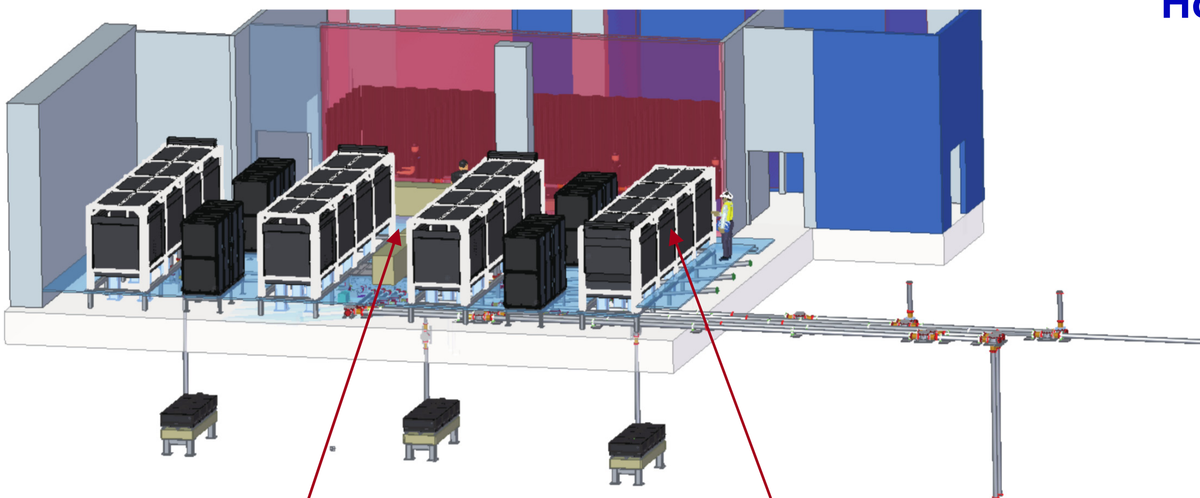


Hongliang Shi *et al.*

D. Barada:
TUPH37

Laser Transport

Laser Hall

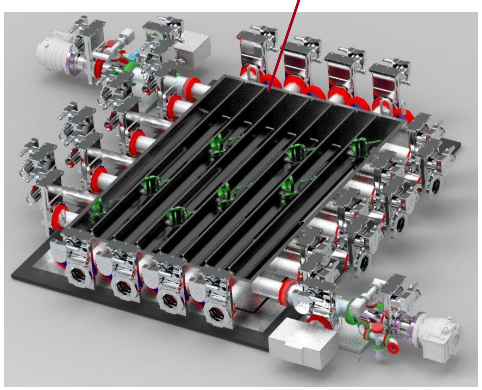


Hongliang Shi *et al.*

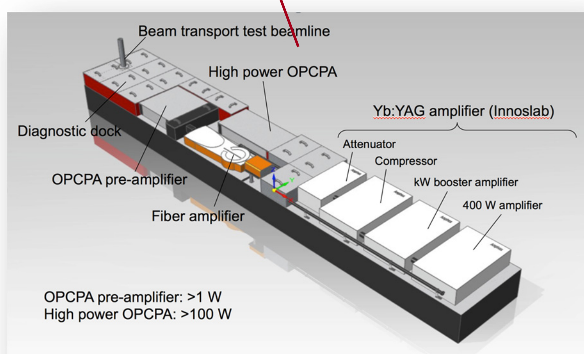
Mechanical design work

- Laser hall construction
- Laser transportation design
- Motion system design
- Optical mechanical design
- Metrology for beam alignment
- Components installation
- Vacuum design

