Progress of the FEL-SSS station

TAC report

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2025-10-20

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SSS-introduction

SSS - Soft X-ray Scattering and Spectroscopy Endstation

Technique:

soft X-ray resonant elastic scattering, absorption, and resonant inelastic X-ray scattering spectroscopy based time resolved studies.

Scientific scope – solid state samples:

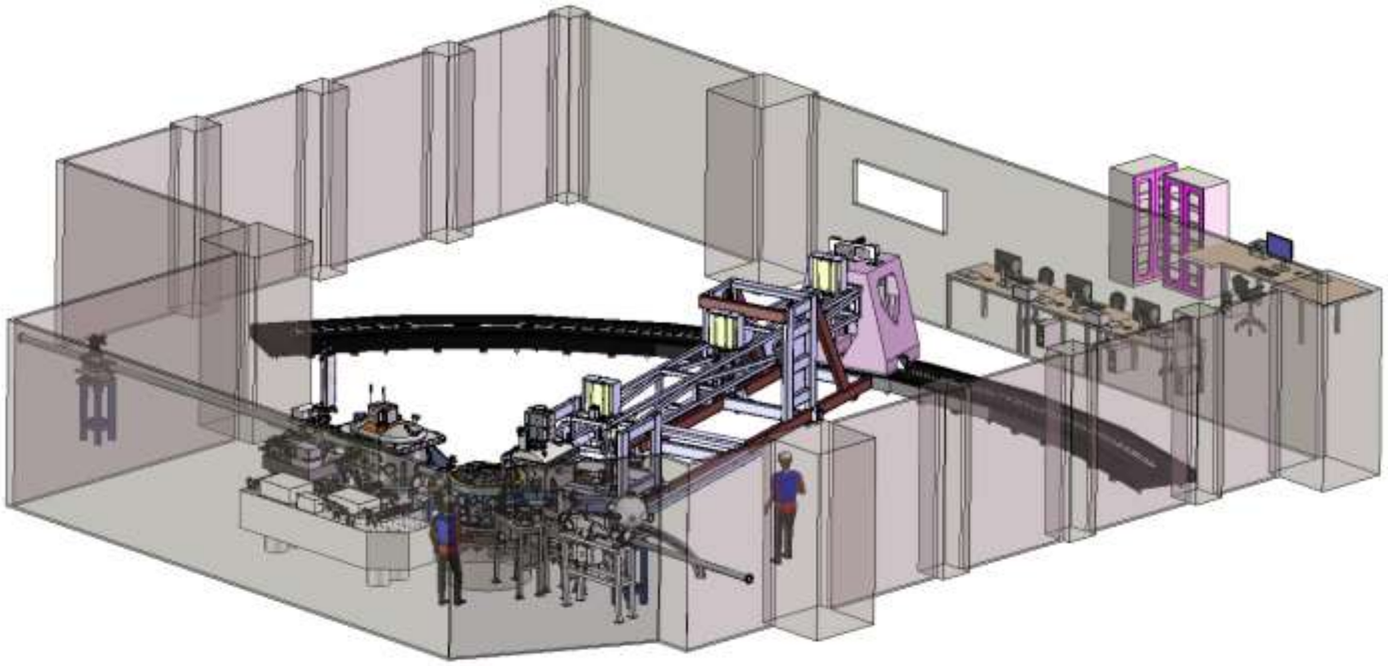
sub pico-second non-equilibrium evolution of the charge、spin and orbital dynamics in condensed matter physics, chemistry and energy materials.

Main parameters：

energy range: 400~1700eV

energy resolution:

On day-one	Design objective
100meV@930eV	50meV@930eV



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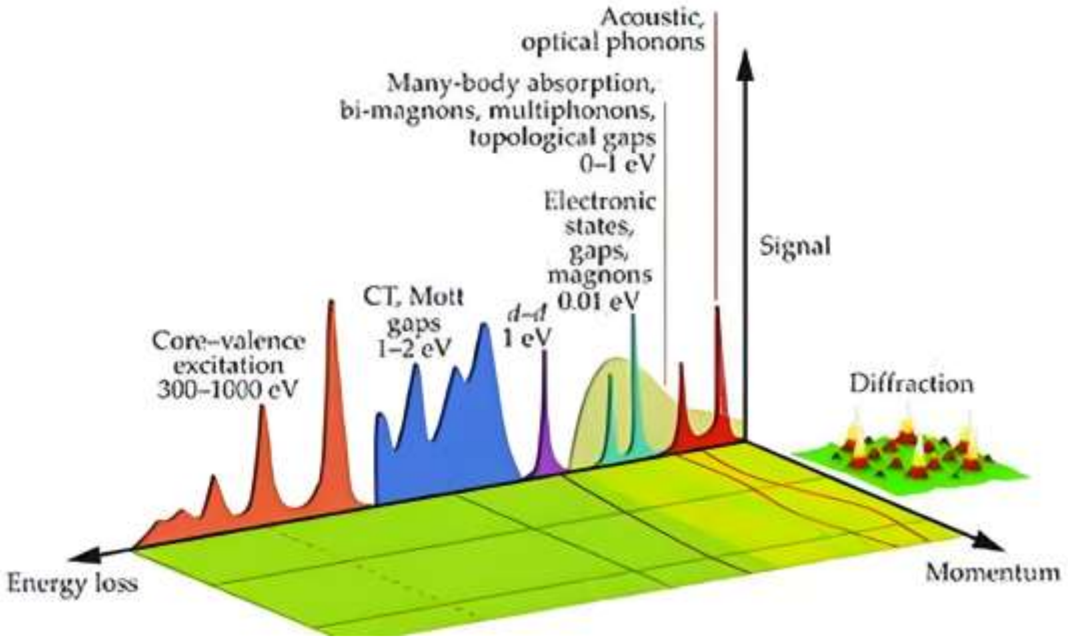
Technical specifics for beamline&endstatoin construction

- Upstream – high resolution monochromator with grating(s)
- Station – high resolution energy dispersion spectrometer with grating(s)

Optical requirements:

- Strong vertical focusing for RIXS energy resolution.
- High stability to achieve average small vertical spot.
- High average flux for weak RIXS signal.
- High rep-rate and moderate single shot strength to avoid sample damaging from strong focusing.



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SSS development process

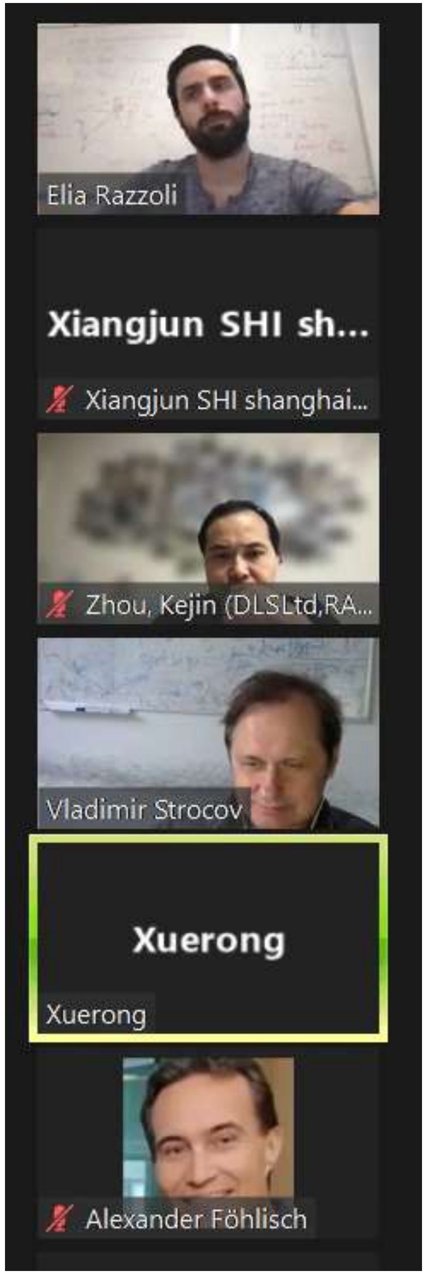
- 2018: launching of the project
- 2021: establishing the Machine Advisory Committee
- 2022: international review of the physical design
- 2024: international review of the technical design
- 2024.03: first contract for major components – focusing mirrors

Report of the 3rd MAC meeting

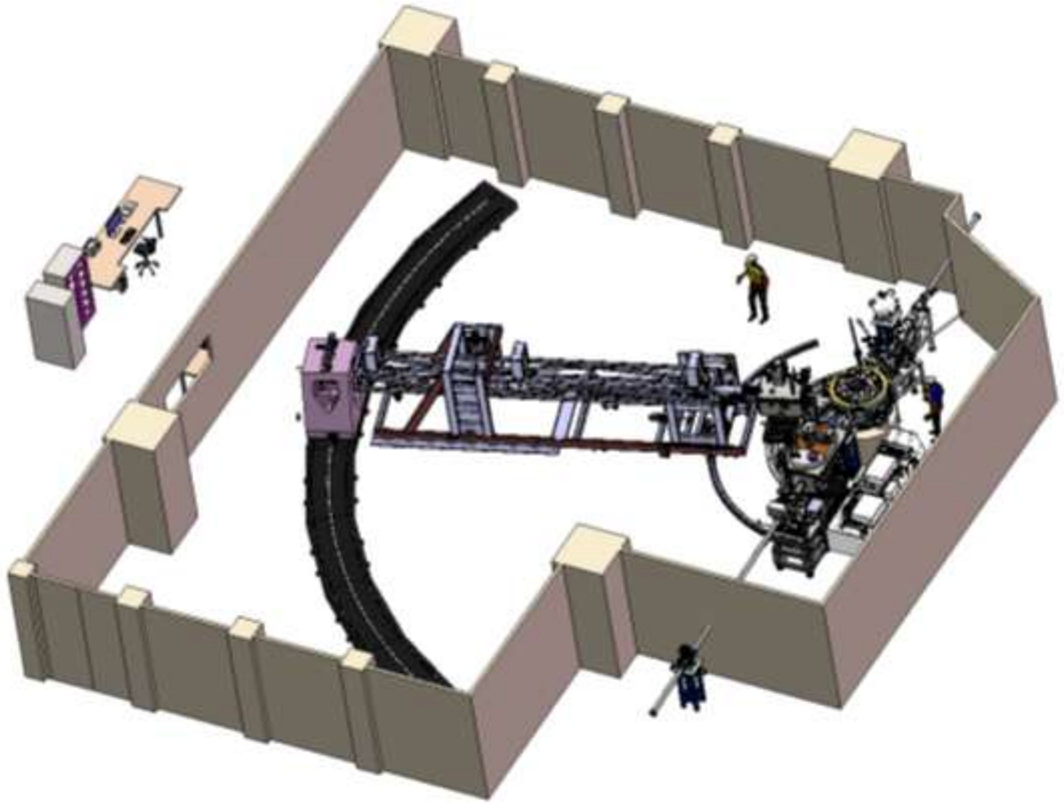
Kejin Zhou (Diamond, chair)
Vladimir Strocov (PSI)
Alexander Föhlisch (helmholtz-berlin)
Elia Razzoli (SwissFEL)

The MAC team for SSS at SHINE held the 3rd meeting on Jan, 5th 2023. Xuerong Liu, the group leader of the SSS station, made presentation about the progress of SSS. The meeting discussed the following major topics:

1. The optical design and the mechanical plan for optical element holding chamber.
2. The current mechanical design on the spectrometer arm and detector support.



