4th Korea-4GSR International Advisory Committee Meeting (Nov. 5-6, 2025)

Hard X-ray Coherent Application and Nanoscopy

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ID10: Jeayong Shin[2], Yonghyun Kim[1], and Jun Lim[2]

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Nov. 06, 2025

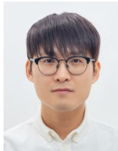
PAL POHANG ACCELERATOR LABORATORY

KBSI KOREA BASIC SCIENCE INSTITUTE

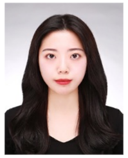
Outline

1. Overview

2. ID03 CoXRD (Coherent X-Ray Diffraction)



Sung Soo Ha
KBSI



Daseul Ham
PAL

Su-Yong Lee
PAL, CoXRD Advisor

3. ID04 CoSAXS (Coherent Small-Angle X-ray Scattering)

Wonhyuk Jo
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Jehan Kim
PAL, CoSAXS Advisor

4. ID10 HXNP (Hard X-ray NanoProbe)

Jaeyong Shin
PAL, Imaging science group leader

Yonghyun Kim
KBSI

Jun Lim
PAL, HXNP Advisor

5. Summary

1. Overview

Beamline design criteria and goal

Wavefront preservation

- High precision optics
  → Ultra-low roughness and slope error mirror
  → Polishing Diamond CRL
  → Clean surface and crystal attenuator(Silicon/Dia.)
- **Simple is the BEST**
  (Configure with as few optics as possible)
- **Diamond diagnostics**
  → Clean and low roughness surface
- **UHV Fast close shutter system**
  → Few vacuum window

Stable beam

- **< 10 % rule** (Beam position and intensity)
  → Using horizontal deflection optics
  → Apply stable temperature control and low vibration
- (Slow) Beam position feedback

Coherence X-ray beamlines

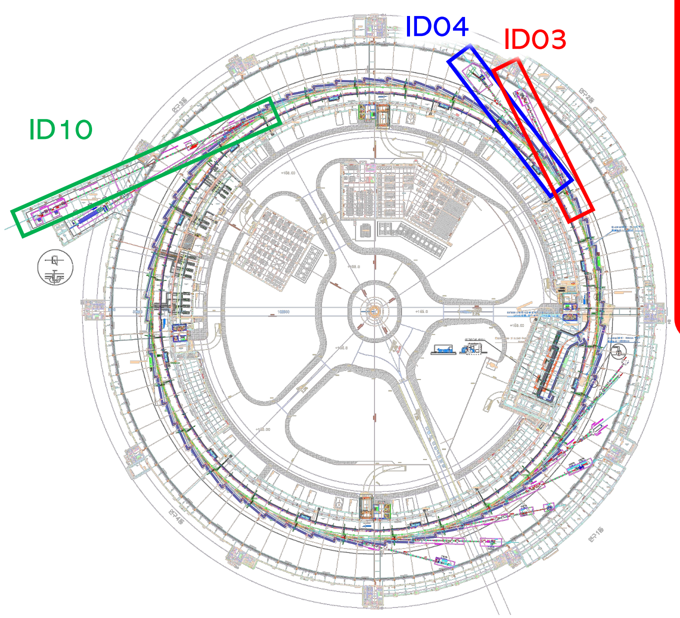
Scalability

- **Large experimental Hutch** (or two exp erimental Hutch)
  → New experimental method and instrument test space
- **Long working distance**
  → In-situ experiments and other instrument assessments
- **Domestically produced equipment**
  → High speed nanoscan stage with wide scan range

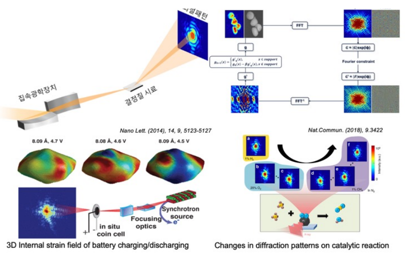
High-Fidelity Beamline Design for Advanced X-ray Science

1. Overview

Korea-4GSR Floor Plan

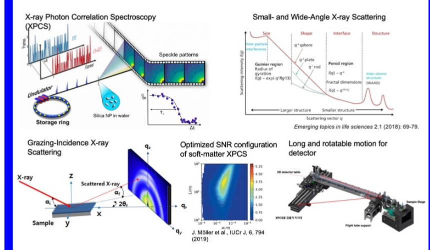


ID03 CoXRD



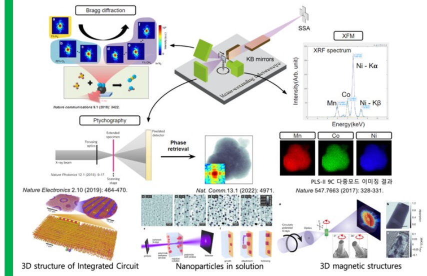
Provides high-coherence X-rays for Bragg CDI and µXRD, enabling nanoscale analysis of strain and structural evolution in crystalline materials.

ID04 CoSAXS



Providing tunable beam sizes and variable detector distances, ensuring flexibility for XPCS, in-situ/operando studies, and scalability for future developments.

ID10 HXNP



Provides high-resolution imaging over a wide area and simultaneous elemental mapping through multimodal analysis using scanning diffraction imaging and X-ray fluorescence microscopy.

	CoXRD	CoSAXS	HXNP
Light source	IVU22	IVU20	IVU24
Energy range [keV] (mainly)	5 - 30 (6-10)	8.4 - 30 (9 - 15)	5 – 25 (8 - 10)
Supporting techniques in the first phase	Bragg CDI, µXRD	(GI)XPCS, (GI)SAXS, (GI)WAXS	(Spectro-)Ptychography, XRF, CDI
Beam size (FWHM)	• KB mirror: 1 µm • CRLs: 2-10 µm	• 3 - 100 µm (Variable)	• KB mirror: 50 nm • CRLs: 100 nm • Unfocused: 30 µm
Coherent Beam flux (ph/s)	• 10^{10} - 10^{12}	• 10^{10} - 10^{12}	• 10^{10} - 10^{12}
Detectors	• EIGER2X 4M	• EIGER2X 4M, TBD	• CITIUS 840k, EIGER2X 1M
Beamline total length	• 75 m	• 75 m	• 150 m

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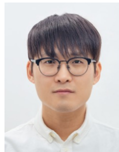

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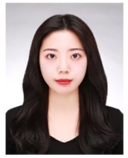

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5. Summary

2. CoXRD

Main techniques

Bragg Coherent X-ray Diffraction Imaging

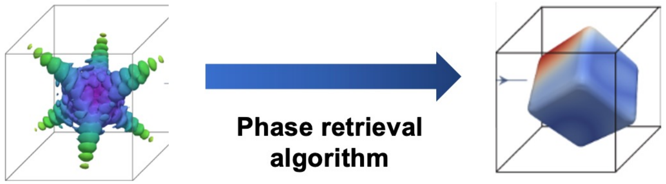
'**Picometer sensitivity**' : *Strain* sensitivity much finer than the atomic spacing

Spatial resolution : 10 nm

Powerful tool : crystal defects, strain relaxations, phase transition, etc.

XRD pattern

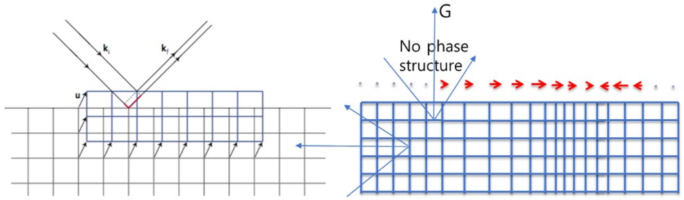
Phase information



Input

Output

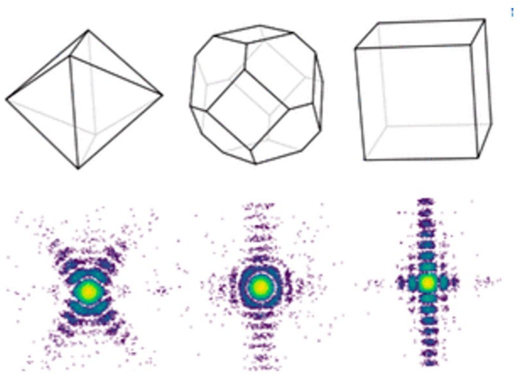
Displacement field u(r): $\widetilde{\rho}(\mathbf{r}) = \rho_{\mathbf{G}_{hkl}}(\mathbf{r}) \exp\left[-i\mathbf{G}_{hkl} \cdot \mathbf{u}(\mathbf{r})\right]$



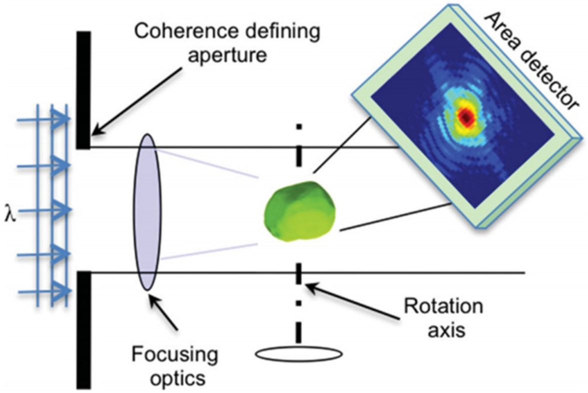
Strain is a gradient of u(r), the **phase** component of the complex-valued density.

Reconstruction

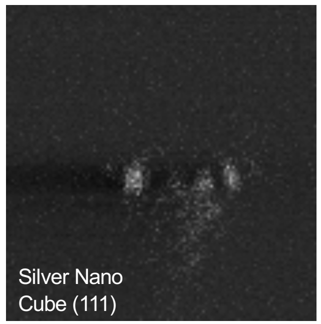
XRD pattern



npj Computational Materials 7.1 (2021):



3D X-ray
Diffraction pattern

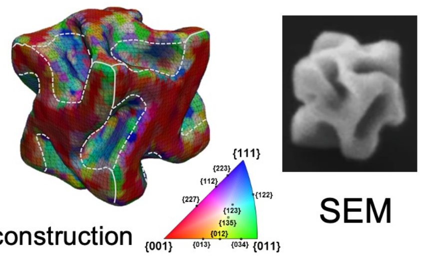


2. CoXRD

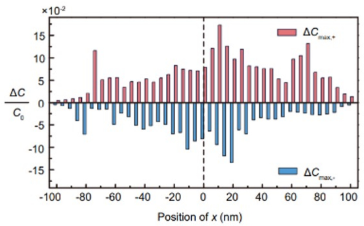
Main target science

Chemical Reaction

In situ, Operando (Chemical catalyst, photo-catalyst)

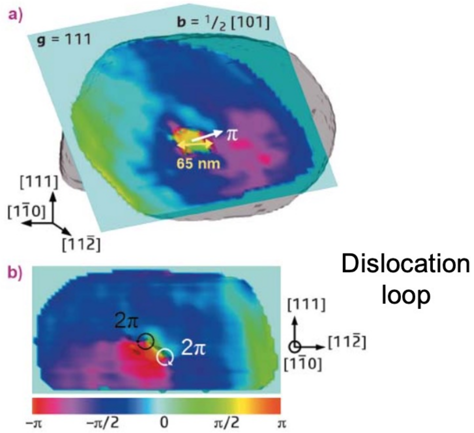


Expected absorption feature

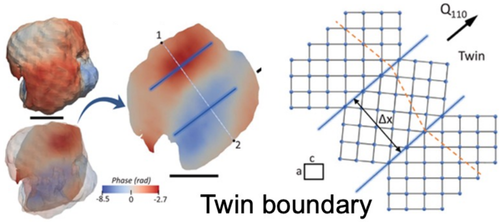


S. Choi et al., *Nat. Commun.*, **14**, 3615 (2023)

Defect & Dislocation



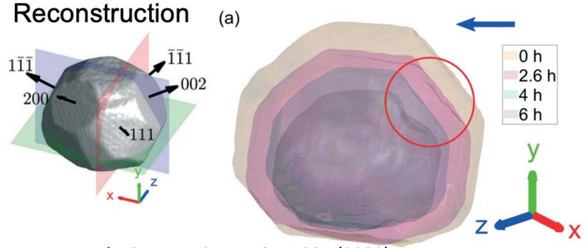
M. Dupraz et al., *Nano Lett.*, **17**, 6696 (2017)



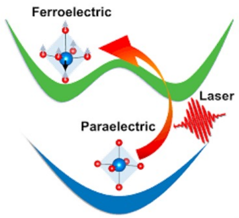
A. F. Suzana et al., *Adv. Funct. Matter.*, **33**, 2208012 (2023)