- Timing: <10 fs
- Repeatability: 10 µrad
- Stability: 10% beam size



Switch box

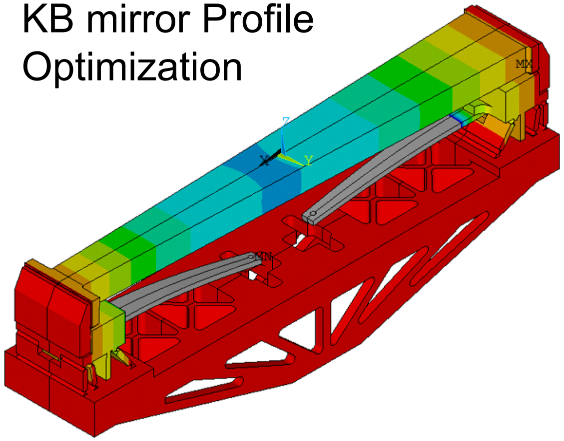


Laser system : **>40W, <20fs, 100kHz**

FEA supporting L2S-I program

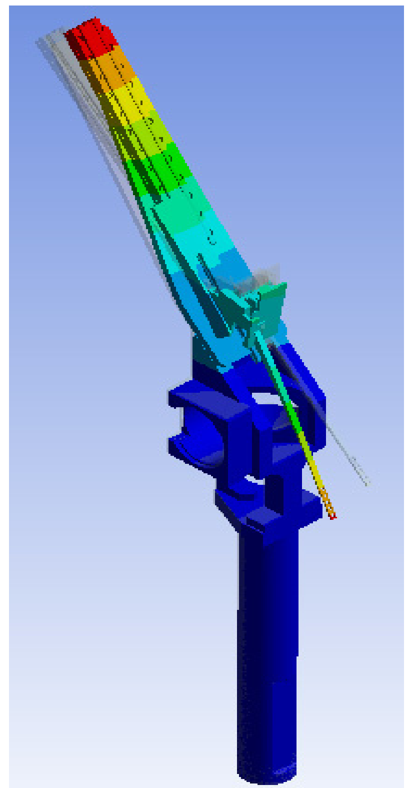
X-ray optics

KB mirror Profile
Optimization



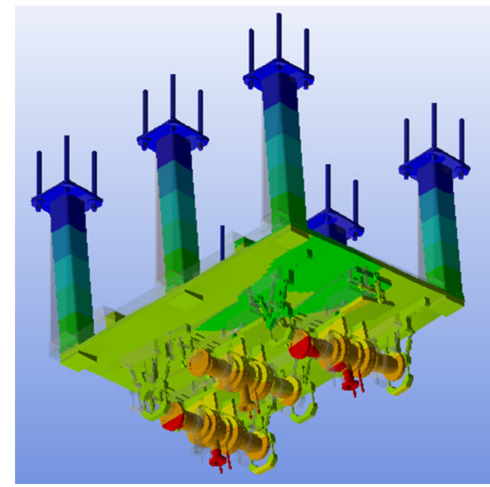
NEH1.1 TMO

Out-coupling Diagnostics
modal analysis *(90.4Hz)*



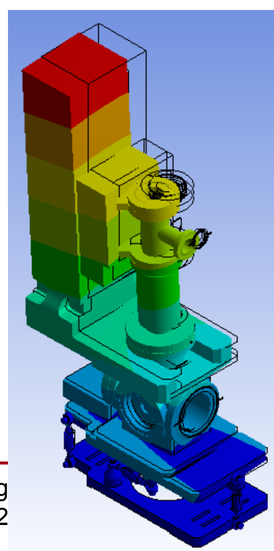
NEH2.2 RIXS/LJE

Top raft (3 Common Comp.)
modal analysis *(36.9 Hz)*