Major components and the floor plan



Detector & supporting

Signal arm

Optics chamber

Hatch wall

Standard element target

Time diagnosis tool

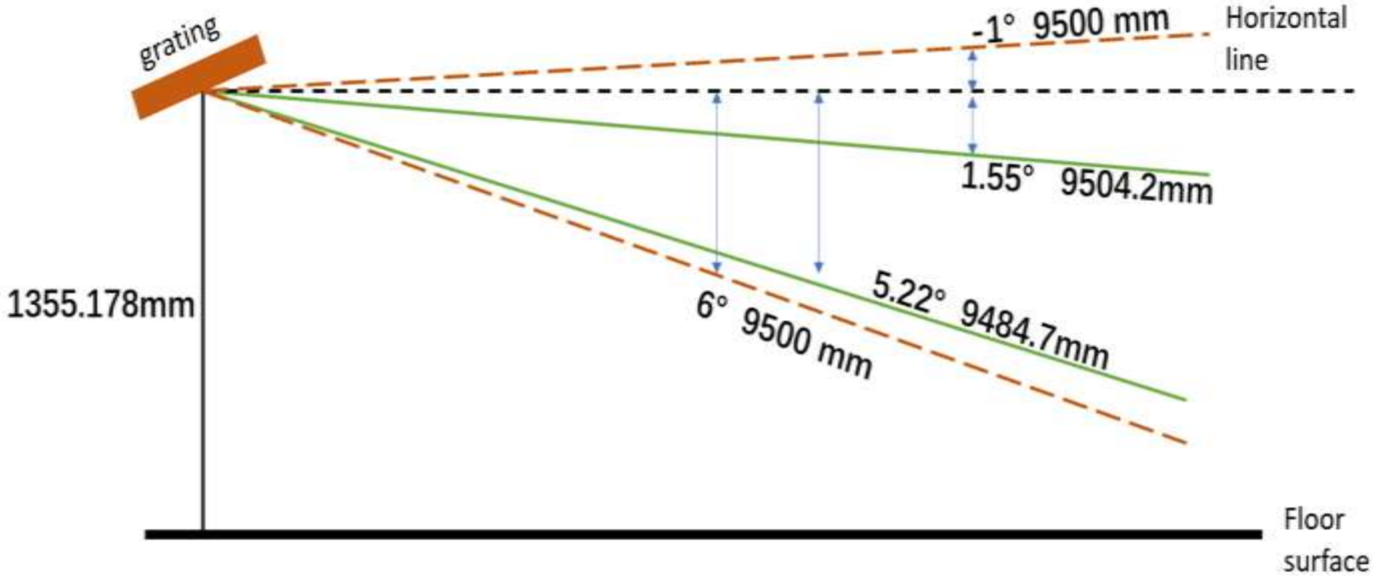
Focusing chamber

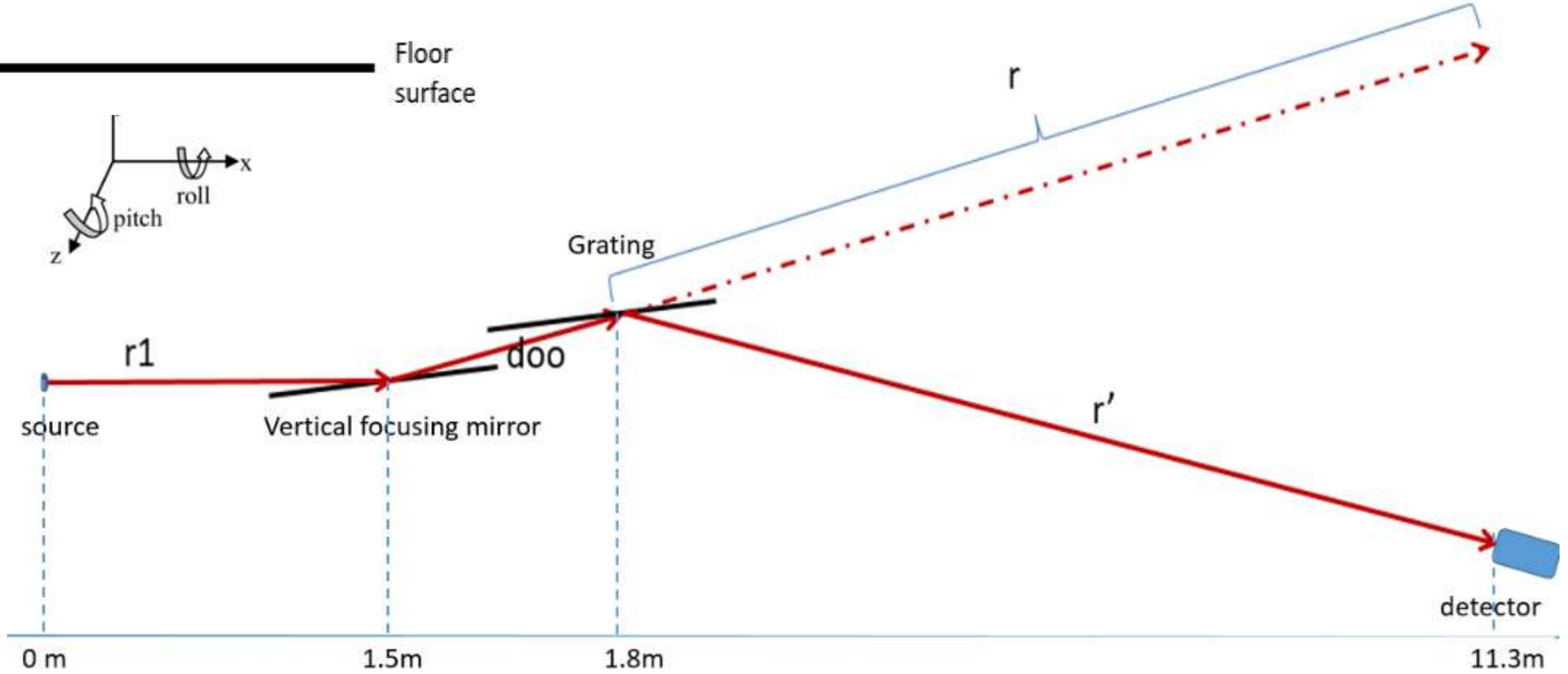
Front peripheral device

Sample chamber

End peripheral device

Optical principle





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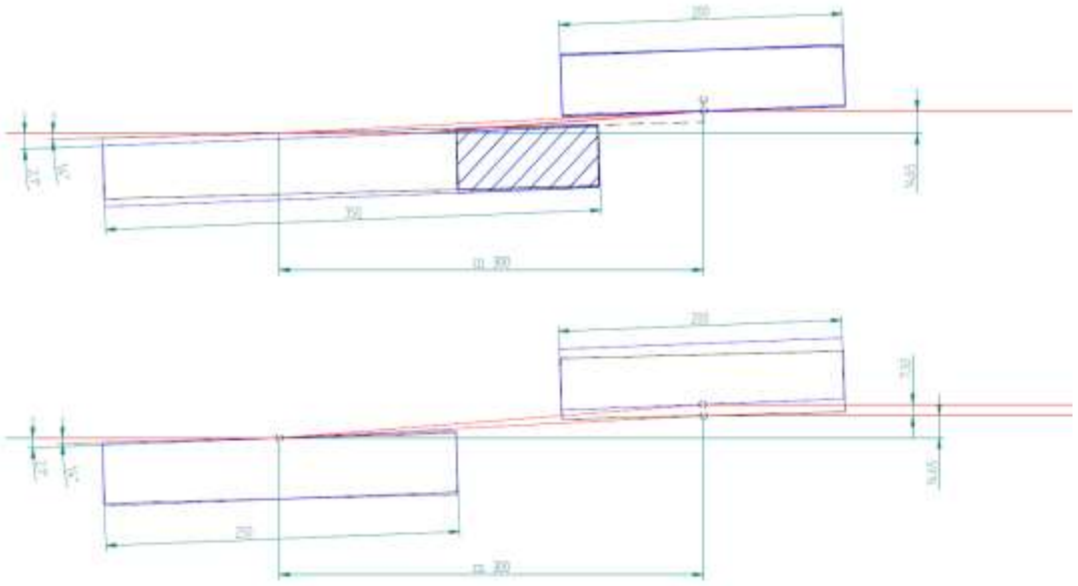