Time-resolved Capability

Corrosion and Chemical Dynamics

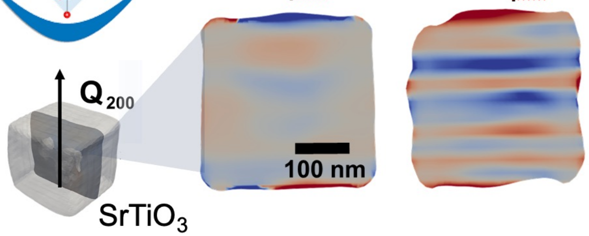


D. Yang et al., *CrystEngComm*, **24**, 1334 (2022)



Ultrafast phase transition

In preparation

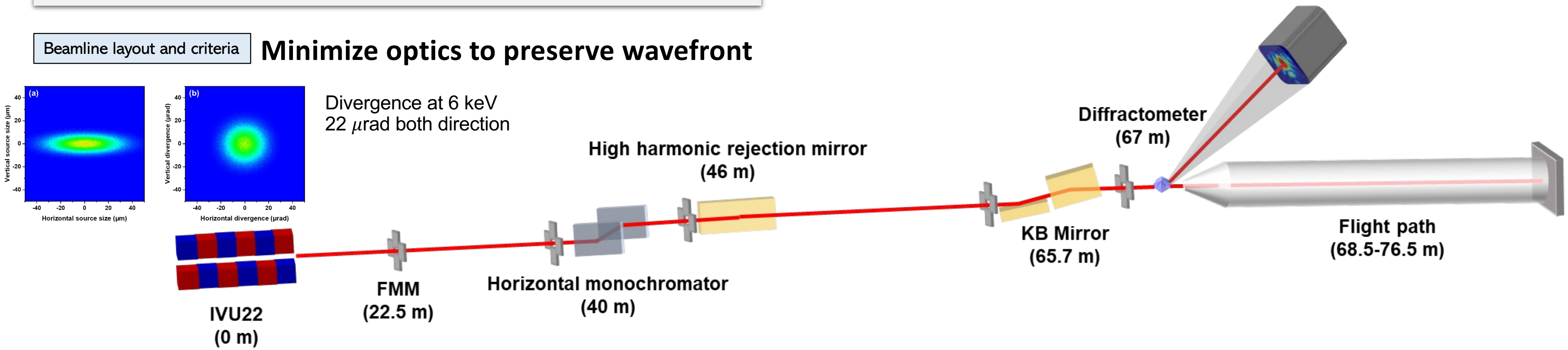


Courtesty by S. S. Ha

2. CoXRD

Beamline layout and criteria

Minimize optics to preserve wavefront



1. **Front-End Movable Mask**
   - **Beam is clipped up to 3σ**
   - **Coherent fraction @6 keV : Vertical ~30%, Horizontal ~10%**
   - **KB mirror only accepts up to 3σ → sufficient aperture**

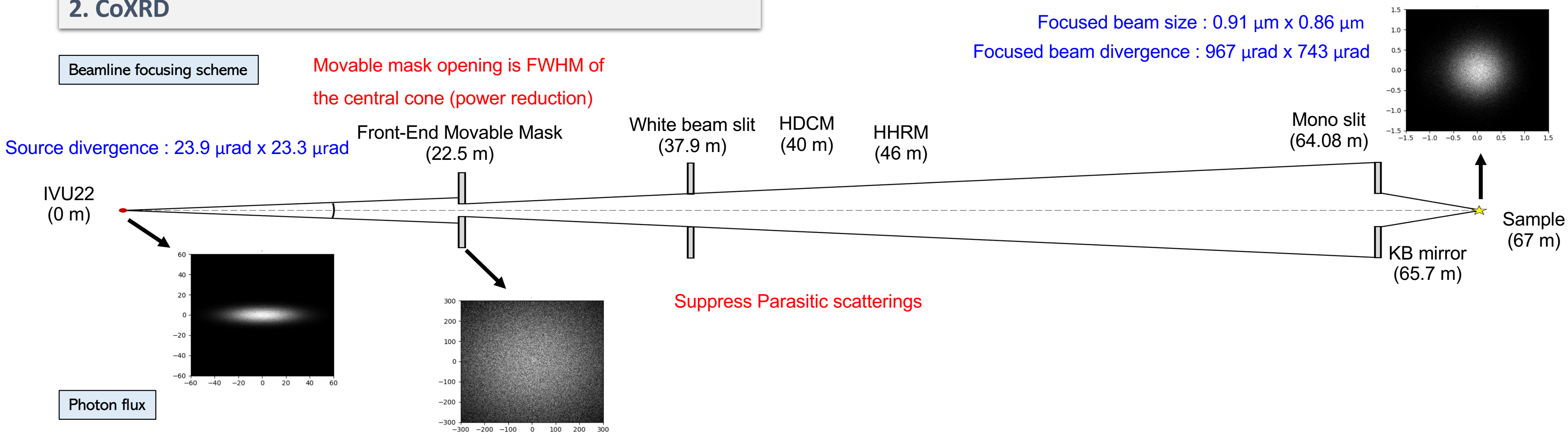
2. **DCM Placement**
   - **Undulator white beam : most power absorbed at DCM 1st crystal.**
   - **Many beamlines: HHRM placed before DCM (to reduce heat load)**
   - **But our case, power already reduced by the movable mask.**
   - **Adding HHRM → cause thermal bump → beam size increases by 20-30%**
   - **Mirrors are sensitive to surface quality → risk of beam degradation**

3. Collimating Mirror leads
→ Make divergence ~ 0.
→ Higher power density on DCM
→ Risk of thermal bump
→ w/o collimating mirror

4. Slit
→ Super-polished slit blades
→ Under 235 nm RMS to reduce parasitic scattering.

2. CoXRD

Beamline focusing scheme



Photon flux

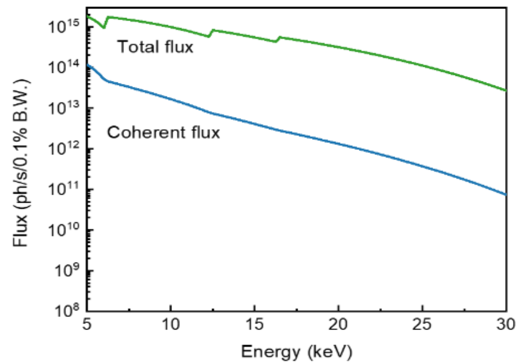
Coherence & Flux mode

- Controlled by slit (Mono slit) in front of KB mirror
- Maximum opening : flux mode
- Coherence length opening: coherence mode

- Including 7th harmonics.
- 0.1 % bandwidth
- 5 keV → coherent flux/ total flux = 6 %
- 30 keV → coherent flux/ total flux = 0.27 %

	6 keV (3rd)	15 keV (5th)	30 keV (7th)
Coherence mode(ph/s)	5.66×10^{12}	6.34×10^{11}	1.43×10^{10}
Full Flux mode (ph/s)	1.77×10^{14}	6.62×10^{13}	3.72×10^{12}

Comparison
- ESRF-EBS, ID01: 10^9 ph/s
- SIRIUS, Cateretê: > 10^{11} ph/s
- MAX IV, NanoMAX: >10^{10} ph/s

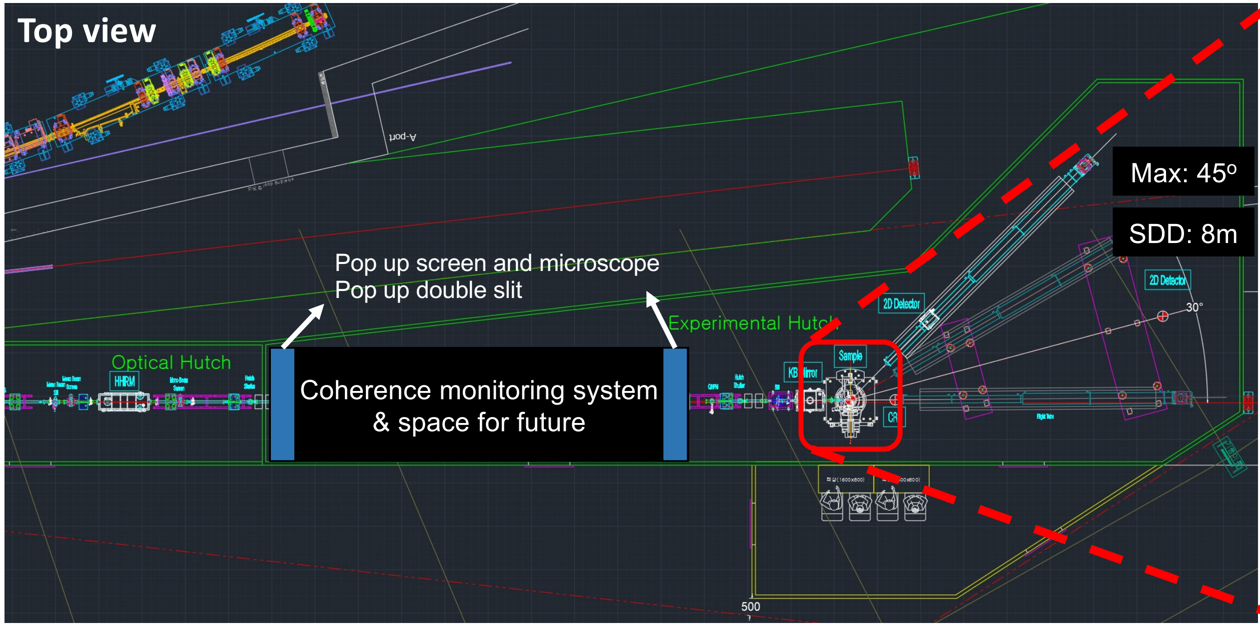


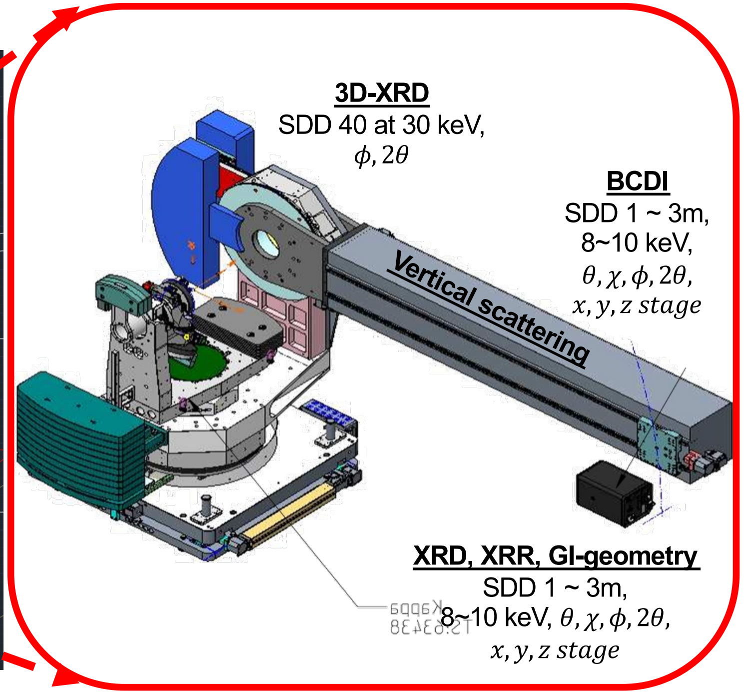
Courtesty by S. S. Ha
Modified by the author