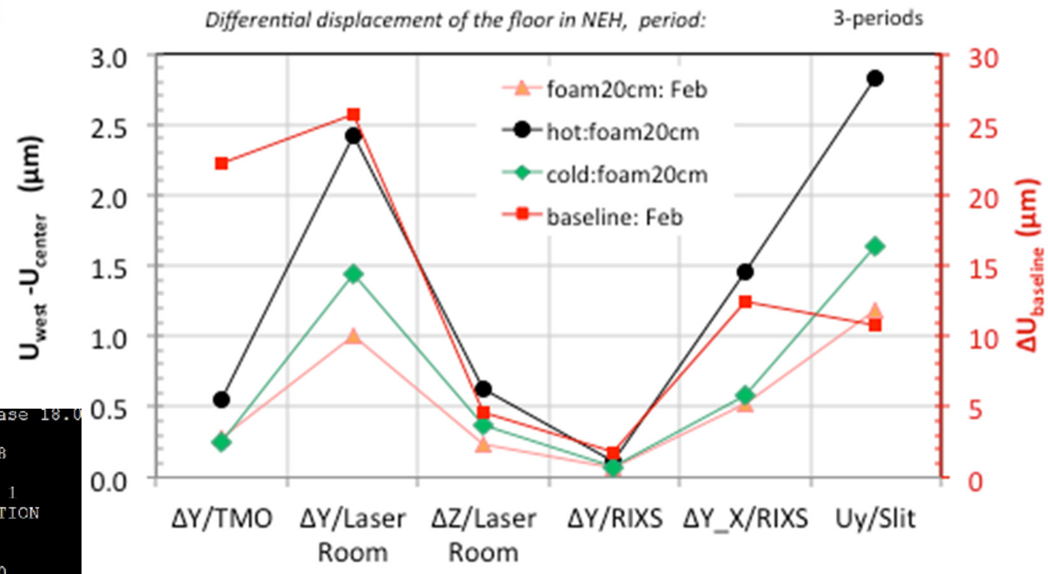
Common Components

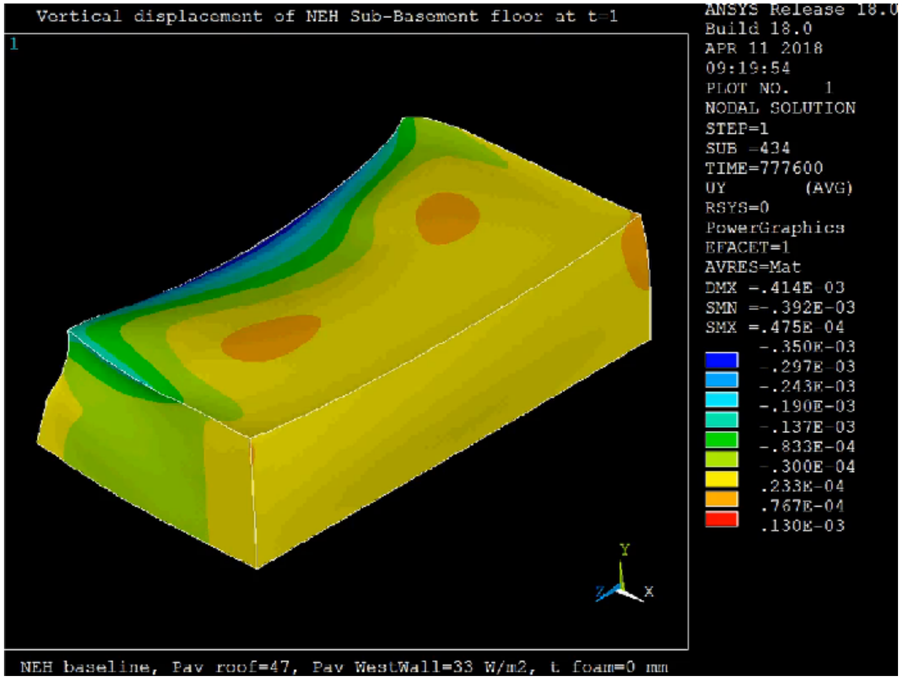
BPM modal analysis
(40 Hz)

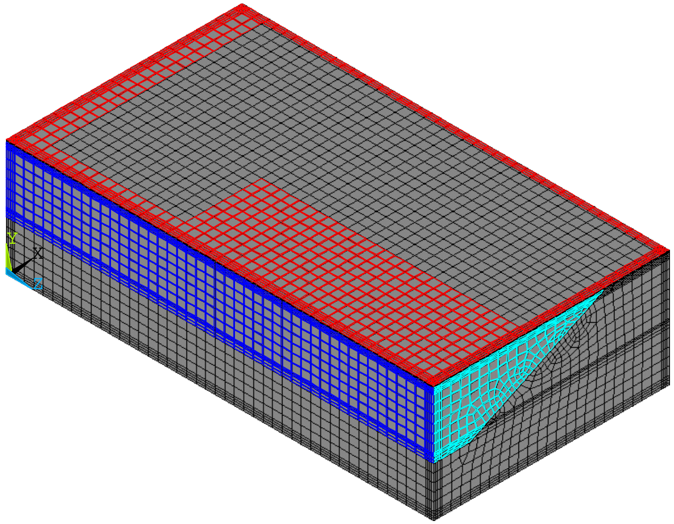


Xianchao Cheng *et al.*

FEA supporting L2S-I program





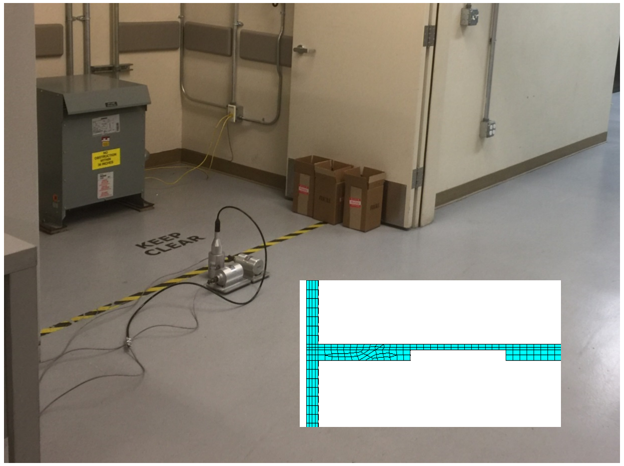


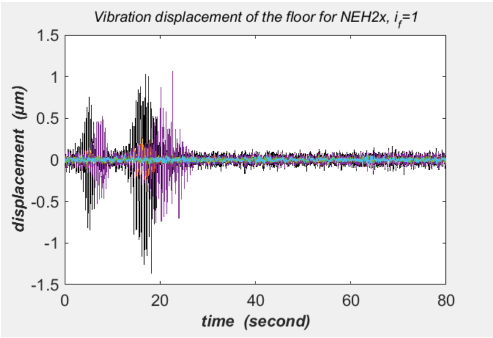
Vibration measurement and analysis

SLAC

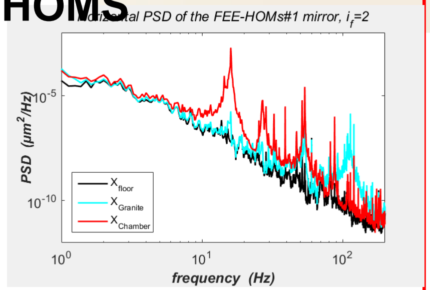
- Floor: baseline data **with Lance Lee's helps**
- Instruments: KB mirror, HOMS mirror, optics, granite and metallic stands, Dil fridge,…