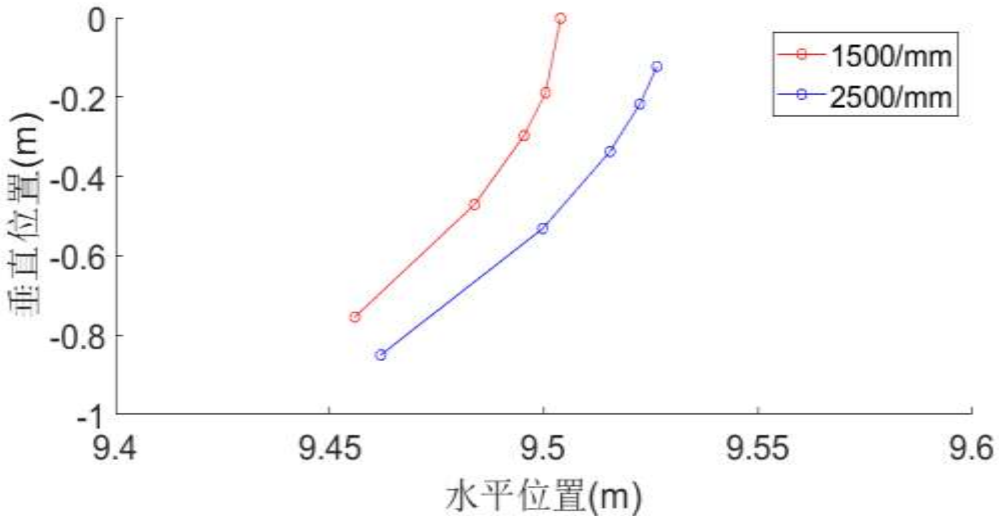
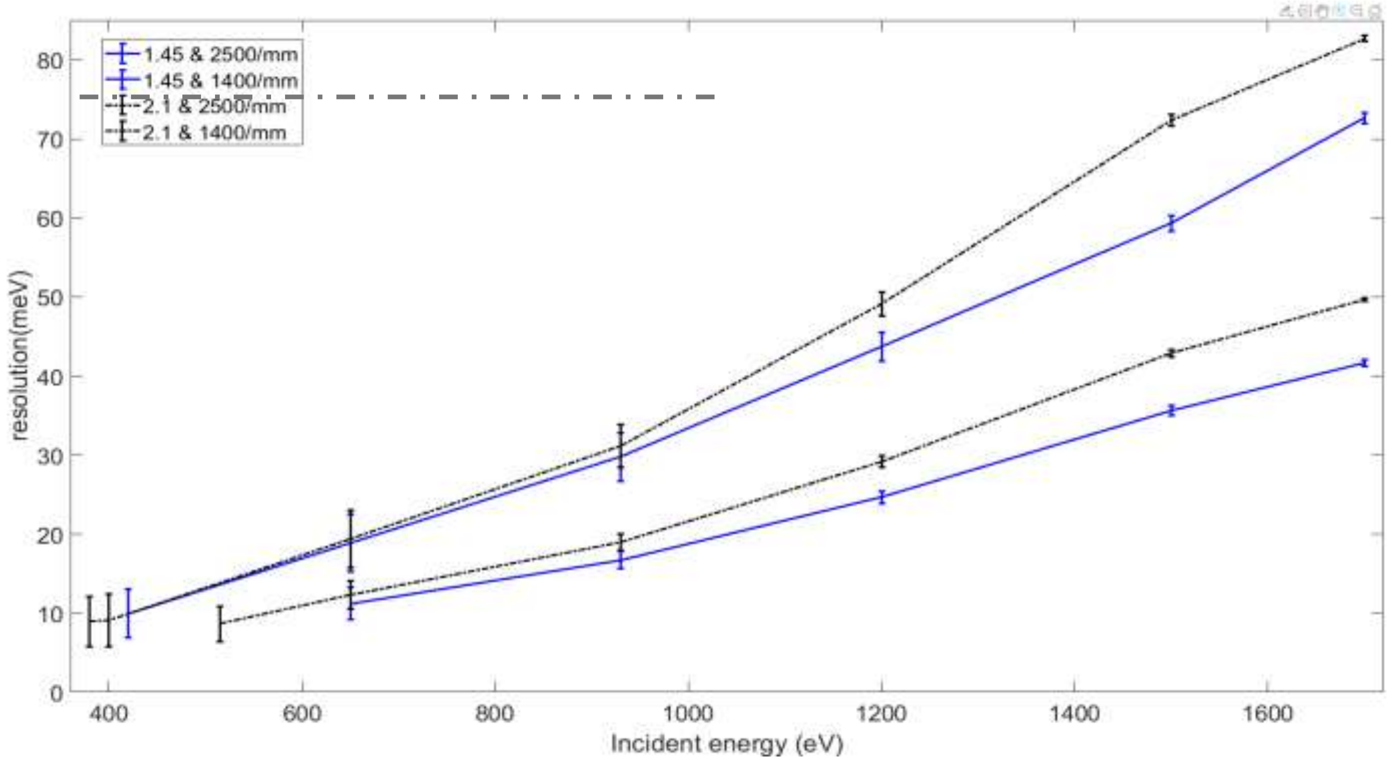
Optical principle

- Two pre-focusing mirrors for exchange
  1.45 degrees v.s. 2.10 degrees
- Three gratings for exchange
  1400 blazed; 2500 lamina; 2500 blazed

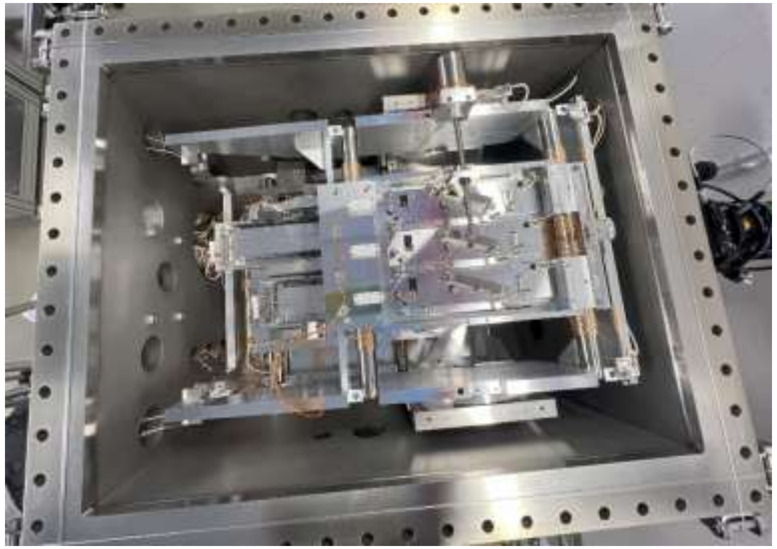


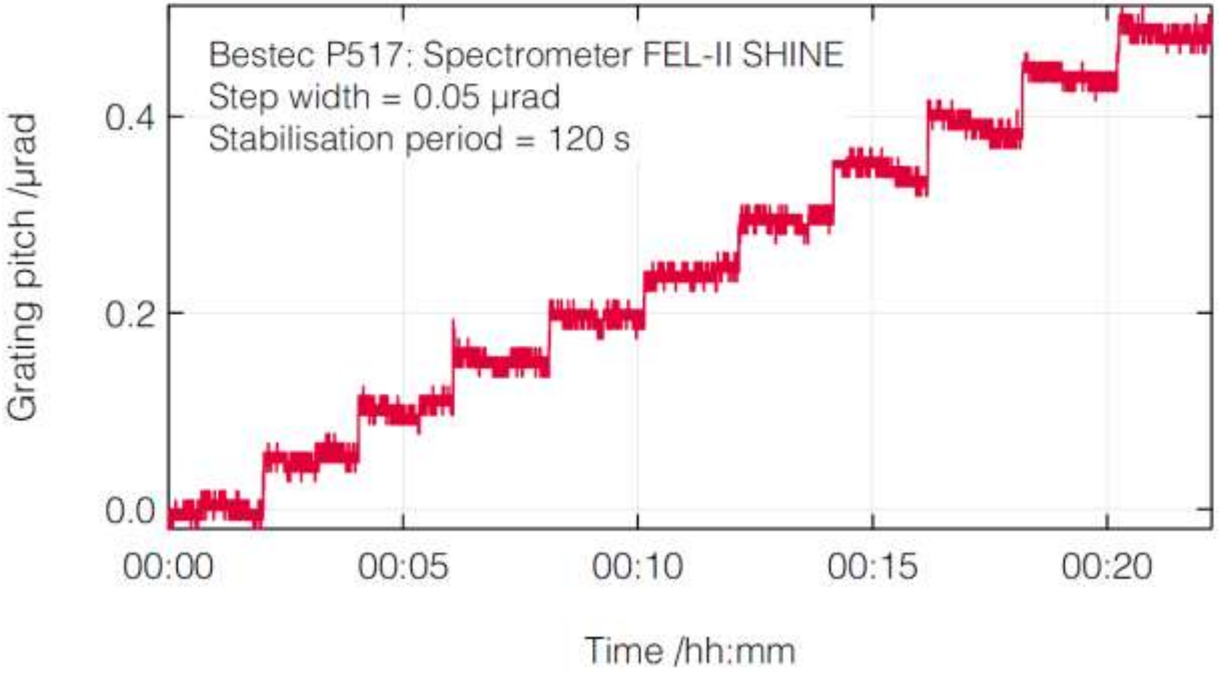


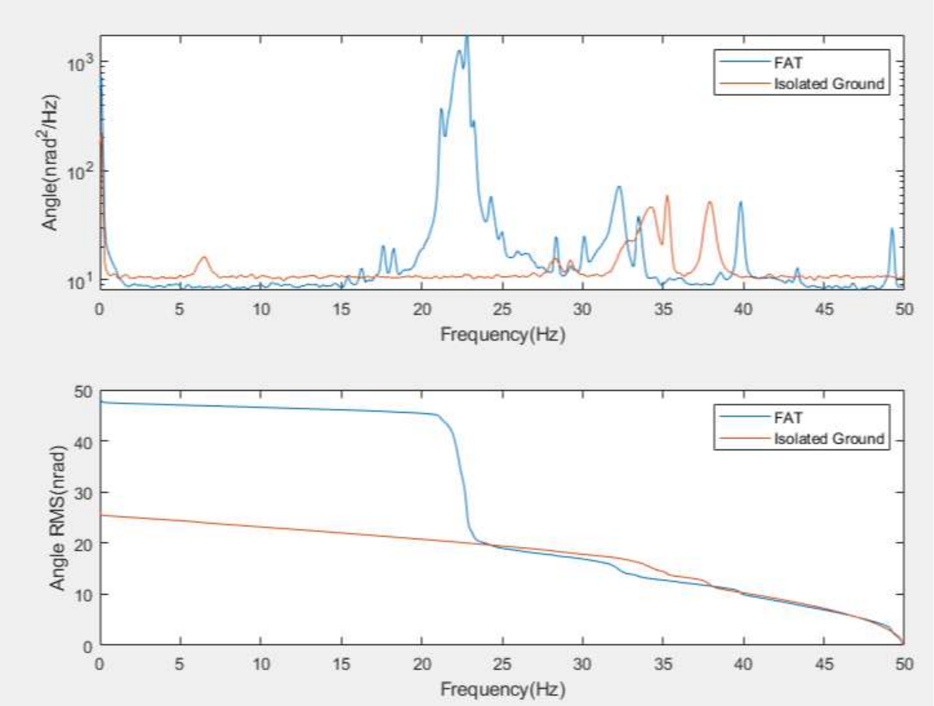


(detector and upstream contribution are NOT included)