2. CoXRD

Experimental hutch

Scalability



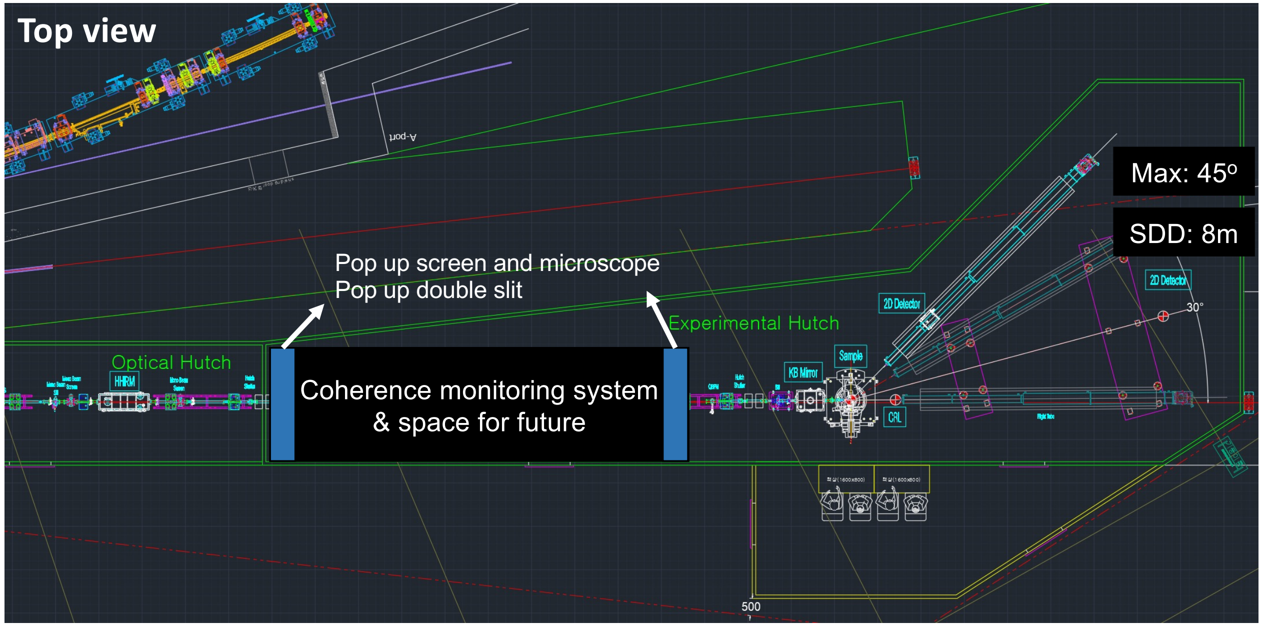


ID03 Experimental Hutch size (L x W x H)
28.15 m x 10.9 m x 5 m

2. CoXRD

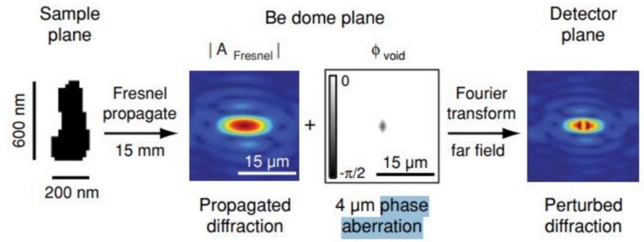
Experimental hutch

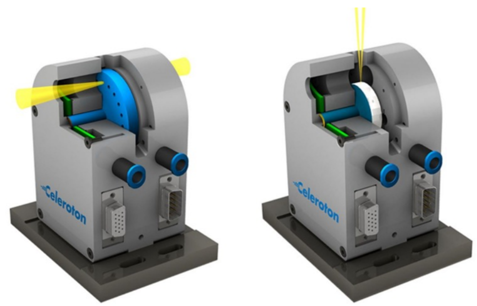
Scalability



ID03 Experimental Hutch size (L x W x H)
28.15 m x 10.9 m x 5 m

Wavefront preservation and X-ray dose





[Fast Shutter-Celeroton company]

Vacuum-compatible magnetic-bearing choppers - Celeroton

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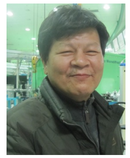

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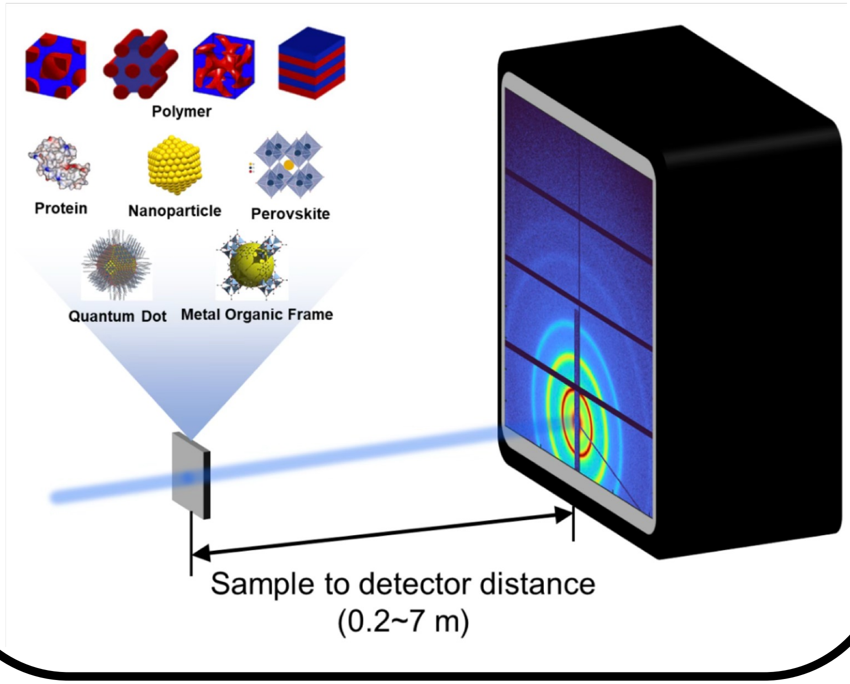
5. Summary

3. CoSAXS

Main techniques and target science

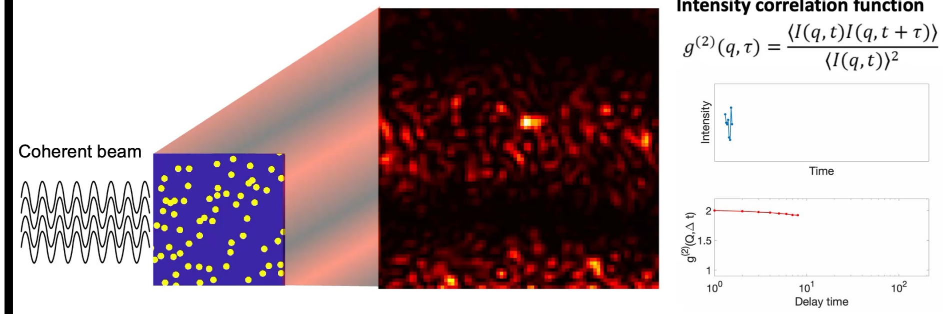
Small-Angle X-ray Scattering (SAXS)

Structural information in molecular length scale

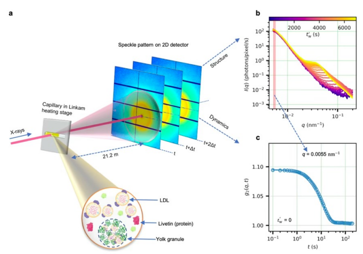


X-ray Photon Correlation Spectroscopy

Dynamical information in disordered system

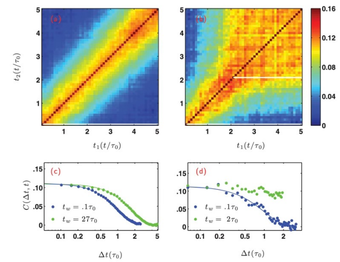


Protein dynamics



N. D. Anthuparambil et al., Nat. Commun., **14**, 5580 (2023)

Charge density wave dynamics



J. Su., Phys. Rev. B, **86**, 205105 (2012)

3. CoSAXS

Beamline criteria

Optimize the Signal to Noise Ratio (SNR)

$$SNR = \beta \bar{k} \sqrt{N_f N_p}$$

β: Spekle contrast

$\bar{k}$: Intensity (photons/frame)

N_f: Number of frames

N_p: Number of pixels

$$\beta = \beta(d_b, l_c, d, L, P, q)$$

Adjustable (5 ~ 100 μm)

$\boxed{d_b\text{: coherent beam size at the sample}}$

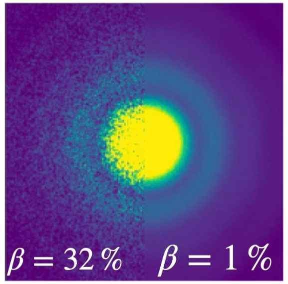
l_c: longitudinal coherence length

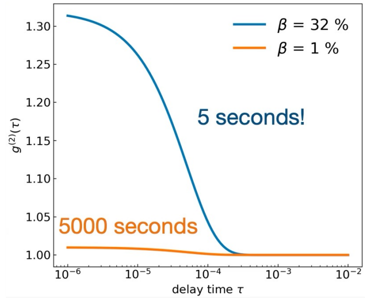
d: sample thickness

$\boxed{L\text{: sample to detector distance}}$ Adjustable (3-10 m and 22 m)

P: detector pixel size

q: wavevector





$$g^{(2)}(\tau) = 1 + \beta \exp(-2\tau/\tau_c)$$

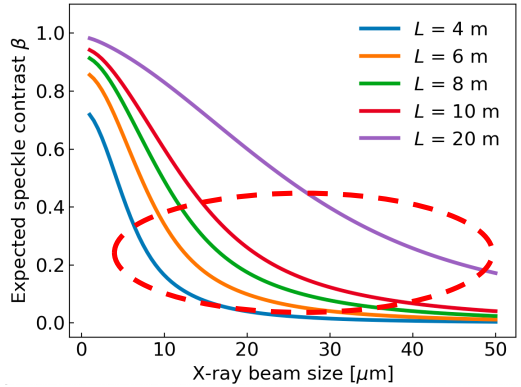
SNR higher than 5 is preferred!

Example

When $\bar{k} = 10^{-3}$ photons/frame, N_p = 10^5 (0.1 Megapixel), and detector frame rate = 500 Hz

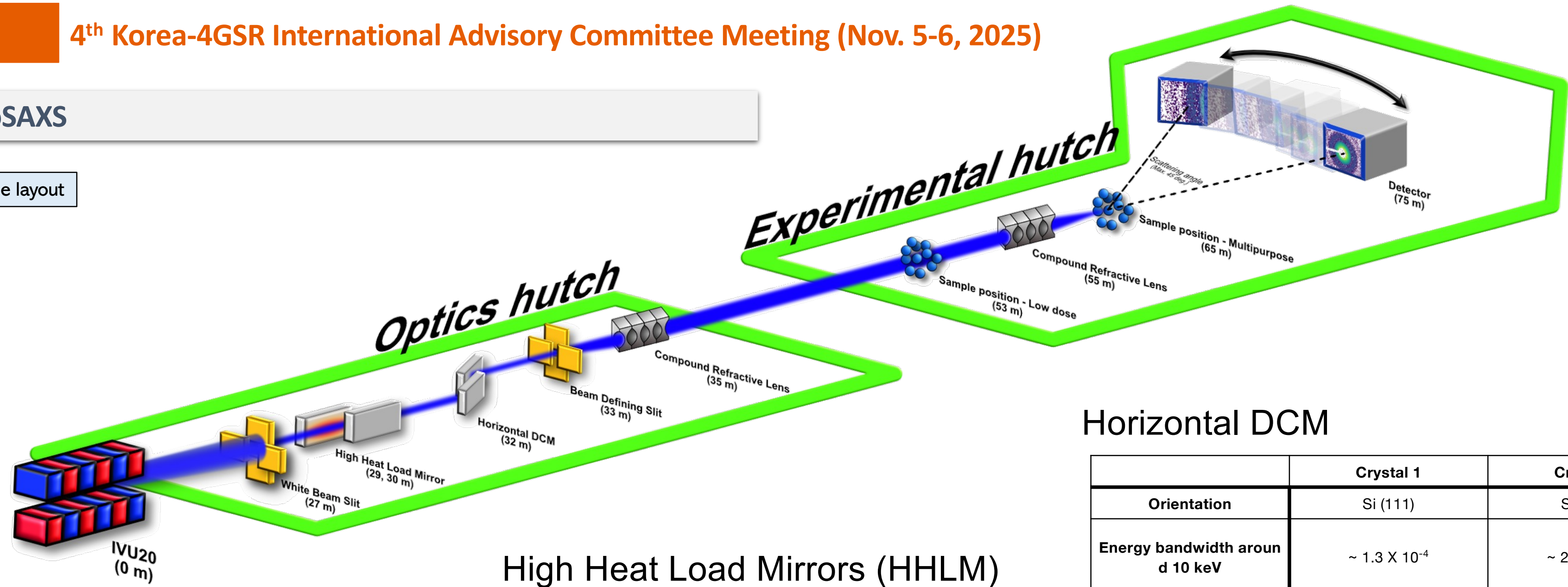
SNR = 5			
Contrast	0.01	0.1	0.3
Needed number of frames	2500000	25000	2777
Acquisition time [s]	**5000 s**	**50 s**	**5.55 s**

Target contrast & beam size for XPCS



3. CoSAXS

Beamline layout



In-vacuum undulator (IVU20)

Total length	3 m
Period length	20 mm
# of periods	148
Gap	5 ~ 16 mm
Max. B	1.0211 T
Max. K	1.9069
Max. Total Power	12.5 kW
X-ray Photon energy range	8.4 keV - 30 keV
Source size (h x v)	18.95 um x 4.6 um
Source divergence (h x v)	9.1 urad x 8.7 urad
Spatial coherence fraction (h x v)	0.06 x 0.28

High Heat Load Mirrors (HHLM)