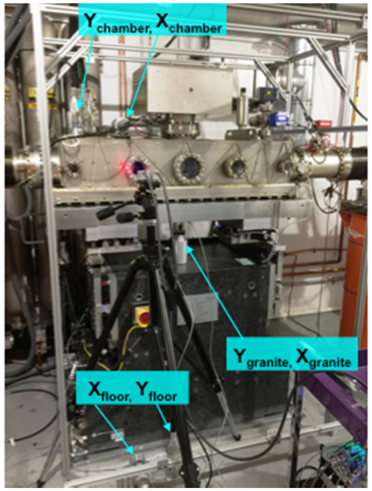
Floor for NEH2.2 RIXS



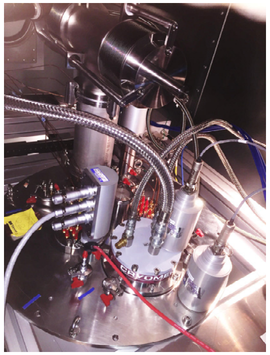


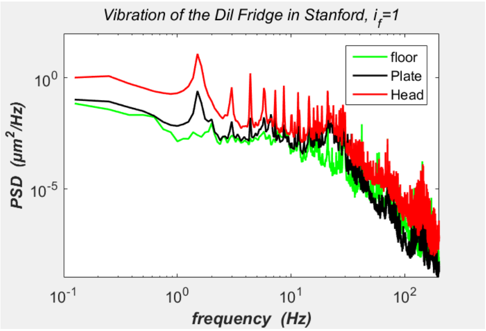
HOMS



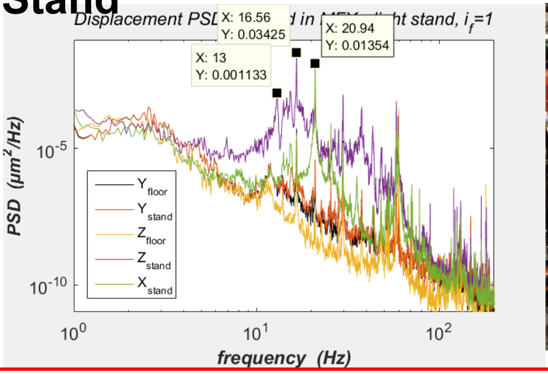


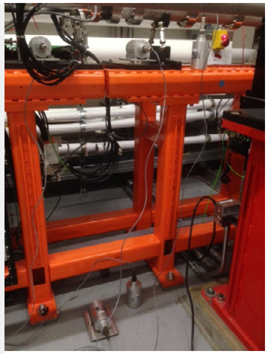
Dil Fridge



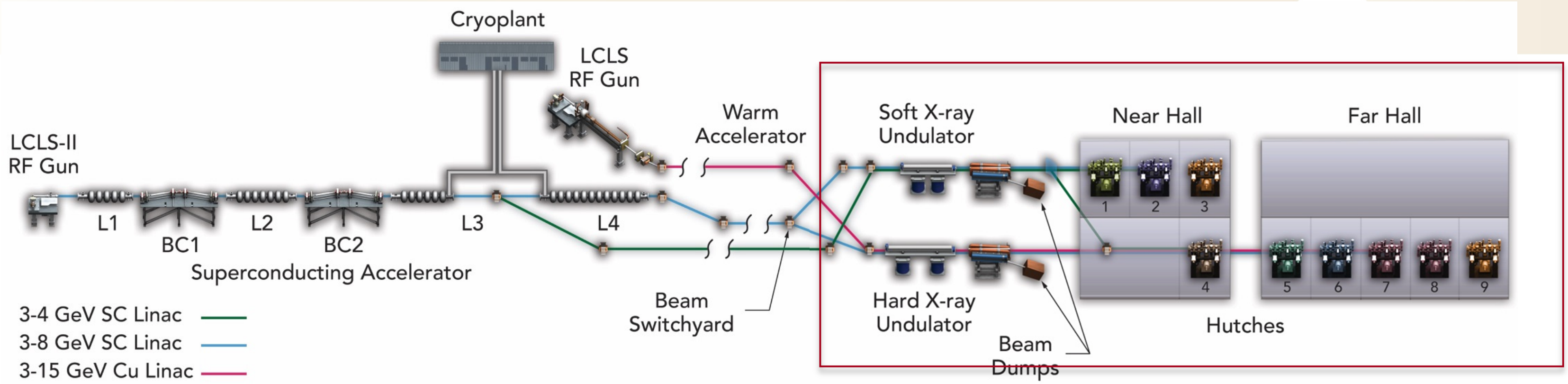


Stand





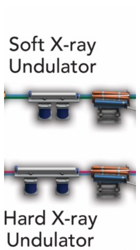
Some other projects



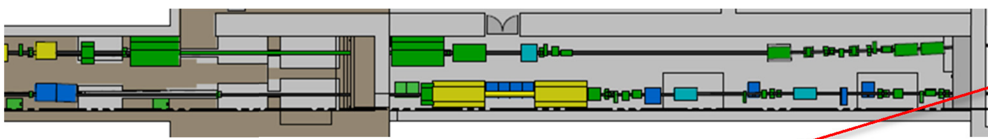
Some other projects

SLAC

Undulators



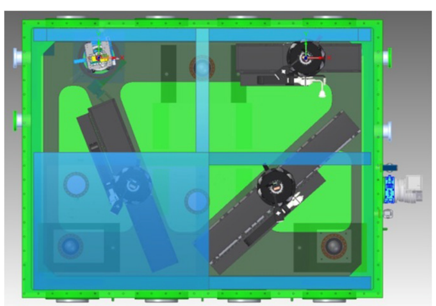
FEE (Front-End Enclosure)