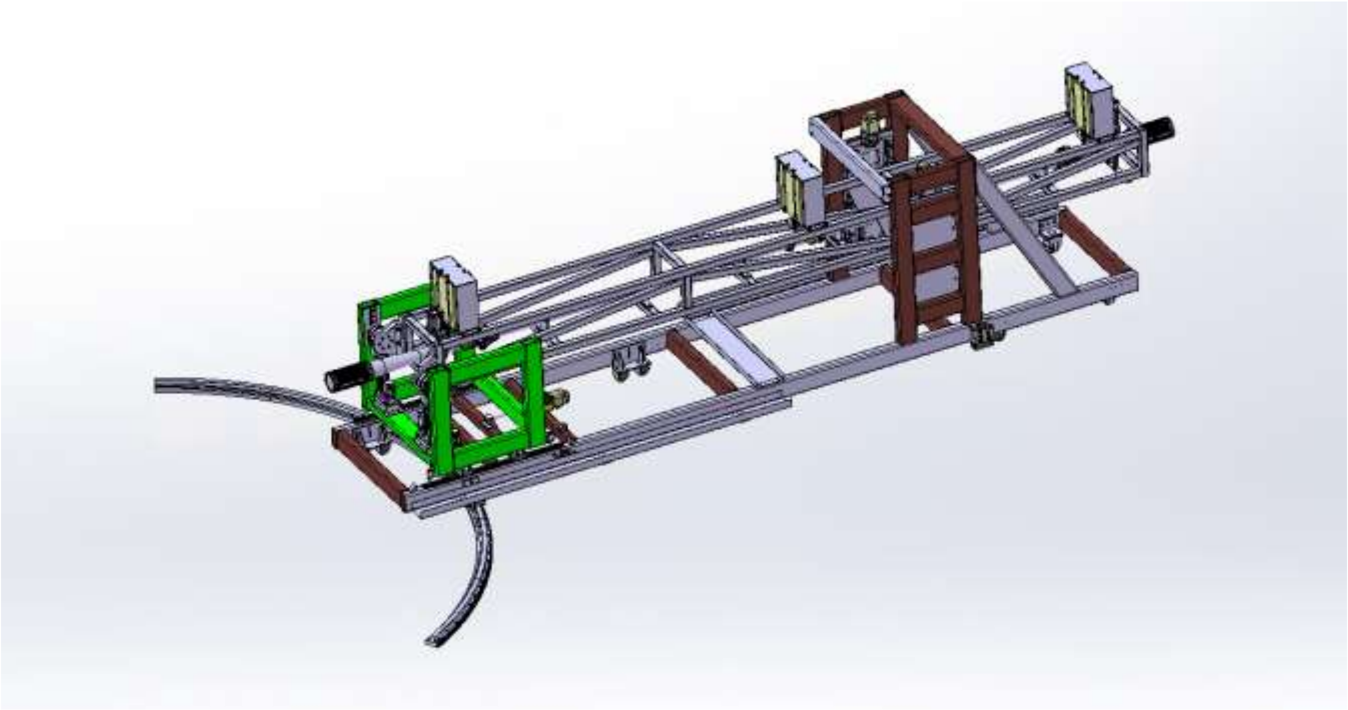
Key component: optical chamber

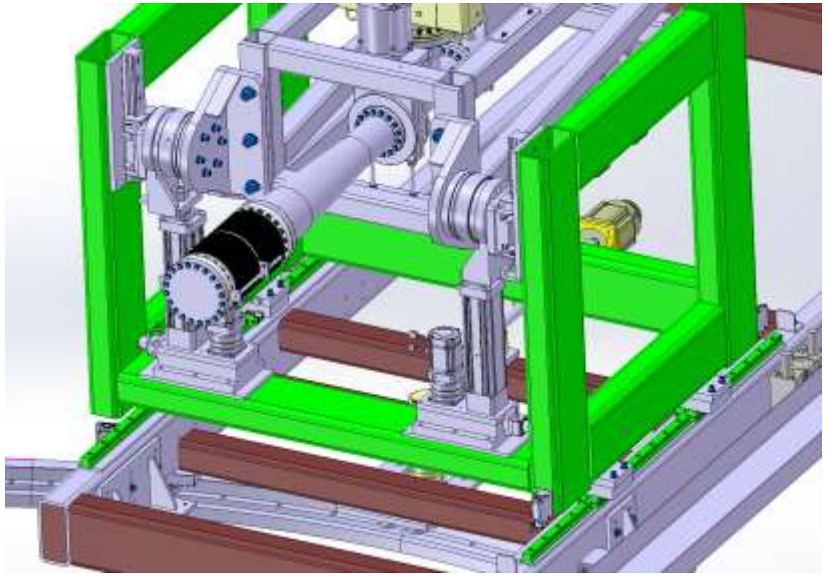


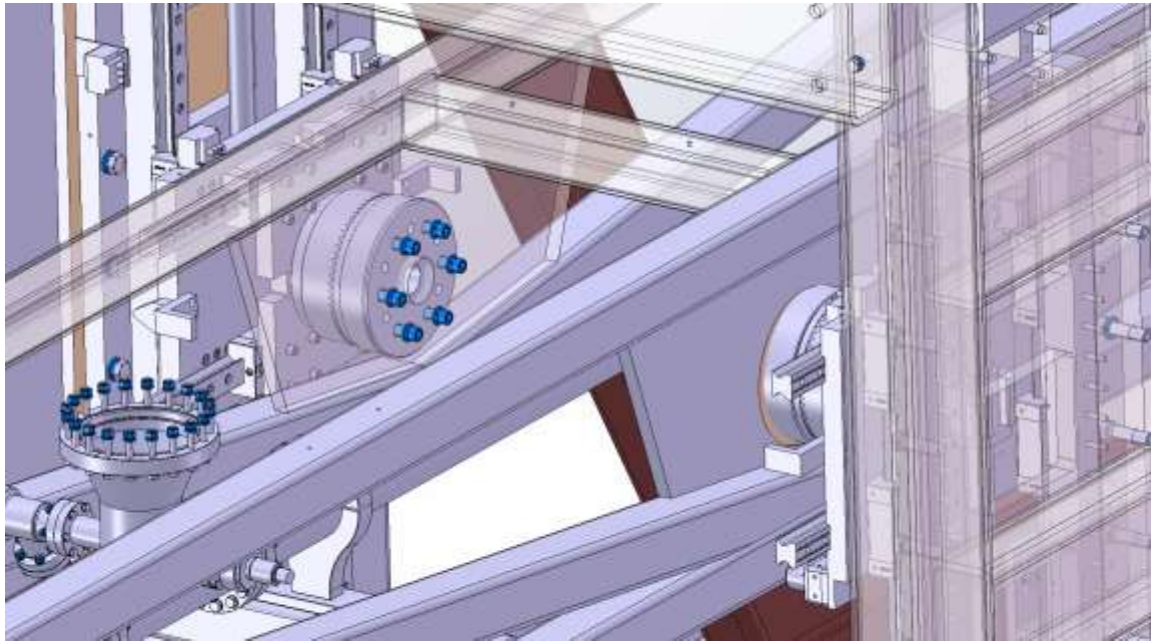




Key component: spectrometer arm







- Rotation in horizontal plane is driven by gear rack.
- Combined motion mechanism to follow the grating rotation.
- Overall radius translation to follow object distance adjustment of the optical system.

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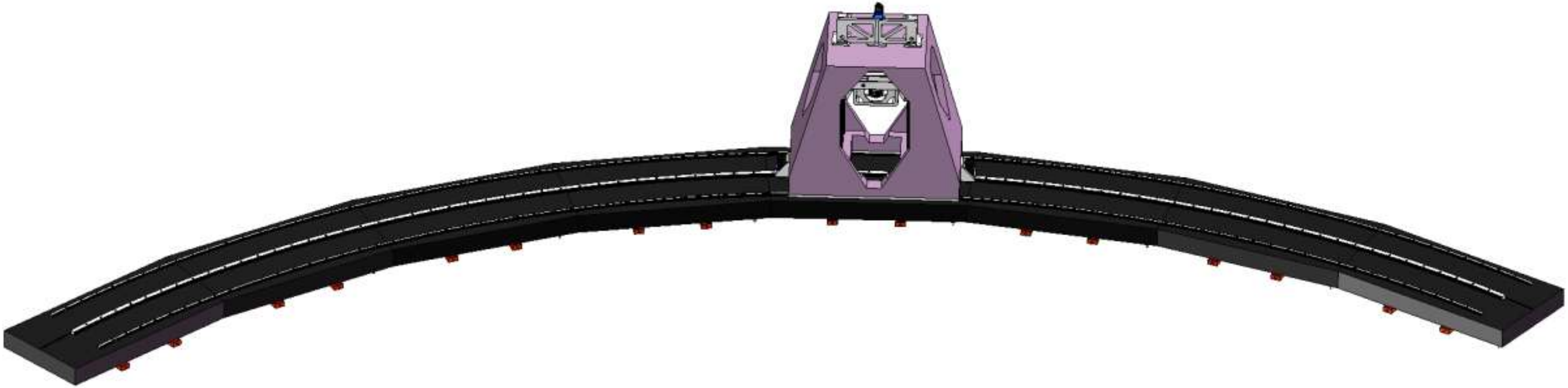
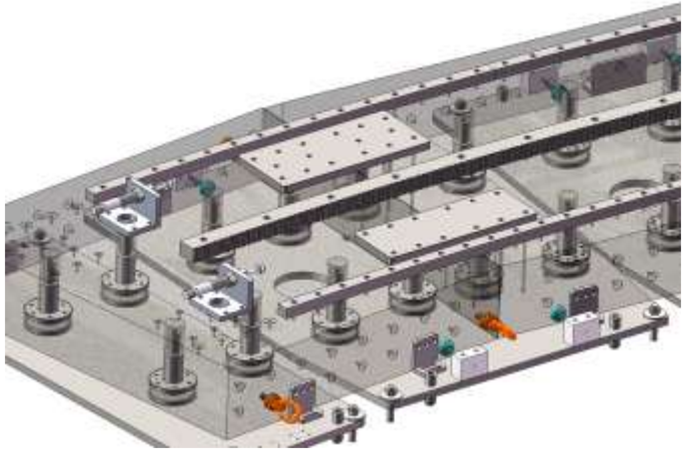
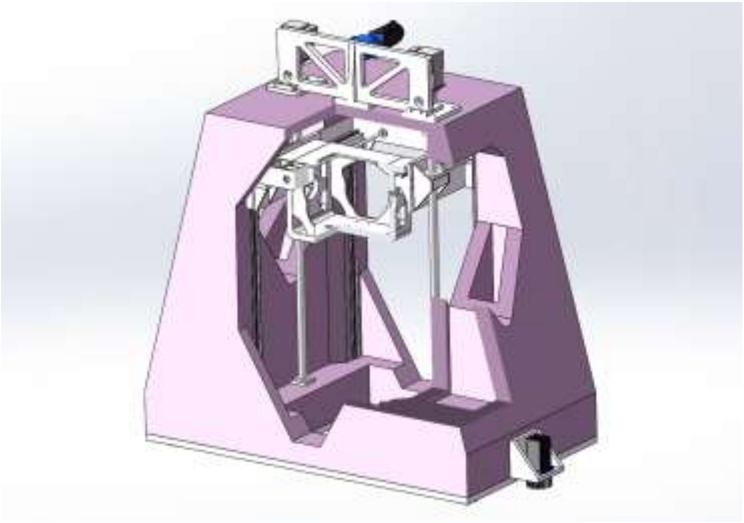
Key component: detector supporting and motion system



- Rotation in horizontal plane is on high precision rail.
- Layered installation and adjustment mechanisms to achieve high precision installation of the rail.
- High stability design of the detector frame with topological optimization.