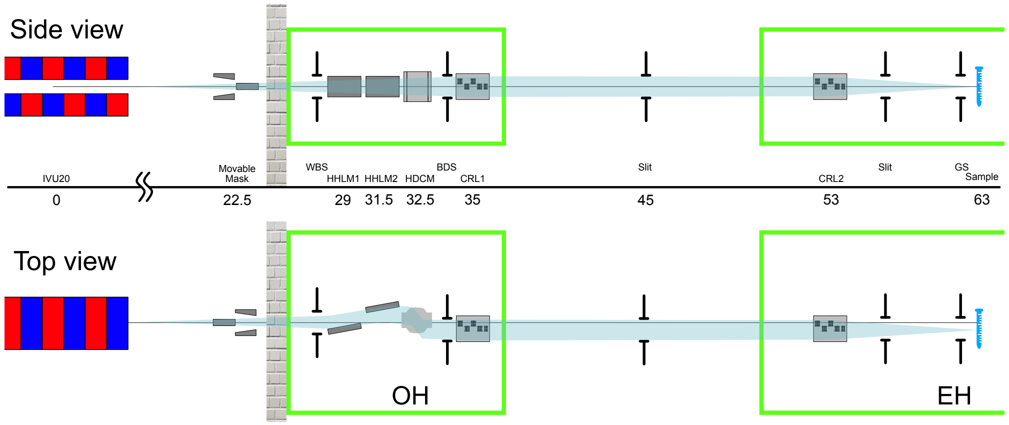
	M1	M2
Shape	Plane	Bendable
Distance from the source	29 m	30 m
Coating materials	Rh < 23 keV Pt > 23 keV	
Foot print (L x W) [mm]	449 x 1	
Substrate	Si	
Surface roughness	< 5 Å RMS	
Tangential slop error	< 0.5 urad RMS	
Sagittal slop error	< 0.5 urad RMS	
Mirror dimensions (L x W x H) [mm]	50 x 600 x 50	

Horizontal DCM

	Crystal 1	Crystal 2
Orientation	Si (111)	Si (311)
Energy bandwidth around 10 keV	~ 1.3 X 10^{-4}	~ 2.5 X 10^{-5}
Longitudinal coherence length	~ 500 nm	~ 2470 um
Operation	Fixed exit operation, closed loop feedback	
First crystal size [mm]	50	50
Second crystal size [mm]	150	150
Offset [mm]	25	25
Slope error	< 0.5 urad	
Vibration	< 0.1 urad	
Cooling	LN2 side cooling	

3. CoSAXS

Beamline layout: focusing scheme



More focusing options, e.g., medium focusing, can be implyed

Dynamic adjustment of beam size through flexible CRL transfocator settings

X-ray photon energy [keV]		8.5	9	10	12
CRL1 (Collimation)	Radius R[um]	725	650	520	350
	# of CRLs	1	1	1	1
CRL2 (Focusing)	Radius R[um]	805	723	588	412
	# of CRLs	4	4	4	4
Beam size (FWHM) [um]	Horizontal	12.97	12.71	12.75	12.86
	Vertical	4.23	4.052	3.967	3.743
Photon flux @ sample [10^{14} ph/s/0.1%B.W.]		3.67	3.79	3.95	3.44
Coherent photon flux @ sample [10^{12} ph/s/0.1%B.W.]		6.74	6.56	6.21	4.55

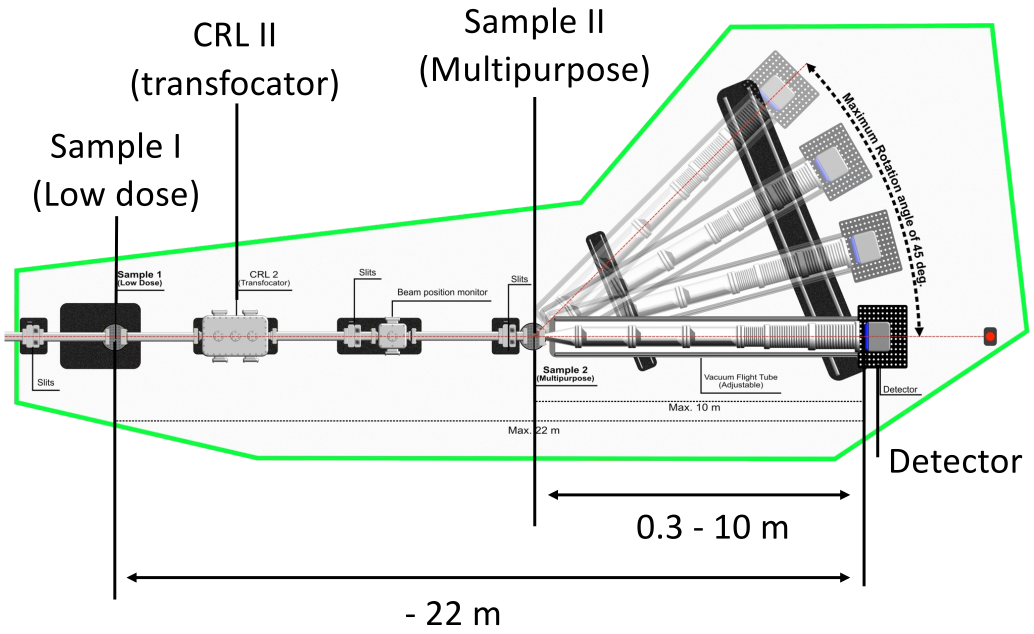
3. CoSAXS

Experimental hutch

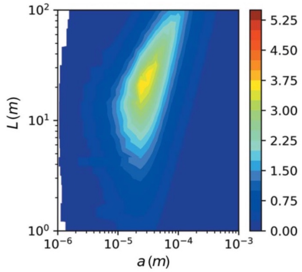
Scalability

Long sample to detector distance with rotatable flight path

Longer sample to detector distance for low dose measurement



Optimum SNR of SAXS XPCS from protein solution as a function of sam ple-to-detector distance L and beam size at 14.7 keV



J. Möller et al., IUCr J, 6, 794 (20 19)

Sample position I - Low dose

- Sample to detector distance: 22 m
- Maximum scattering angle: 0.52 degrees (detector arm at 0 degrees)
- Maximum q range @ 9 keV: 0.041 $Å^{-1}$
- Beam size: 20 um^2 – 150 um^2 (Adjusted by CRL1)

Sample position II – Multipurpose

- Sample to detector distance: 0.3 - 10 m (Vacuum flight tube)
- Scattering angle: 45 degrees (Rotatable detector arm)
- Maximum q range @ 9 keV: 3.4 $Å^{-1}$
- Beam size: 5 um^2 – 30 um^2 (Adjusted by CRL1, and CRL2) (additional CRL is an option to smaller beam in future)
- WAXS detector stage: 0.25 m downstream of the sample position

Detector candidates

- For robust SAXS and slow XPCS (> millliseconds): EIGER2X 4M or Lambda
- For fast XPCS (microsecond ~ milliseconds): SPARTA, Rigaku XSPA, TEMPUS, etc.
- Temporal resolution? Single bunch resolving?

Sample environment

- Glass capillary with fly scan
- Time resolved SAXS (Temperature control)
- Microfluidics
- Acoustic Levitator
- Powder sample
- Etc

Outline

1. Overview

2. ID03 CoXRD (Coherent X-Ray Diffraction)

Sung Soo Ha
KBSI

Daseul Ham
PAL

Su-Yong Lee
PAL, CoXRD Advisor

3. ID04 CoSAXS (Coherent Small-Angle X-ray Scattering)

Wonhyuk Jo
KBSI

Jehan Kim
PAL, CoSAXS Advisor

4. ID10 HXNP (Hard X-ray NanoProbe)


Jaeyong Shin
PAL, Imaging science group leader


Yonghyun Kim
KBSI


Jun Lim
PAL, HXNP Advisor

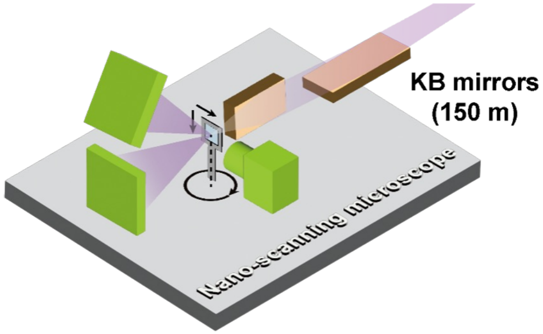
5. Summary

Courtesty by J. Shin
Modified by the author

3. HXNP

Main techniques and target science

Multimodal analysis with 3D imaging

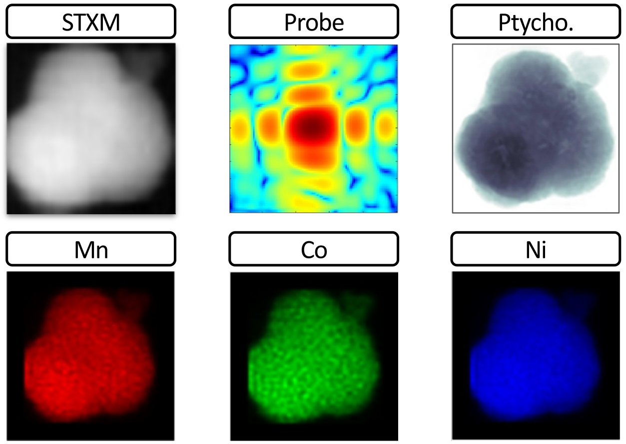


- **Target sample**
  → Semiconductor (CPU, HBM, etc)
  → Energy material (NMC, NRO, etc)
  → Quantum material (Vanadium Kagome metal, CDW, etc)
  → Micro/Nano-particle (Mesoporous silica, Metallic glass-NiB, etc)

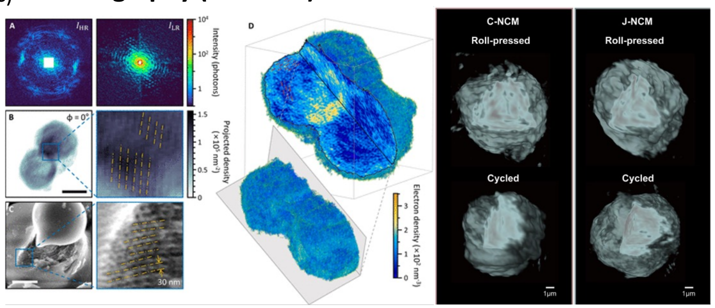
- **Primary method**
  → Ptychography with Nano-XFM
  → Tomography

- **Auxiliary method**
  → Diffraction mapping
  → Spectro-ptychography; Nano-XANES

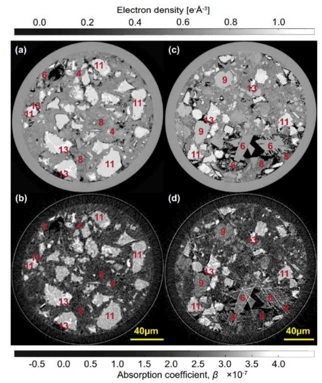
Multimodal imaging (PLS-II 9C)



Tomography (PLS-II 9C)

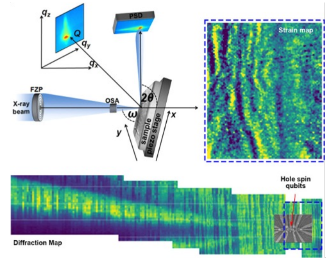


Near-field ptychography



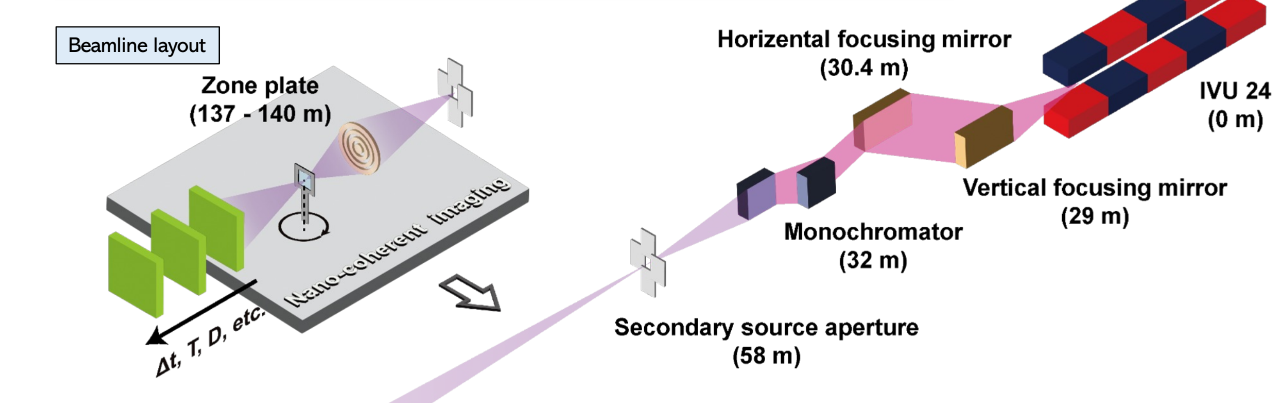
S. Shirani et al., *Cem.Concr. Res.*, **185**, 107622 (2024)