NEH

FEH

- **Instrument TXI**
  - Delay line (special mono)



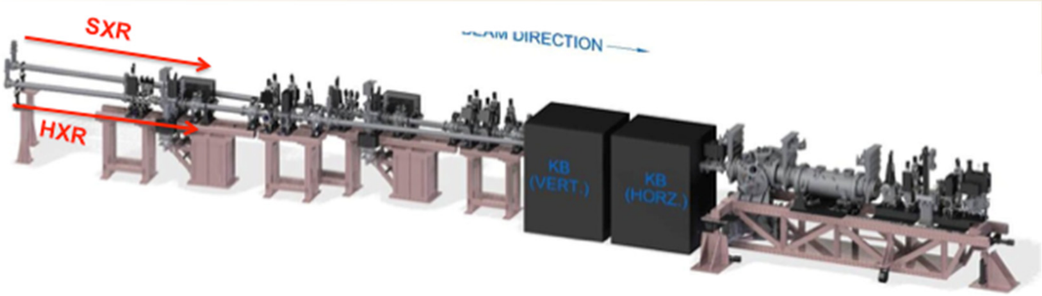
- **Instrument XPP**
  - CCM
    - **LODCM**
  - LJE
  - Transfocator
  - Exit Window

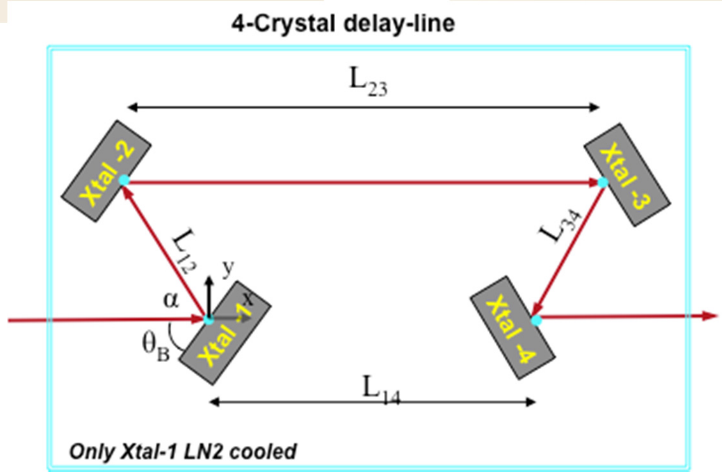
HongLiang Shi, Hangzi Wang,
Serge Guillet, Antonio Cedillos

LCLS-II-HE

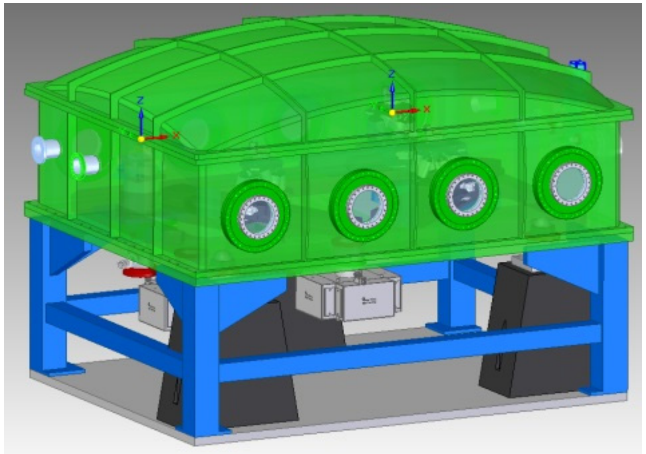
- **Instrument DXS**
  - **High eR mono** (1~10meV, >12 keV)
  - Transforcator
- **Instrument CXI**
  - KB mirror