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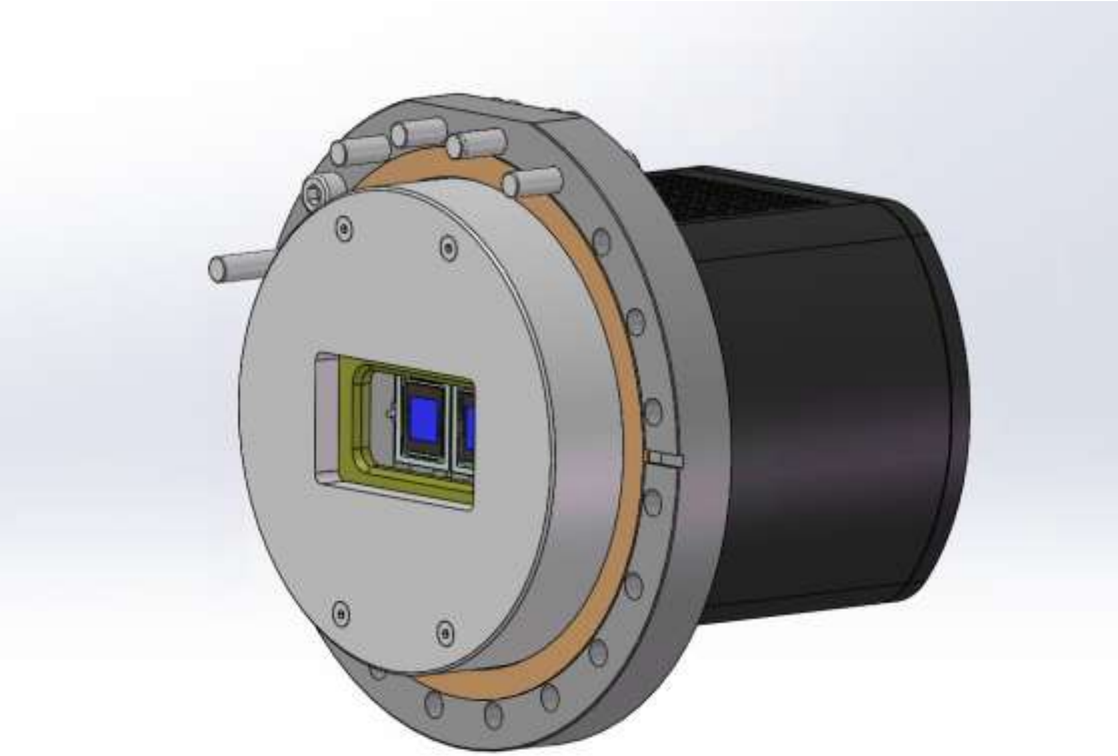
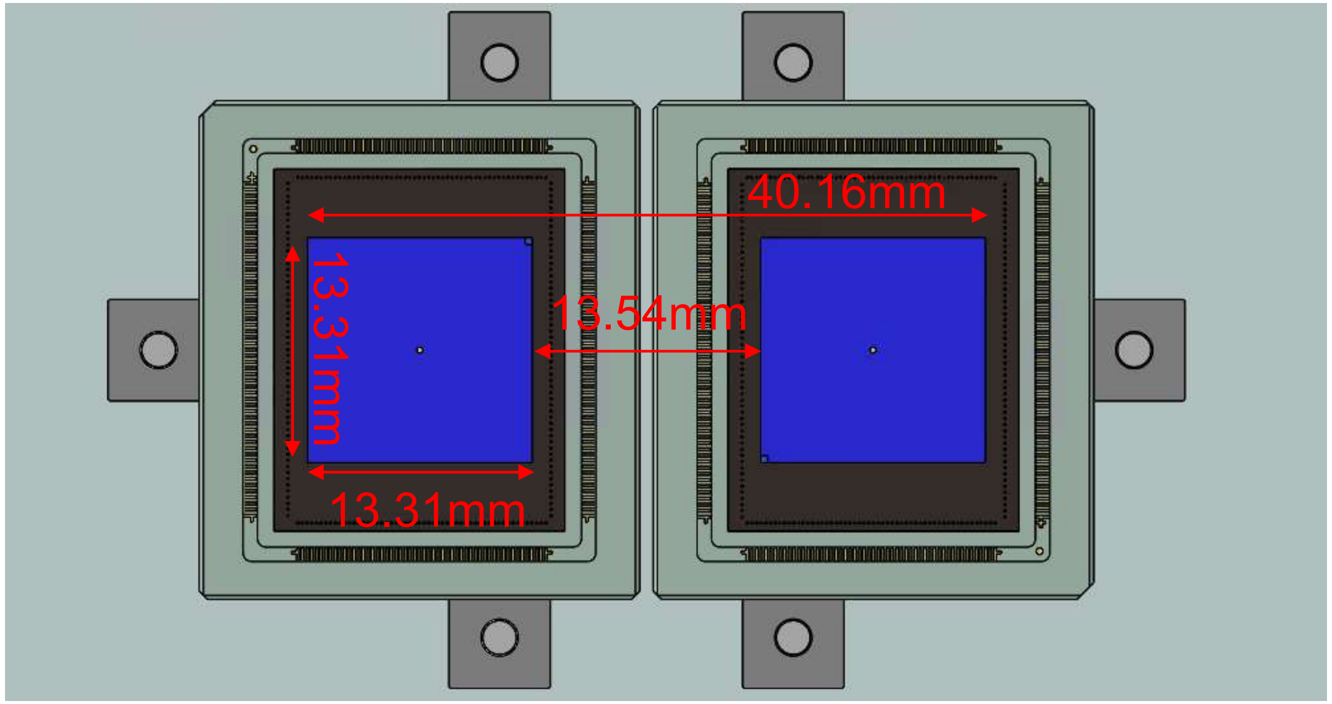
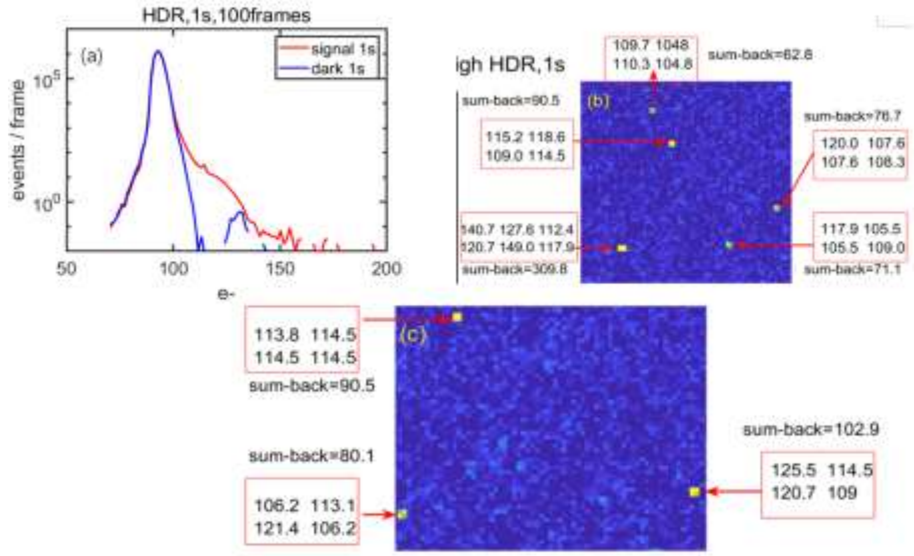
Key component: detector







- Dhyana-CMOS detector with customized double chip design.
- Low noise single photon counting tested.

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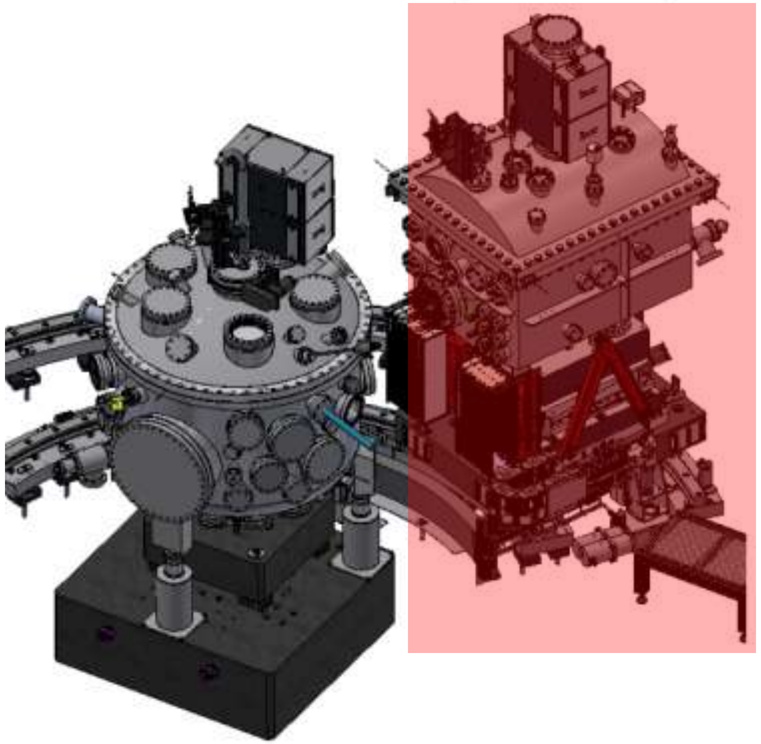
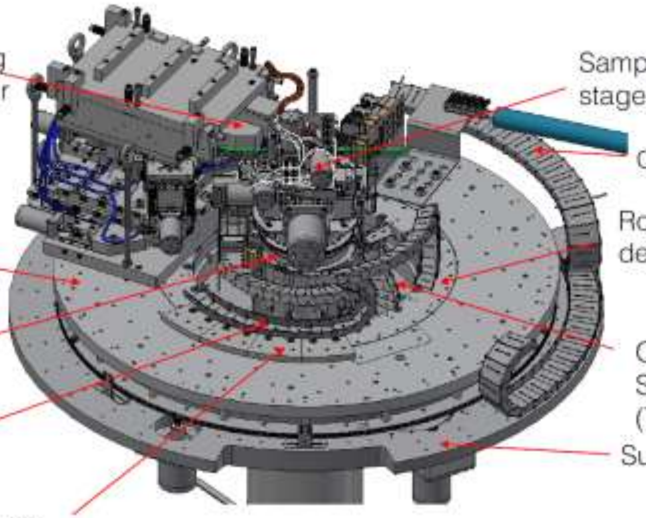
Key component: sample chamber