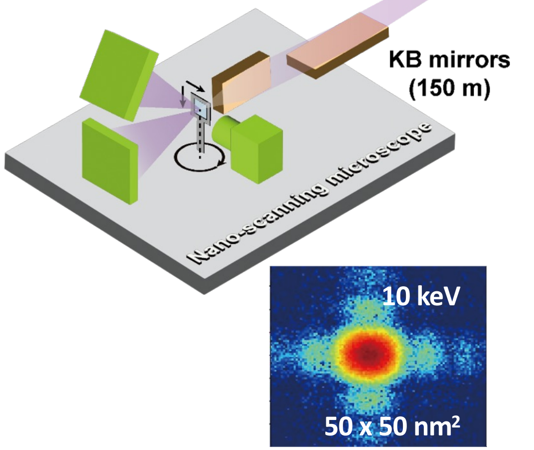
X-ray Diffraction Mapping



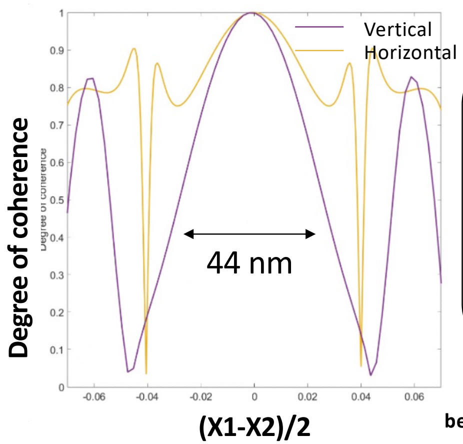
C. Corley-Wiciak et al., *ACS. Appl. Mater. Interfaces*, **15**, 3119 (2023)

4. HXNP





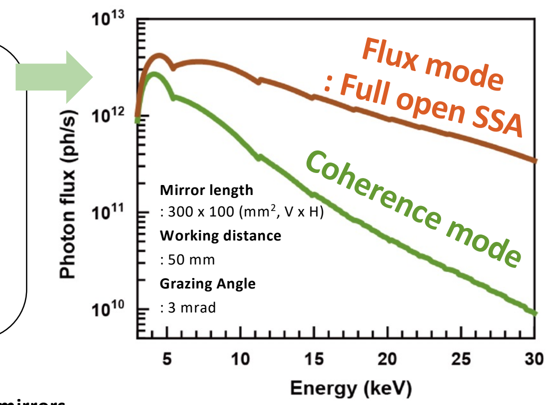
Light Source	IVU 24 (L=3.0m)
Photon energy	5 - 25 keV
Beam size	@ 10 keV 50 nm @ sample (FWHM, KB) 100 nm @ sample (FWHM, ZP) 30 μm @ sample(Unfocused)
Working distance	50 mm (KB mirror) 100 mm (ZP or DCRL)
Spatial resolution	< 50 nm (Scanning) < 10 nm (Imaging)
Coh. photon flux	10^{10} -10^{12} phs/s @ Sample



Considering to

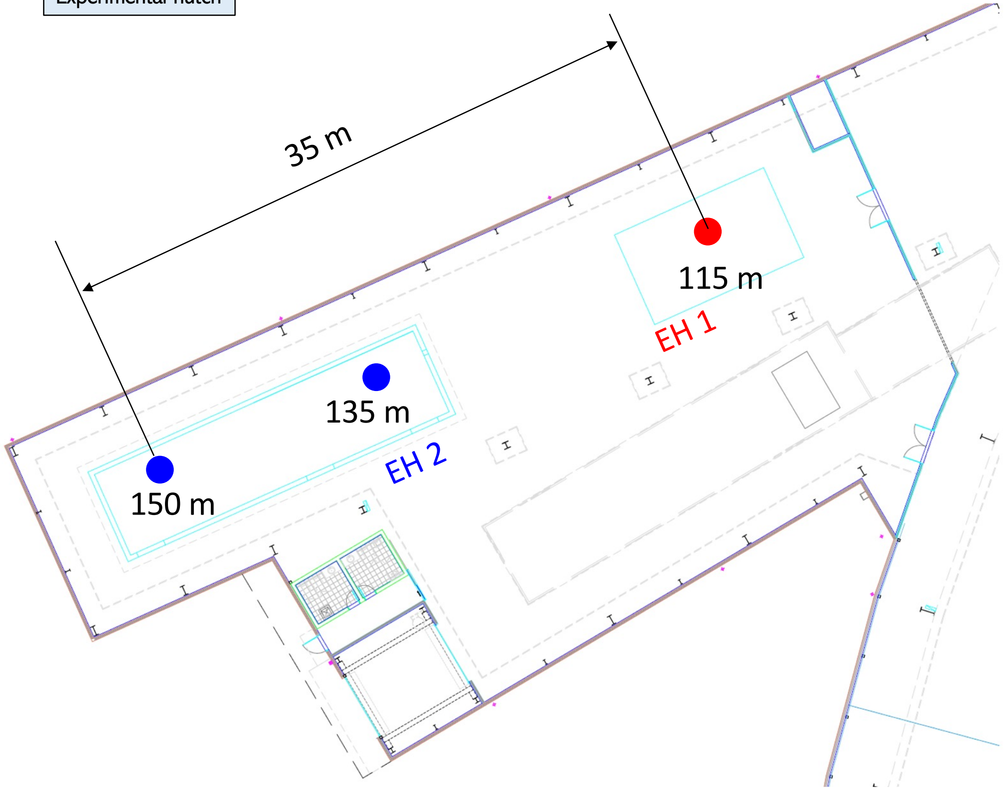
1. Mirror reflection coefficient
2. SSA gap size
   for μ = 0.8
3. KB mirror acceptance
4. Monobeam
5. Polarization effect from HDCM

μ: Degree of coherence between the beam center and the edges mirrors



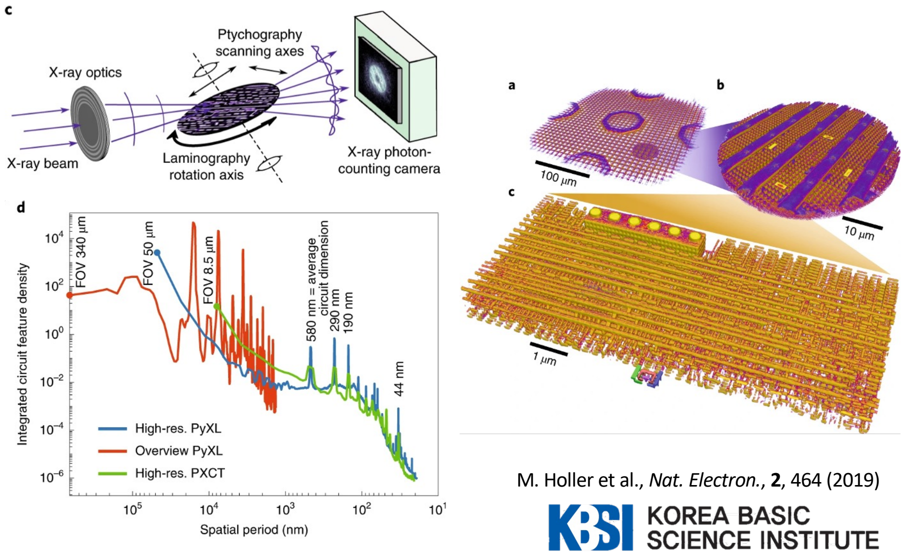
4. HXNP

Experimental hutch



Experimental Hutch 1 (Ongoing design)

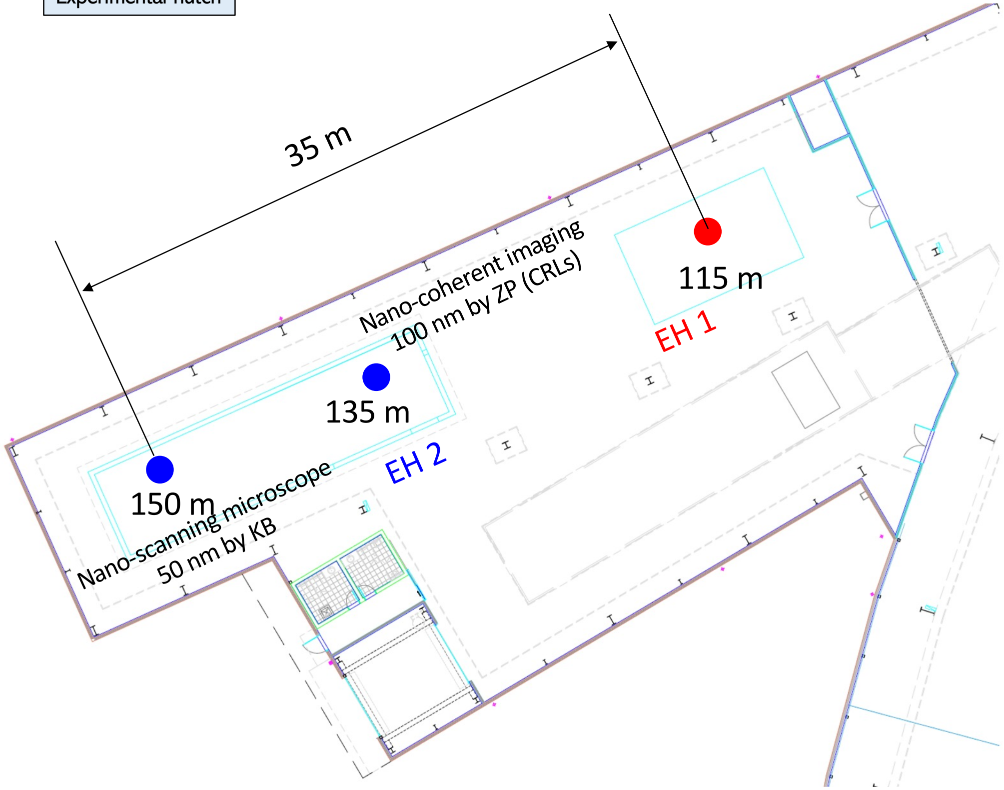
- **Hutch dimension**
  : 10 x 6 x 3.5 m^3(L x W x H)
- **Sample position**
  : 115 m
- **Maximum sample to detector**
  : Around 35 m (On-axis)
- **Beam path aperture**
  : 300 mm (30 nm resolution)
- **Purpose**
  : (Initial phase) Coherence characterization, New instrument test
  : (Mature phase) Ptychographic laminography with unfocused beam



M. Holler et al., *Nat. Electron.*, **2**, 464 (2019)

4. HXNP

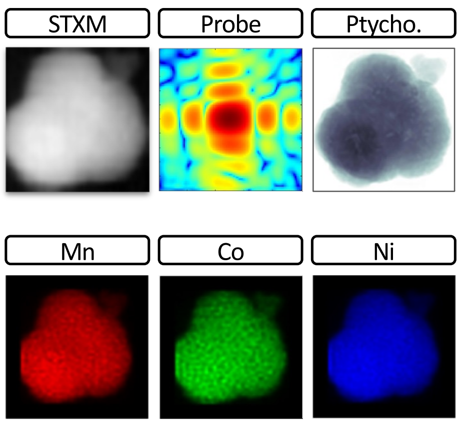
Experimental hutch

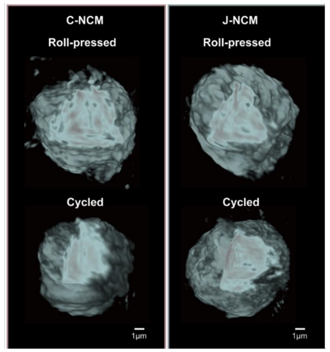


Experimental Huch 2

- **Hutch dimension**
  : 20 x 6 x 3.5 m^3(L x W x H)
- **Sample position**
  : 135 m and 150 m
- **Maximum sample to detector**
  NCI station: 15 m (On axis), 7 m(45°)
  NSM station: 0.5 - 2.0 m (0 - 20°)
- **Beam path aperture**
  : 200 mm (< 10 nm resolution)
- **Purpose**
  : (Initial phase) Multimodal imaging using nanobeam
  - Ptychography, Spectro-ptychography, XRF
  : (Mature phase) WAXS, XDM