TXI delay line



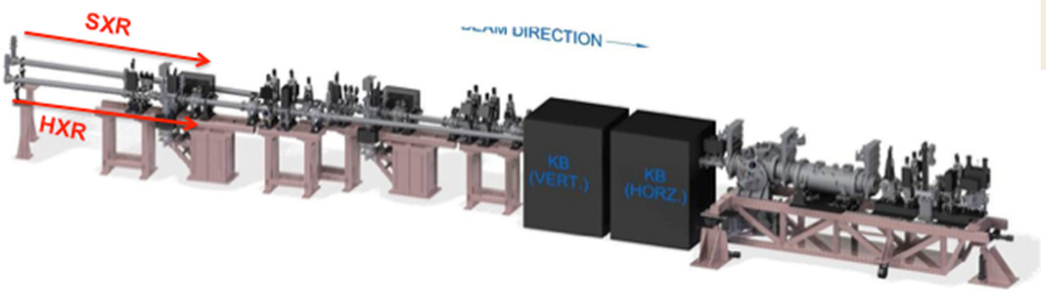


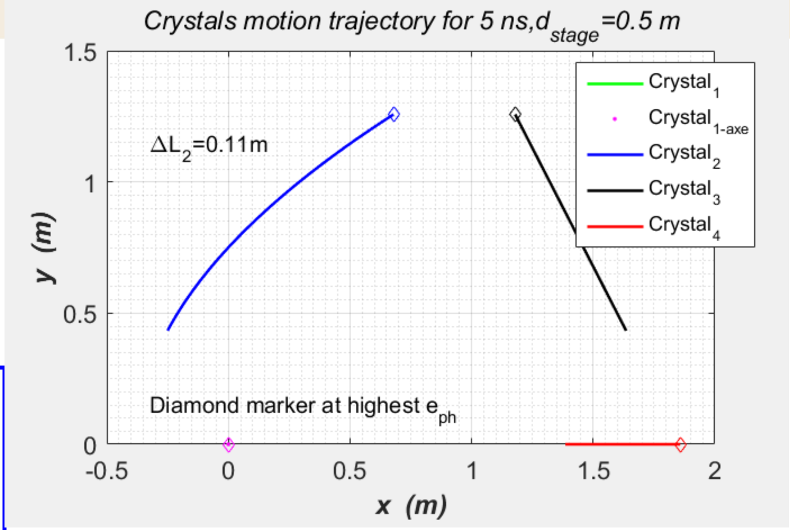
- **TXI Time delay line for HXR branch**
  - 4 pairs of crystals to: Si(111) + Si(220) = 1 pair
  - Covered photon energy range: 2.28 – 6.3 keV
  - HXR power: **20 W**
  - Required HXR delay
    - **5 ns ±** (1 ns) : 1.5 m ± 0.3 m, **accuracy 2.5 fs**
  - 1st pair of crystals: **LN2 cooled**, fixed position
  - Other 3 pairs of crystals: T-controled, straight linear motion trajectories
- **To keep beam parallel and fixed exit**
  - Boron doped Silicon crystals (uncooled) for 2nd pair to match lattice distance of Silicon at T_{LN2} (1st pair)
  - Accurate temperature control of the crystal (~10 mK)



TXI delay line

SLAC





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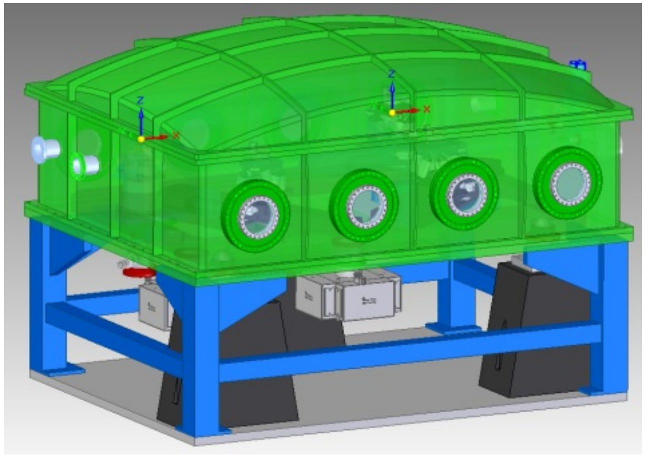
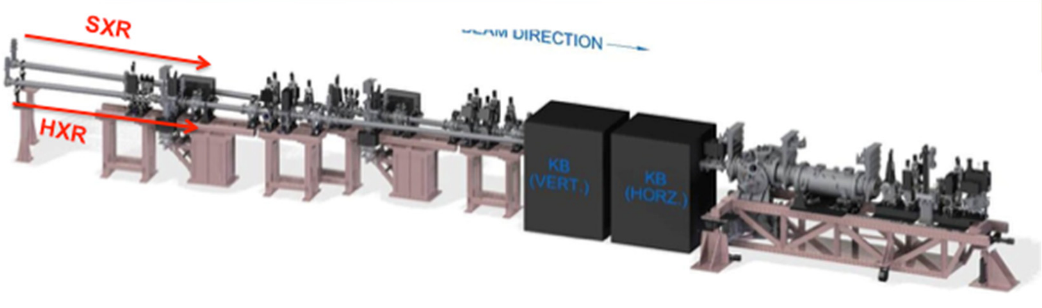
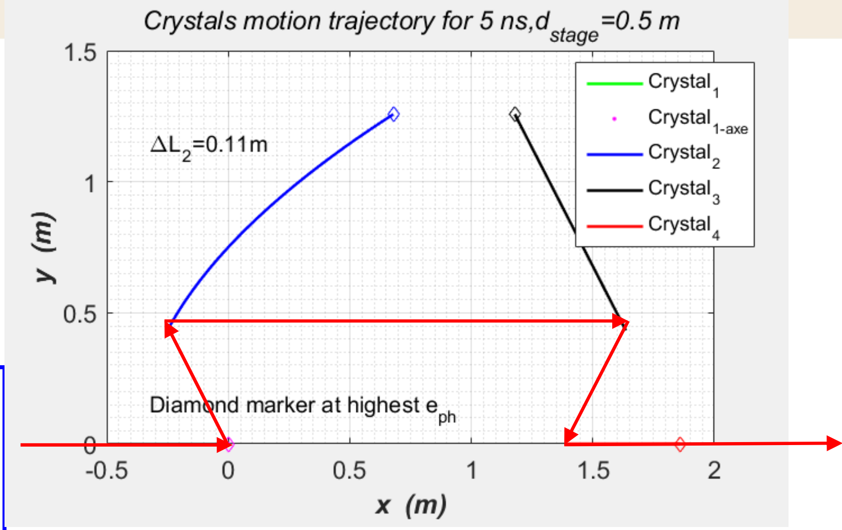