- External: fixed ports for commissioning.
- Internal: 6 axis sample stage + collecting mirror pair stage
- Sliding seal chamber replacement after commissioning

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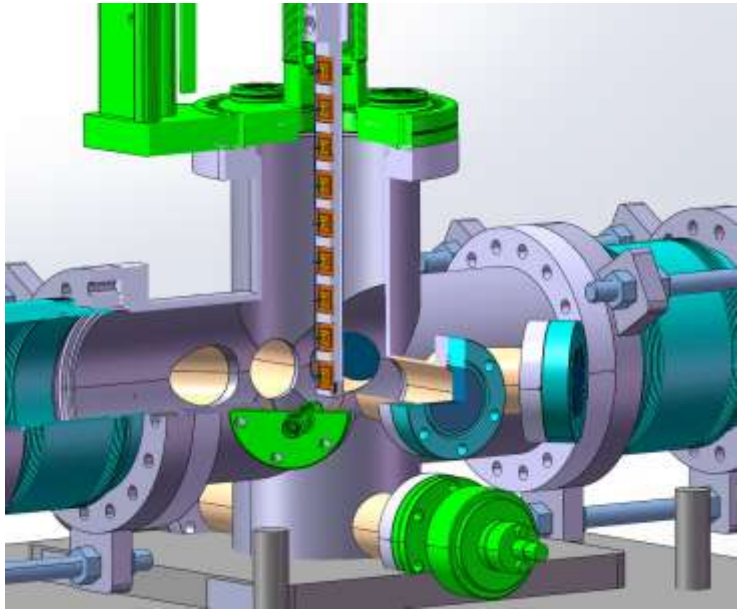
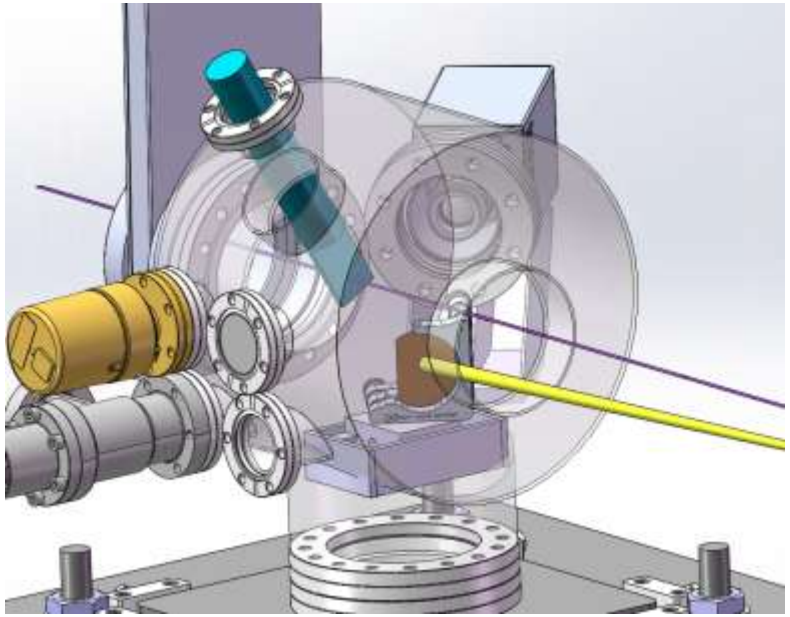
Peripheral components:

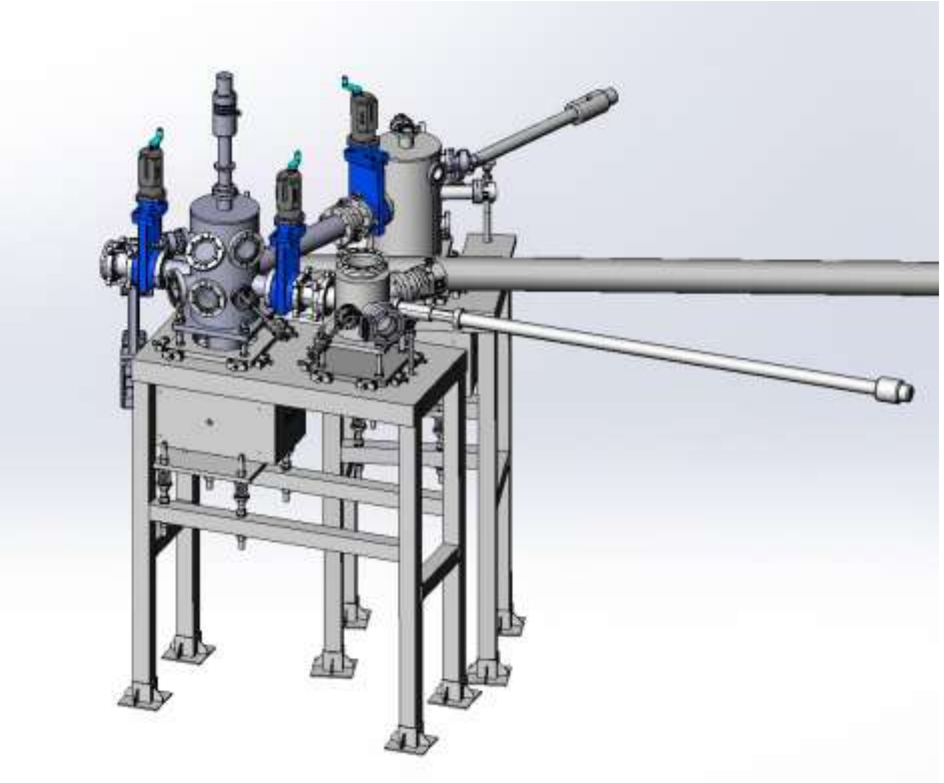
Standard sample chamber



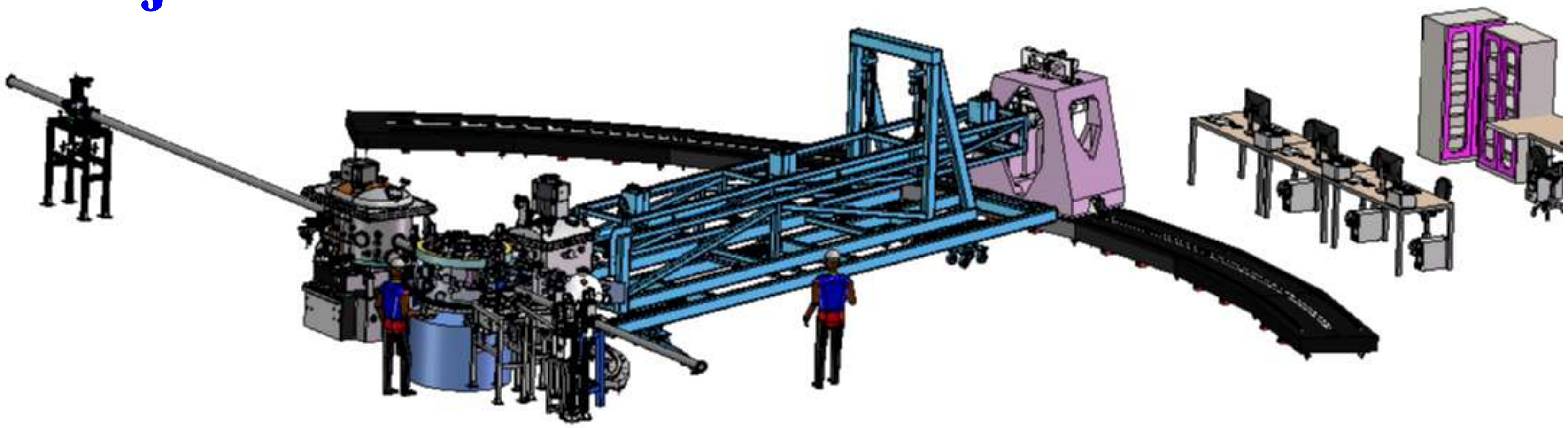
Beam in-coupling chamber



Sample preparing and transfer chamber



Project timeline



- The major long term key component: sample chamber, expected delivery date – Aug, 2026.
- Other main components are expected be installed before Jun., 2026.
- Station is expected to be ready for commissioning in Nov., 2026.