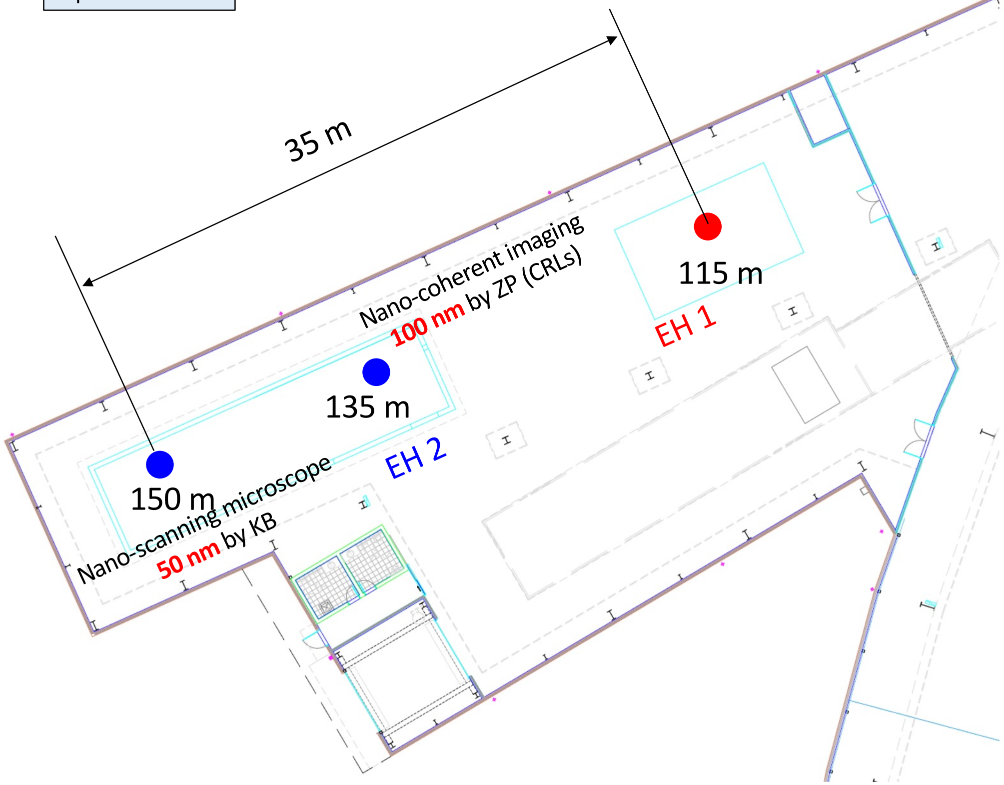
- **Multimodal imaging**



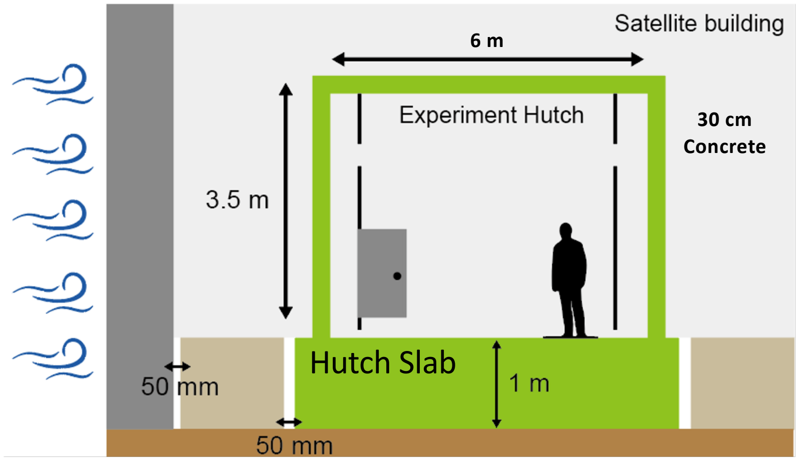


4. HXNP

Experimental hutch



Building structure



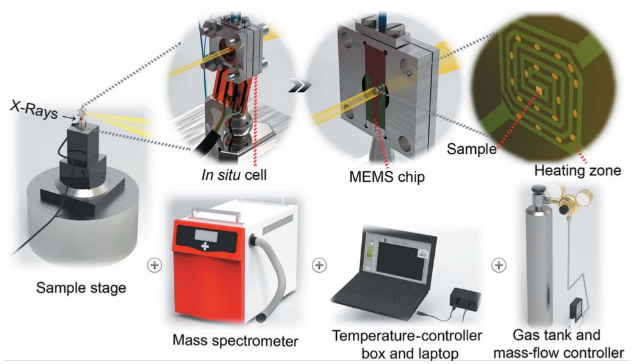
- Stone ground
  → 1 m concrete slab
- Seperated to the experimental hutch slab from the storage ring slab and wall House in house structure
  → Satellite building temp. ± 0.5 ℃
- Concrete hutch(30 cm thickness)
  → Low vibration, stable temperature

4. HXNP

Endstation **Compact in-situ cell and high throughput Exp. Sys.**

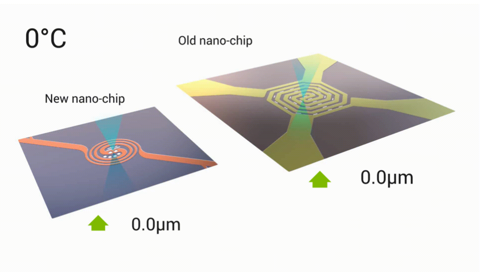
Mini-in situ cell (< 100g)

Gas supply system



Y. Fam et al., *J. Synchrotron. Rad.*, **26**, 1769 (2019)

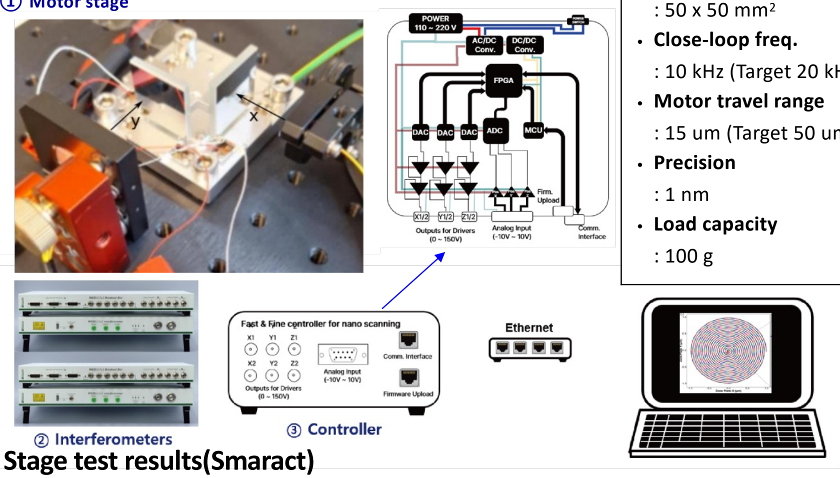
https://denssolutions.com/products/wildfire/



FOV : 25 um; Membrane window thickness: 30 nm(SIN)

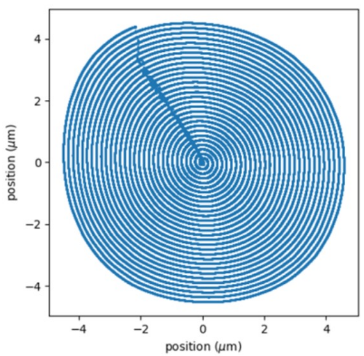
Fast precision nanoscan stage (Prototype)

① Motor stage

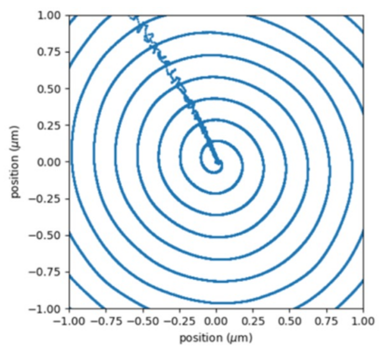


- **Det. Frame rate**
  : > 1kHz (Target > 5 kHz)
- **Table size**
  : 50 x 50 mm²
- **Close-loop freq.**
  : 10 kHz (Target 20 kHz)
- **Motor travel range**
  : 15 um (Target 50 um)
- **Precision**
  : 1 nm
- **Load capacity**
  : 100 g

Stage test results(Smaract)



Full spiral scan in the xy-plane.



Center of the spiral scan.

5. Summary

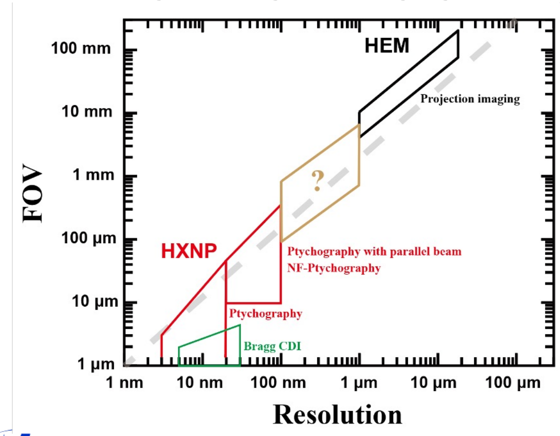
Summary

- Three hard X-ray beamlines, CoXRD, CoSAXS, and HXNP, will extensively utilize the high spatial coherence of 4GSR.
- Each beamlines will focus on its primary technique: Bragg CDI, XPCS, and Ptychogrophy, respectively, in the initial phase.
- Beamline optics design have been almost completed and optimized to enhance performance for these specific techniques.
- These three beamlines are designed to operate in a complementary manner, forming a coherence suite that enables structural and dynamical investigations from atomic to mesoscale regime in K-4GSR

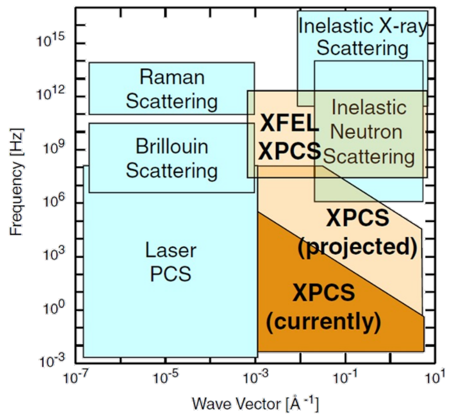
Future work

- Development of endstations and additional beamline components, including X-ray monitoring systems and vacuum flight tube.
- Selection of suitable detectors and establishement of DAQ systems to handle large data volumes.

Missing coverage in Imaging techniques



Accessible spatiotemporal resolution of XPCS

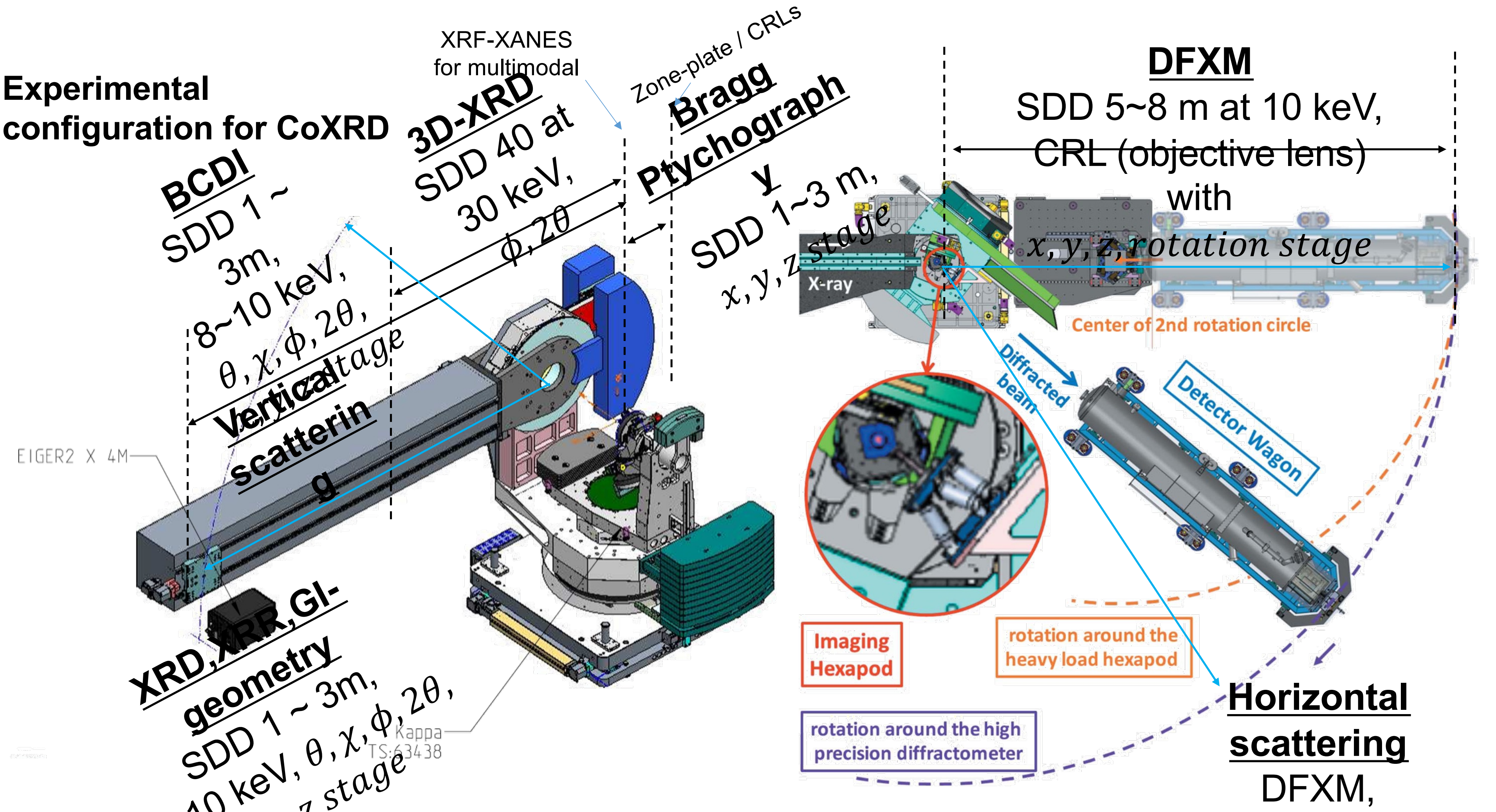


Thank You For Your Attention

CoXRD: Sung Soo Ha (sungsoo87@kbsi.re.kr)
CoSAXS: Wonhyuk Jo (wins1119@kbsi.re.kr)
HXNP: Jeayong Shin (jys1221@postech.ac.kr)