TXI delay line





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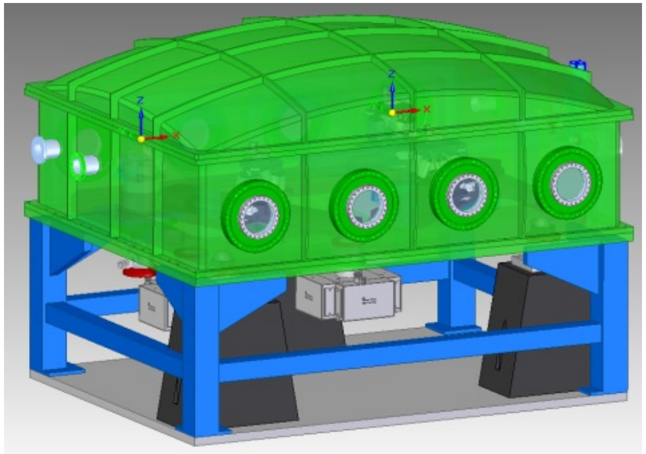
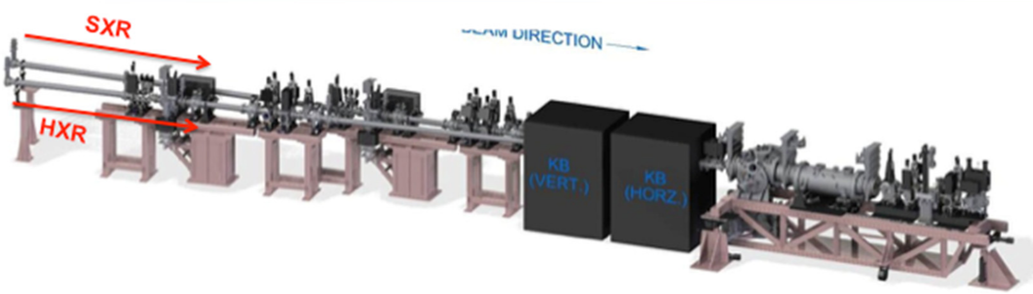
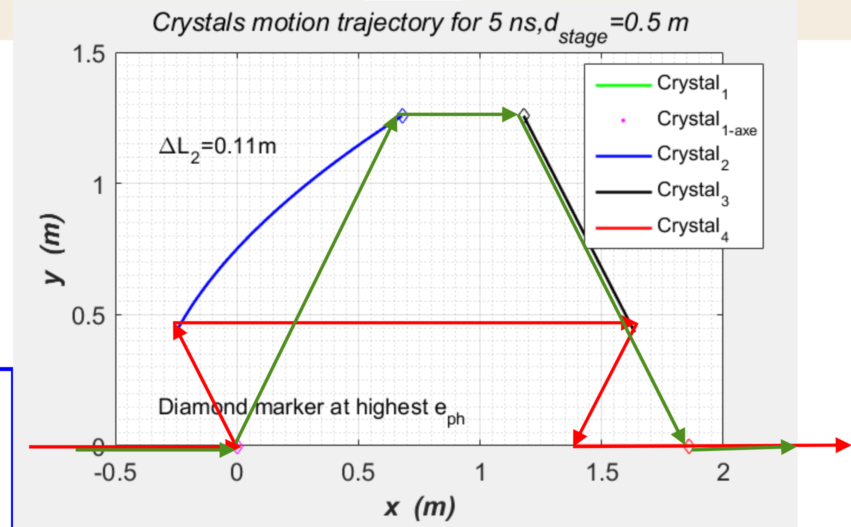