Detector & supporting — 10.25

Signal arm — 02.26

Optics chamber — 12.25

Hatch wall

Standard element target — 04.26

Time diagnosis tool

Focusing chamber

Front peripheral device — 10.26

Sample chamber — 08.26

End peripheral device — 01.27

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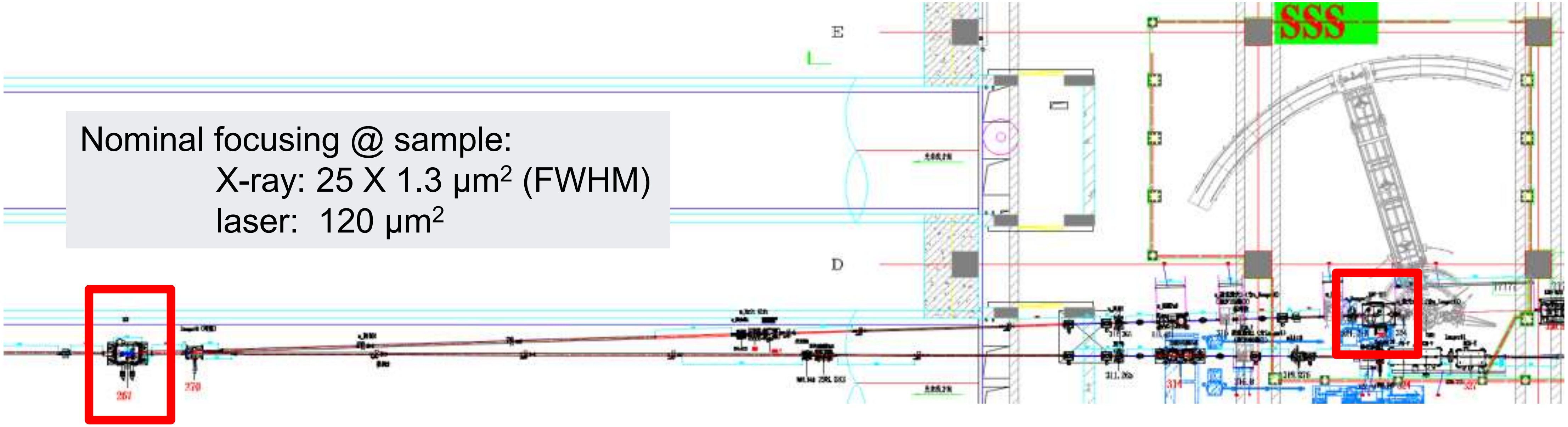
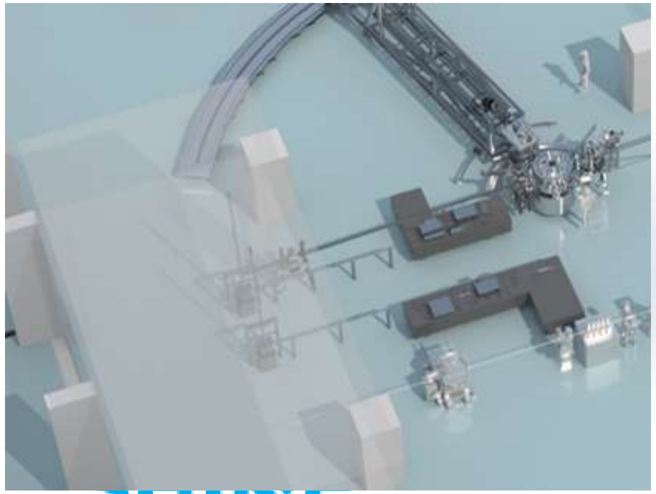
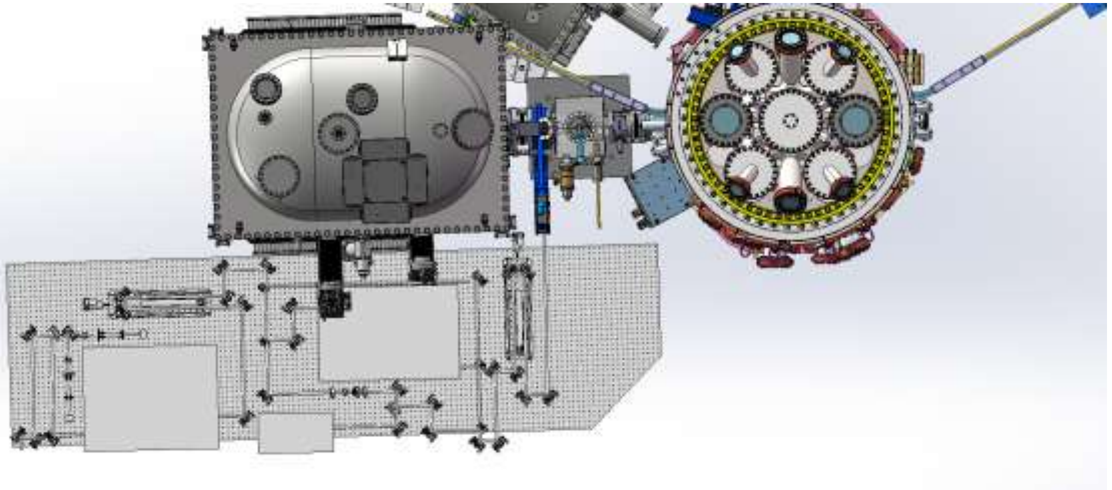
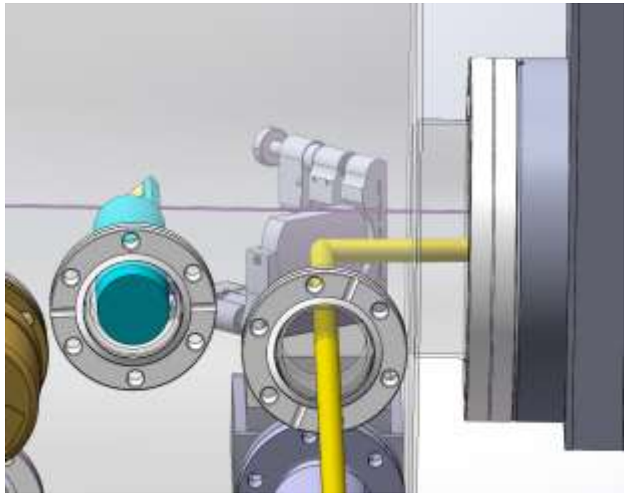
Upstream focusing and laser system

Nominal focusing @ sample:
X-ray: 25 X 1.3 μm^2 (FWHM)
laser: 120 μm^2

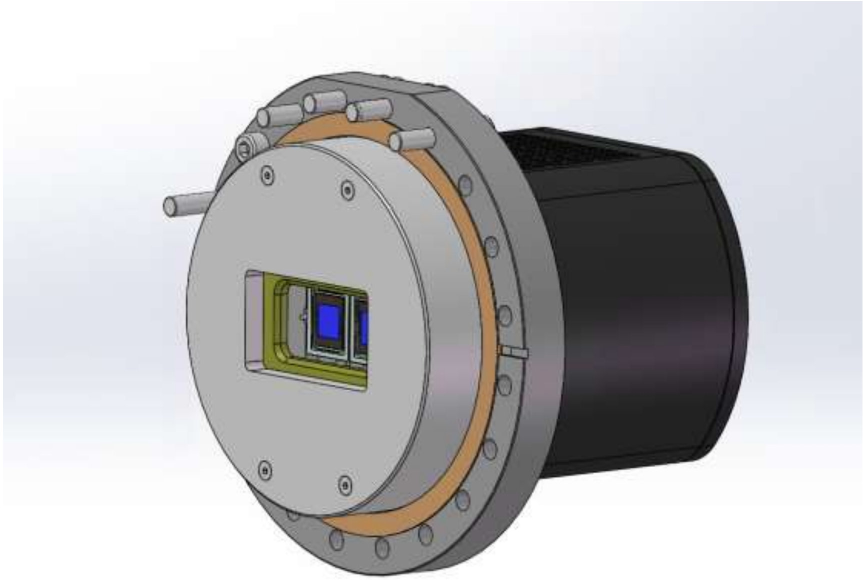




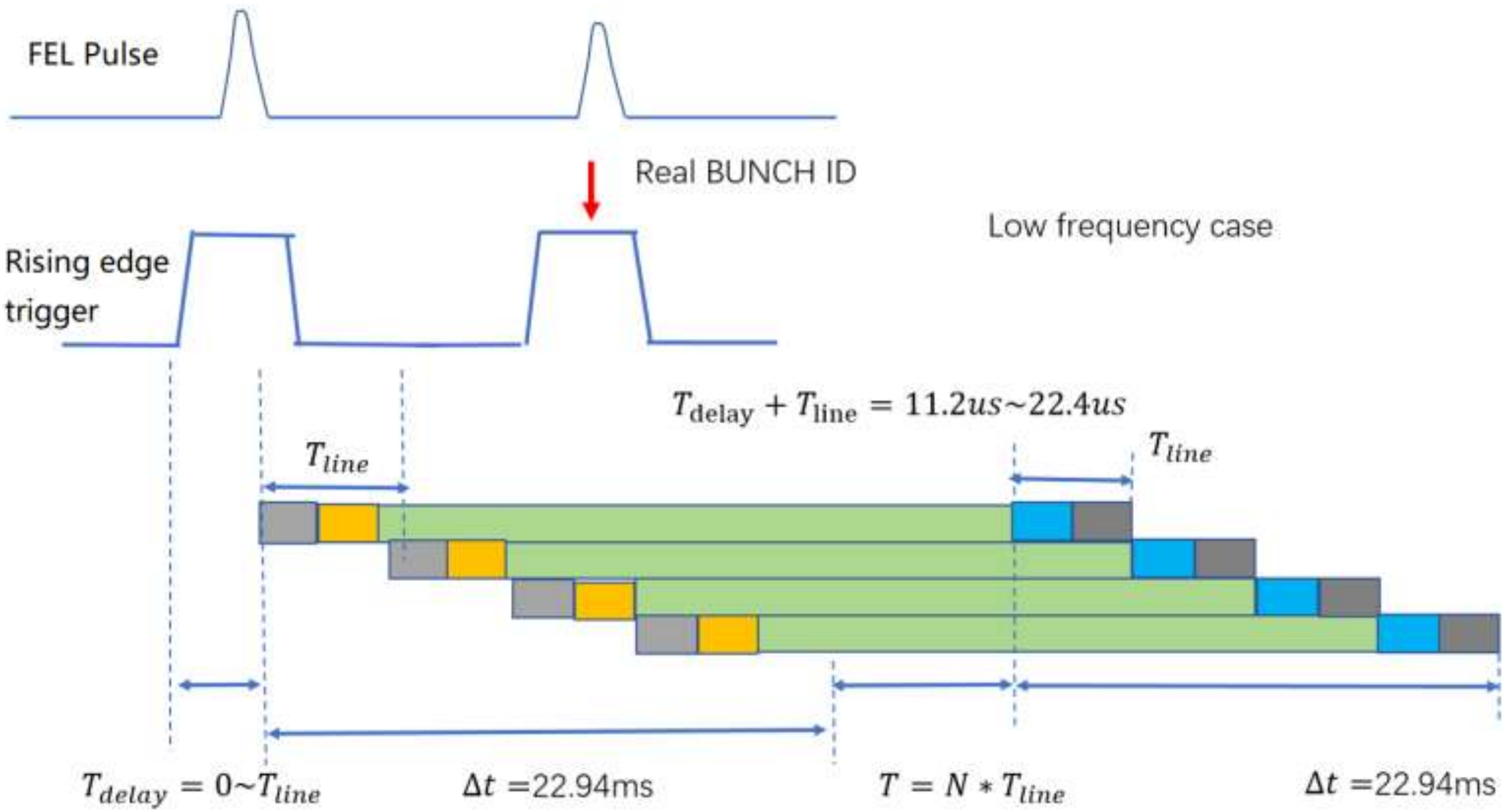




Timing and data collection



1. External trigger for the detector → initial bunch registry.
2. Collecting time + detector functioning timing sequence on internal clock.
3. Ending signal feedback → last bunch registry check.
4. Detector image + information (timing, motor, monitor etc) → hdf5 file.