SI for CoXRD

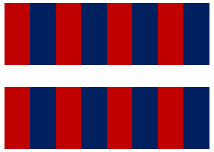
Experimental configuration for CoXRD



Ref. ESRF-EBS, ID01

Insertion Devices : In-vacuum undulator

IVU22

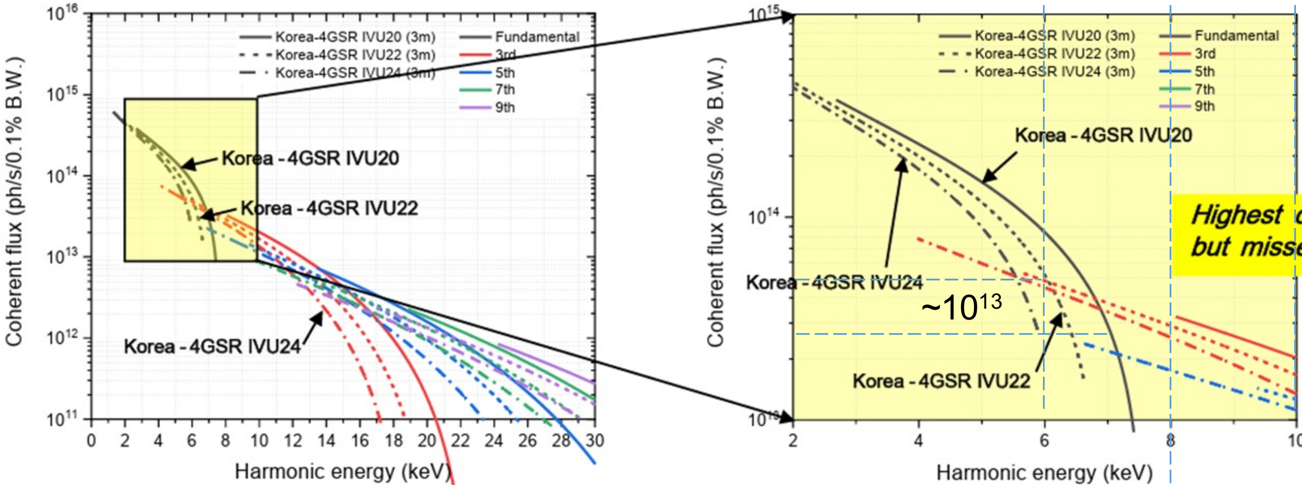


IVUs	Period (mm)	Length(m)	Number of periods, N	Max. Power (kW)	Max. K value
IVU20	20	3	150		1.91
IVU22	22	3	135	15.165 (400 mA)	2.315 (5 mm gap)
IVU24	24	3	125		2.74

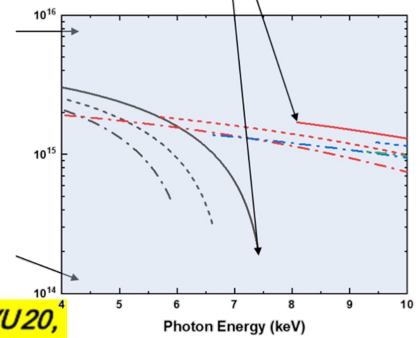
IVU20, 22, 24

Common 3-meter framework but differ in period

Coherent flux (total flux × coherent fraction)



Main selected x-ray energy



Highest coherent flux in IVU20, but missed spectral continuity

ESRF-EBS, ID01: 10^{13} ~ 10^{14} ph/s at 8 keV.
PETRA III P10: 2×10^{11} ph/s at 8 keV.
APS 34ID : 10^{12} ph/s/0.1% BW at 8.7 keV

~10^{12} at 8keV (IVU22)

BCDI & XRF-XANES

	HDCM	HHRM	KB (VFM)	KB (HFM)
Distance	40 m	46 m	65.08 m	65.7 m
Incident Angle	3 ~ 45 degree	2.5 mrad	3.75 mrad	3.75 mrad
Direction	Horizontal (Hall 25 mm offset)	Horizontal (Hall)	Vertical (Up)	Horizontal (Ring)
Shape	Plane	Plane	Elliptical	Elliptical
Image distance	-	-	1.92 m	1.3 m
Coating materials	-	Si, Rh, Pt	Si, Rh, Pt	Si, Rh, Pt
Mirror size (L x W x T, mm^3)	1^{st} : 50 x 20 x 40 2^{nd} : 60 x 20 x 40	600 x 50 x 50	600 x 50 x 50	600 x 50 x 50
Slope error (μrad, RMS)	< 1	< 0.1	< 0.1	< 0.1
Roughness (nm, RMS)	< 0.5	< 0.2	< 0.2	< 0.2

SI for CoSAXS

ID04 CoDEX (Tentative name)

Beamline Criteria for SAXS and GI-SAXS

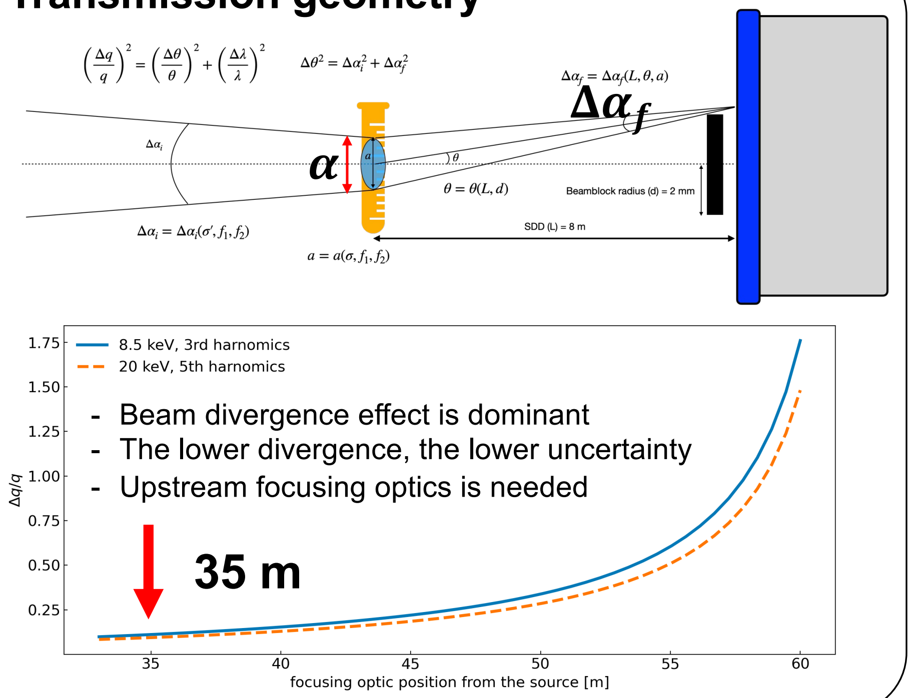
$$\left(\frac{\Delta q}{q}\right)^2 = \left(\frac{\Delta\theta}{\theta}\right)^2 + \left(\frac{\Delta\lambda}{\lambda}\right)^2$$

$\boldsymbol{\alpha}$: ***beam size***

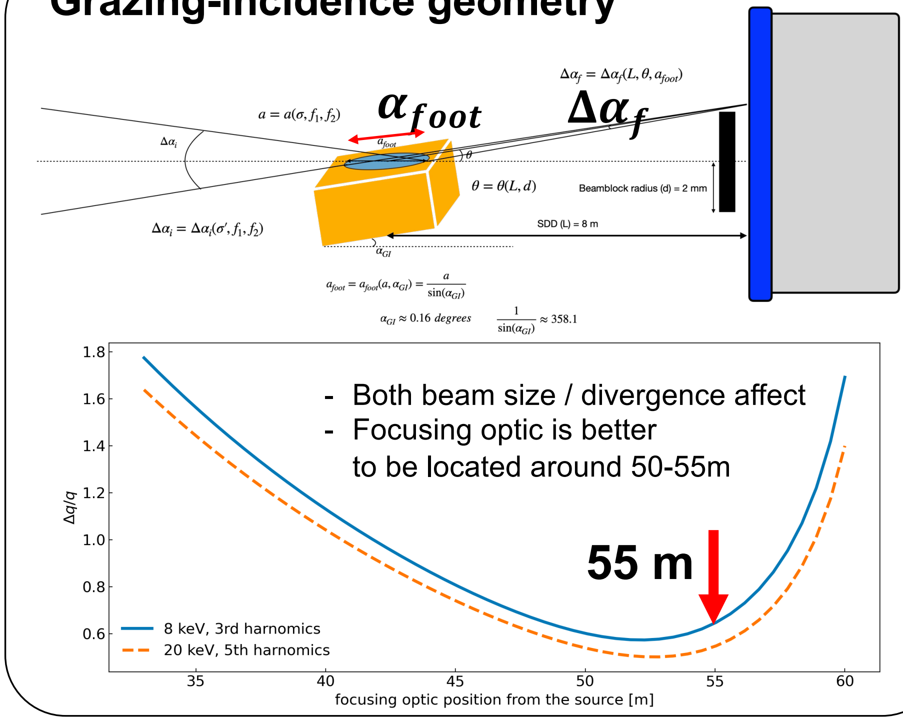
$$\Delta\theta^2 = \Delta\alpha_i^2 + \Delta\alpha_f^2$$

Minimize angle uncertainty at low scattering angle

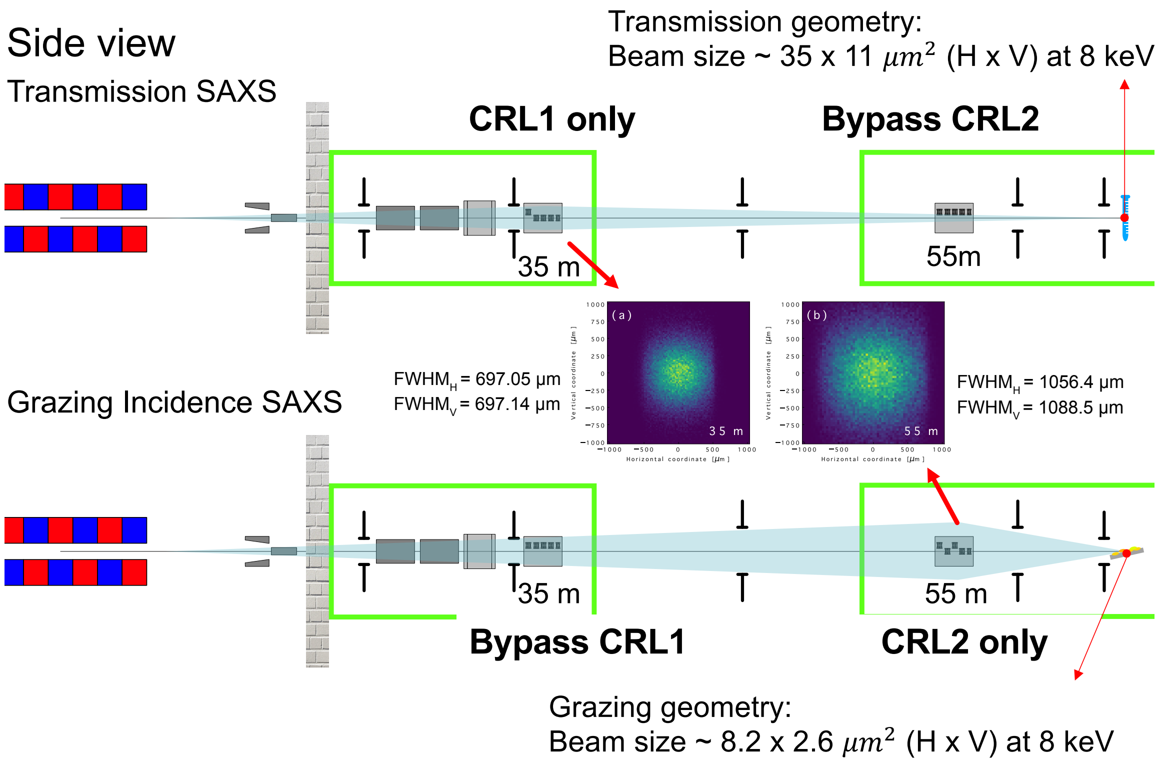
Transmission geometry



Grazing-incidence geometry



Focusing schemes for SAXS and GI-SAXS → Two diamond CRLs transfocators located at ***35 m*** and ***55 m***

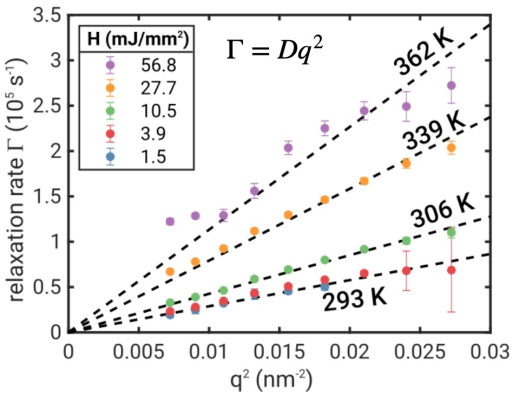


X-ray photon energy [keV]		8.5	20	8.5	20
Scattering geometry		Transmission SAXS		Grazing Incidence SAXS	
CRL1	Radius R[um]	946	455	-	-
	# of CRLs	3	8	-	-
CRL2	Radius R[um]	-	-	588	430
	# of CRLs	-	-	4	14
Beam size (FWHM) [um]	Horizontal	35.9	33.9	8.21	8.22
	Vertical	11.31	9.215	2.62	2.28
Beam divergence (FWHM) [urad]	Horizontal	18.51	14.26	51.14	54.56
	Vertical	18.94	17.92	48	56.98
Photon flux @ sample [10^{14} ph/s/0.1%B.W.]		5.65	1.27	2.09	0.79

Why not the smallest beam?