TXI delay line





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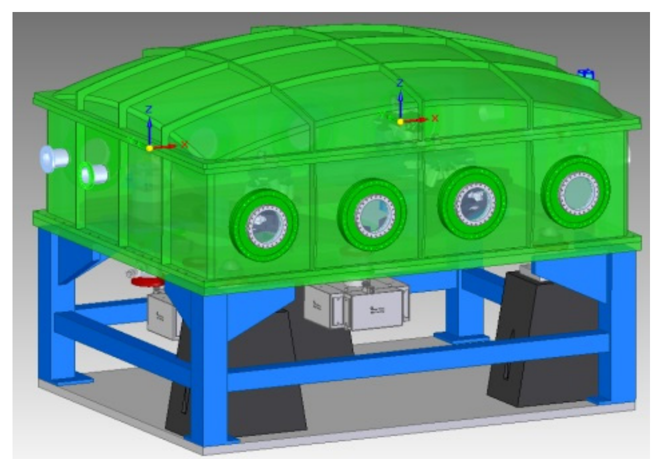
  - Boron doped Silicon crystals (uncooled) for 2nd pair to match lattice distance of Silicon at T_{LN2} (1st pair)
  - Accurate temperature control of the crystal (~10 mK)

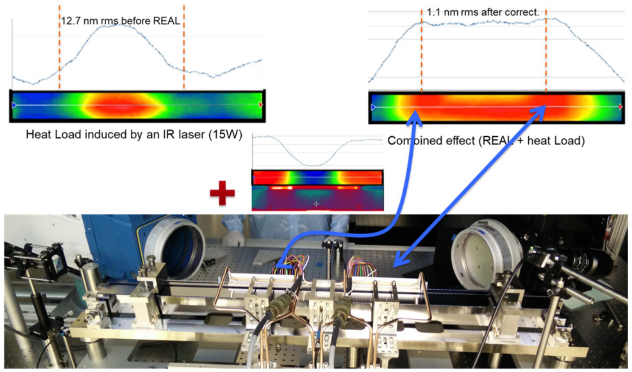


R&D projects

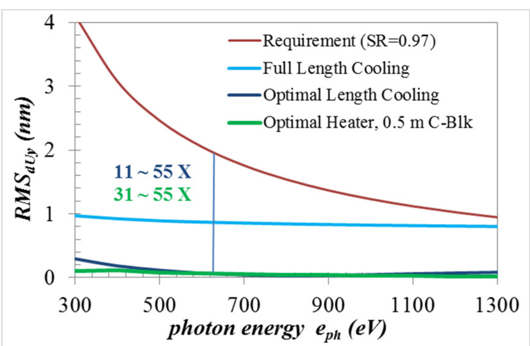
with Xianchao Cheng & Lance Lee's helps

REAL cooled optics

Active compensation to reduce FEL power induced deformation

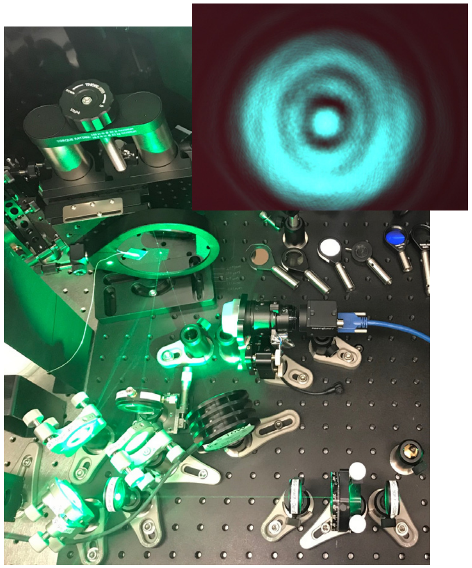


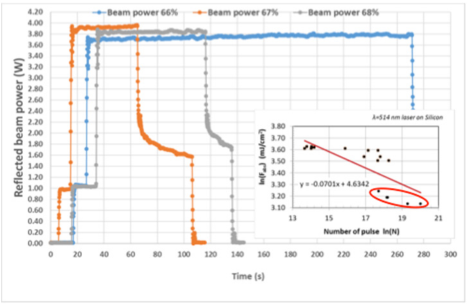
(**Corey Hardin: THOPMA05**)



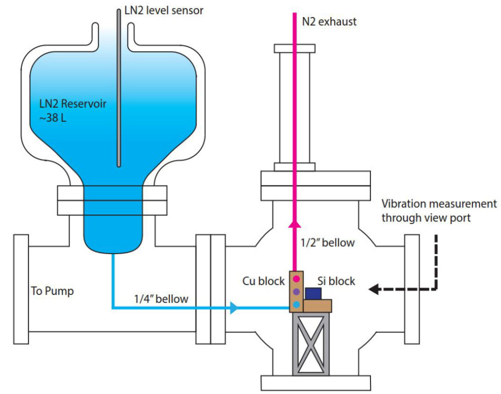
JSR 2015, Zhang et al.

Large No. pulses fatigue damage





LN2 cooling by phase change



Some other projects

- ✓ **Doped Silicon Crystal**
- ✓ **Time-resolved crystal thermal deformation**
  - **Exp. + simulation**
- ✓ *Eutectic GaIn mechanical properties*
- ✓ **Optics cooling**
- ✓ Close form solution

Thank you for your attention