- Multi-pulse integration mode
- CMOS architecture and line rolling mode

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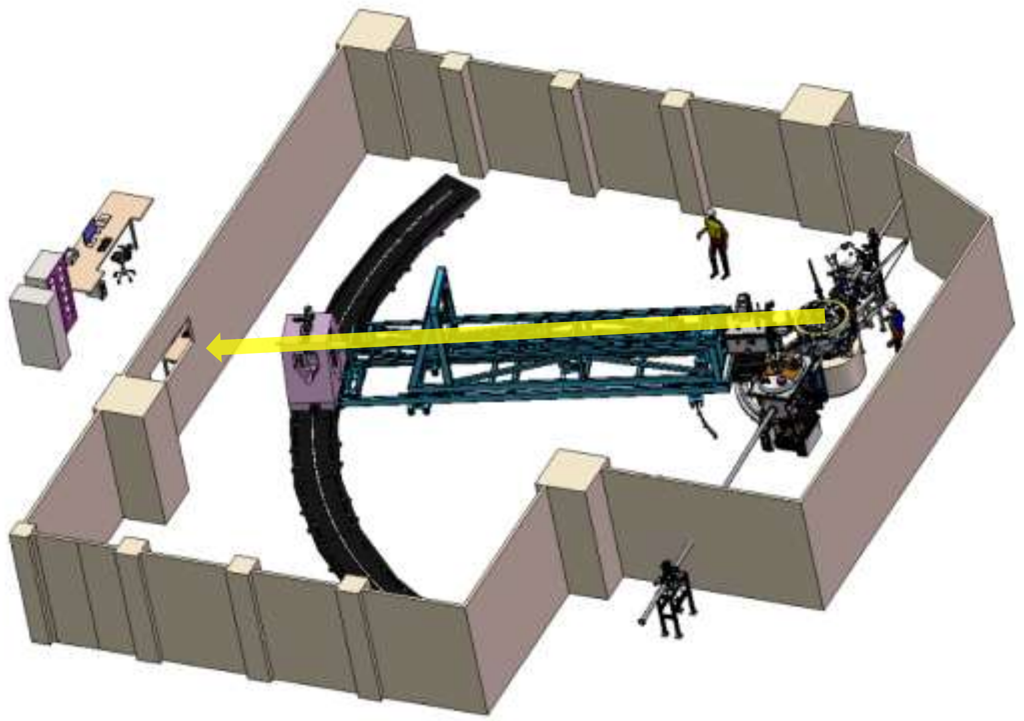
Main challenge expected: rotation synchronization

Sample chamber→ optical chamber → arm → detector support



- Co-rotation center from design and installation.
- High precision installation alignment between optical chamber and the sample chamber, and high precision collaborative rotation.
- Synchronization of the rotations from the sample chamber to the detector support.

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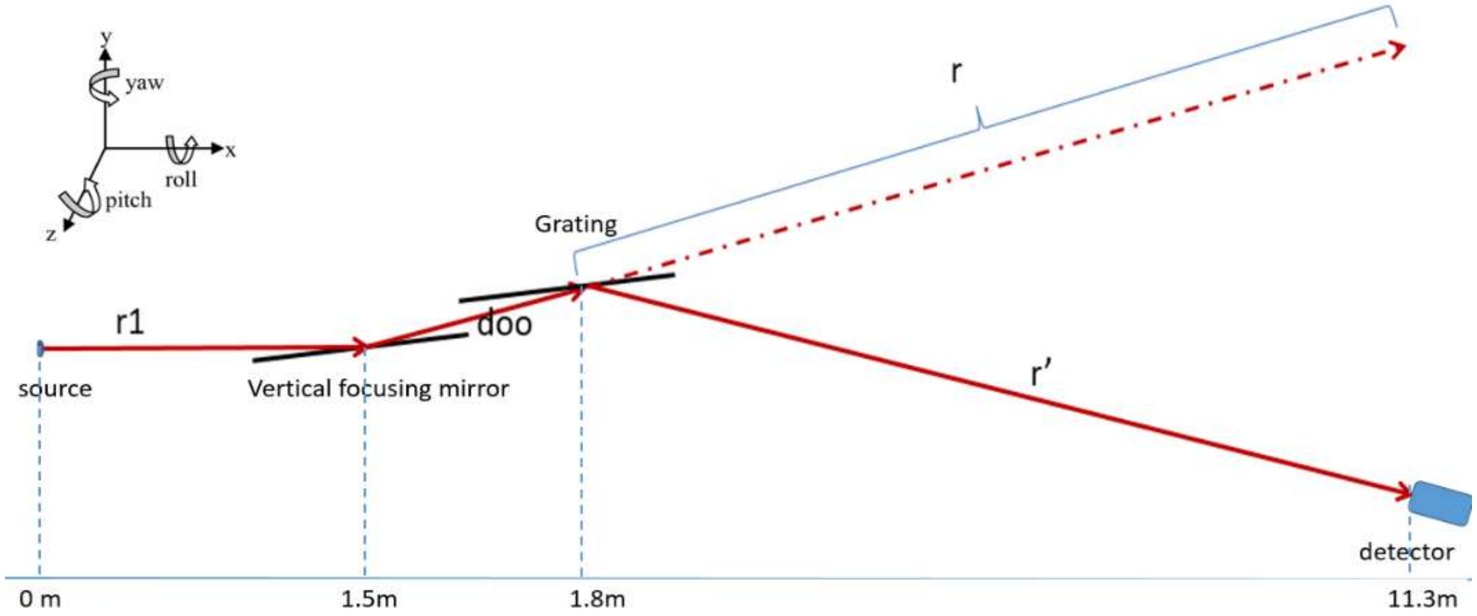
Main challenge expected: optical element alignment



- Conventional one optics design v.s. H-U combo design: much tighter constrains with much reduced redundancy.

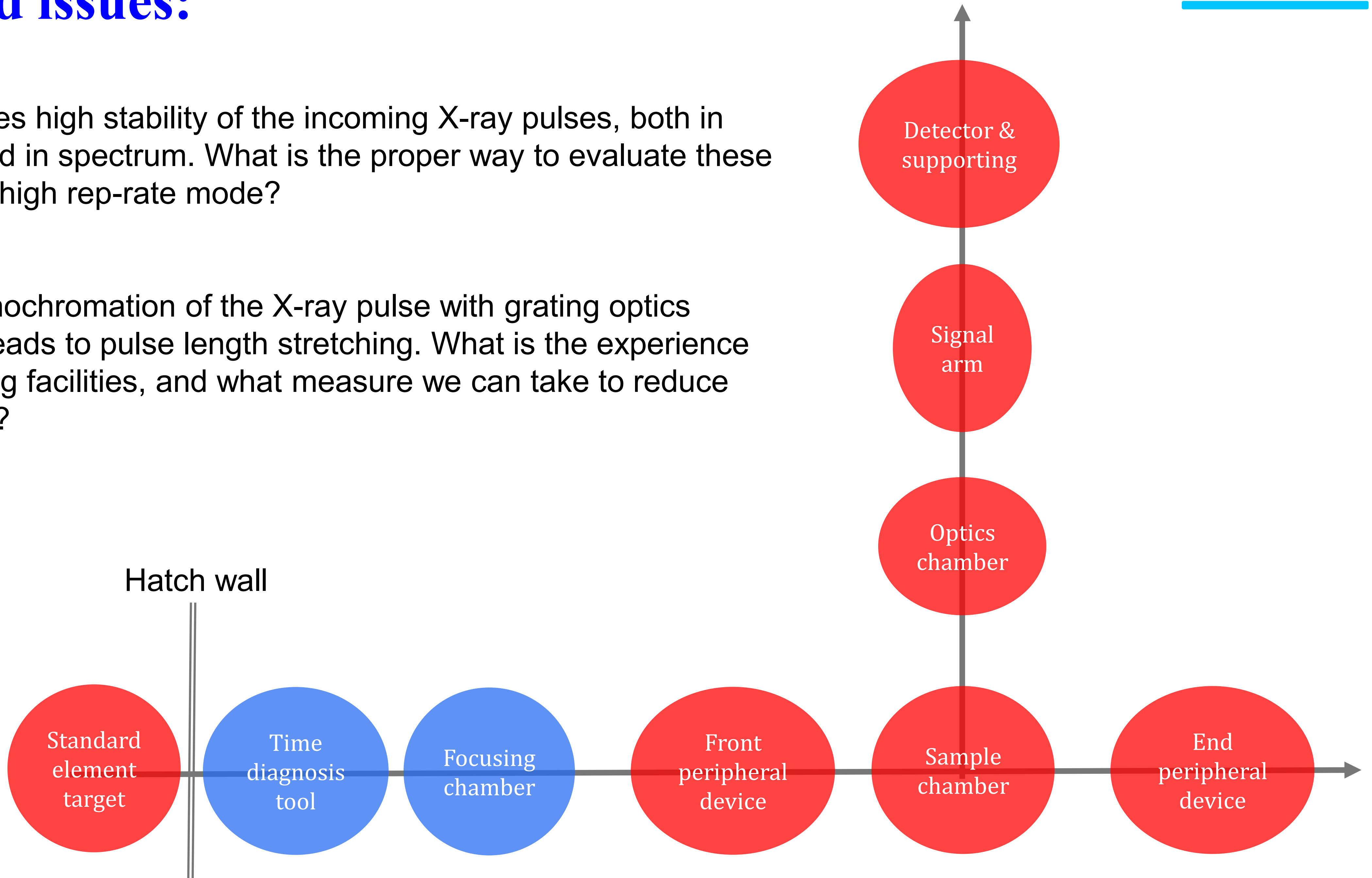
- Quite a few additional mechanical motion mechanisms are implemented in design, including consideration on optical element manufacturing errors.

- Still we expect the alignment will be challenging.

Concerned issues:

- SSS requires high stability of the incoming X-ray pulses, both in strength and in spectrum. What is the proper way to evaluate these qualities in high rep-rate mode?

- Strong monochromation of the X-ray pulse with grating optics inevitably leads to pulse length stretching. What is the experience from running facilities, and what measure we can take to reduce such effect?



Thank you!

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Li, Zhetong (Ph.D. student)

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