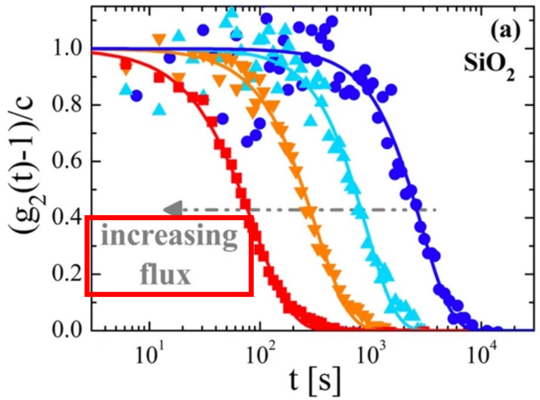
X-ray induced dynamics

Beamline Criteria for X-ray Photon Correlation Spec



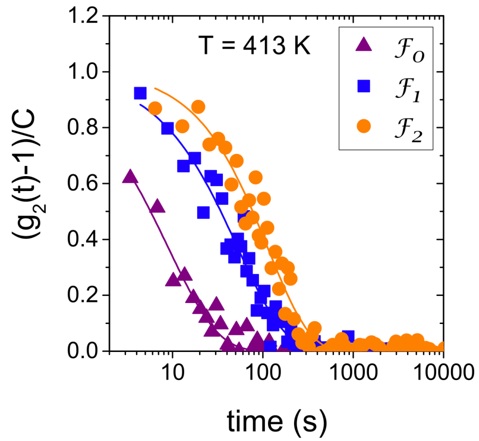
Relexation rate of silica NPs
in water for **various X-ray flux**

F. Lehmkühler et al., PNAS, 117, 24110 (2020)



Intensity correlation function
measured in silica NPs in water

B. Ruta, Scientific Reports 7, 3962 (2017)



Intensity correlation function
measured in glass-former B_2O_3

G. Pintori, Phys. Rev. B, 99, 224206 (2019)

Strongly focused beam for higher contrast might enhance the beam induced effect

→ Require more attenuator → Lower scattering intensity $\bar{k}$ → Lower SNR 🤨

$$SNR = \beta \bar{k} \sqrt{N_f N_p}$$

→ Irradiate more sample with larger beam 🧐 → Suppressing speckle contrast β 😭 → Longer detector distance needed 😂

Variable beamsize and **long detector distance** are
the key component of optimizing XPCS expriment!

Beamline Criteria for X-ray Photon Correlation Spectroscopy

Long sample to detector distance

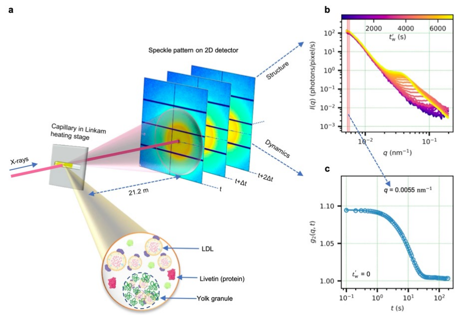
CoSAXS beamline at Max IV

8-ID-I beamline at APS-U

The freshly installed Small-Angle XPCS (2024)

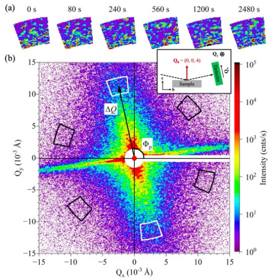
Extension in length scale

Protein dynamics in SAXS



N. D. Anthuparambil et al., Nat. Commun., 14, 5580 (2023)

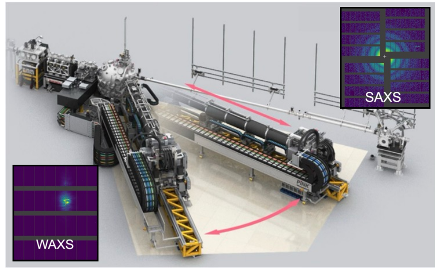
Charge Density Wave dynamics in WAXS



L. Shen., Phys. Rev. B, 108, L201111 (2023)

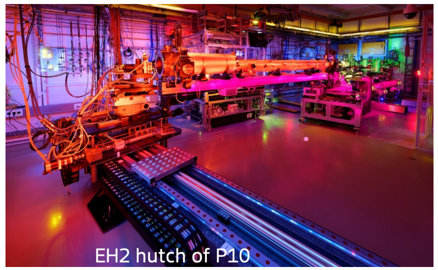
Rotatable detector arm for WAXS

Material Imaging and Dynamics insturment at EuXFEL



SDD: 3-8 m & Detector angle : < 50 degrees

P10 beamline at PETRA III

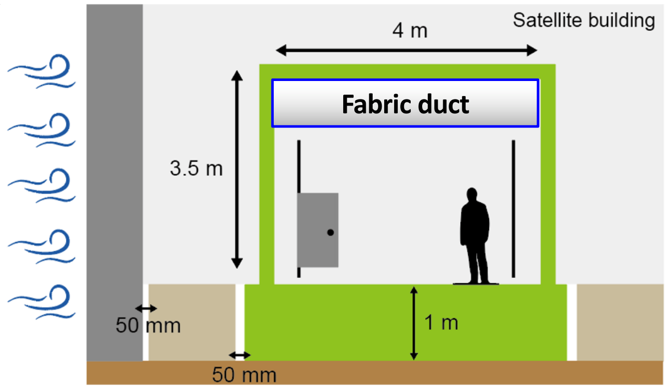


SDD: < 5 m & Detector angle : < 30 degrees

SI for HXNP

Hybrid approach for hutch cooling system

❖ **Strategies for high thermal stability in exp. hutch**



Heating, Ventilating, and Air Conditioning system

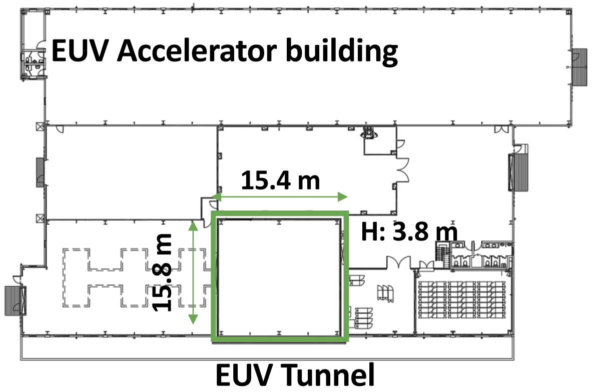
- ± < 0.1 ℃ / h
- 20 x 6 x 3.5 m^3 (L x W x H)

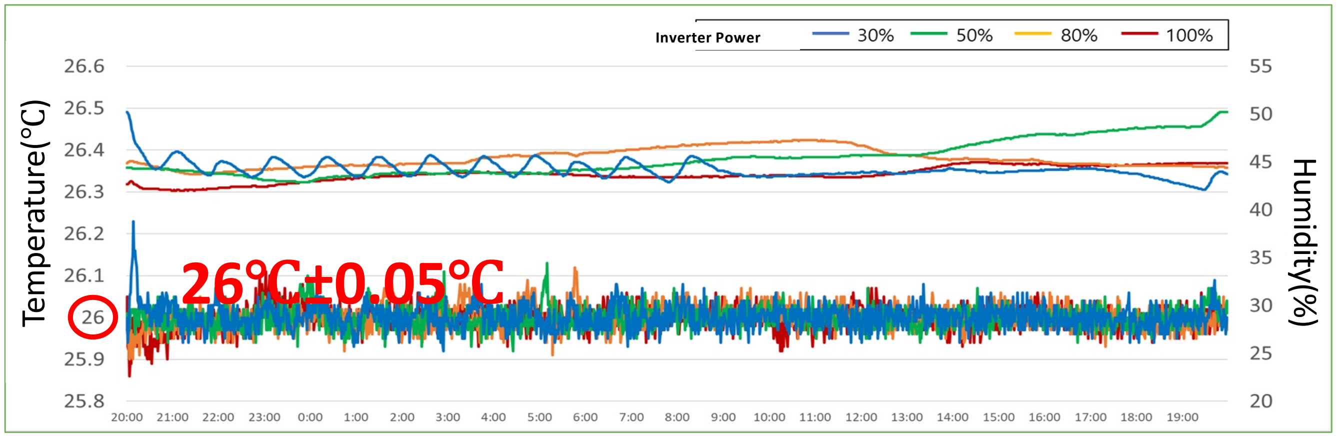
Air curtain or enclosure for exp. equipments

- ± 0.02 ℃ / h
- 2 x 1.5 x 2 m^3 (L x W x H)

Temperature derivation ± 0.02 ℃ / h

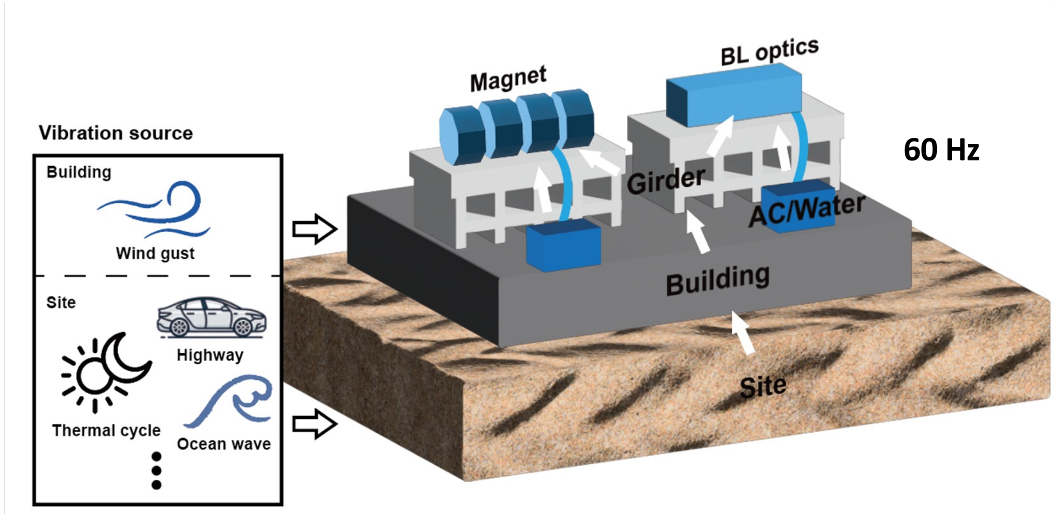
❖ **HVAC system of PAL-EUV tunnel**

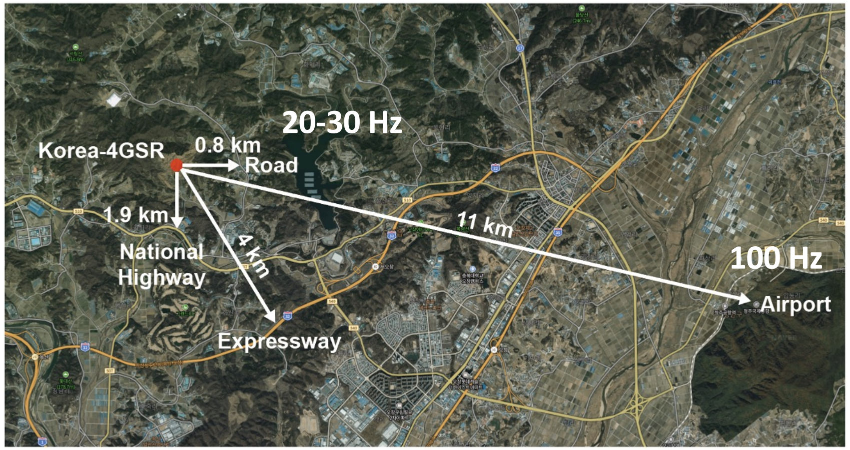




Compare vibration level with other SR facility

❖ **Vibration source and propagation**





1 - 30 Hz

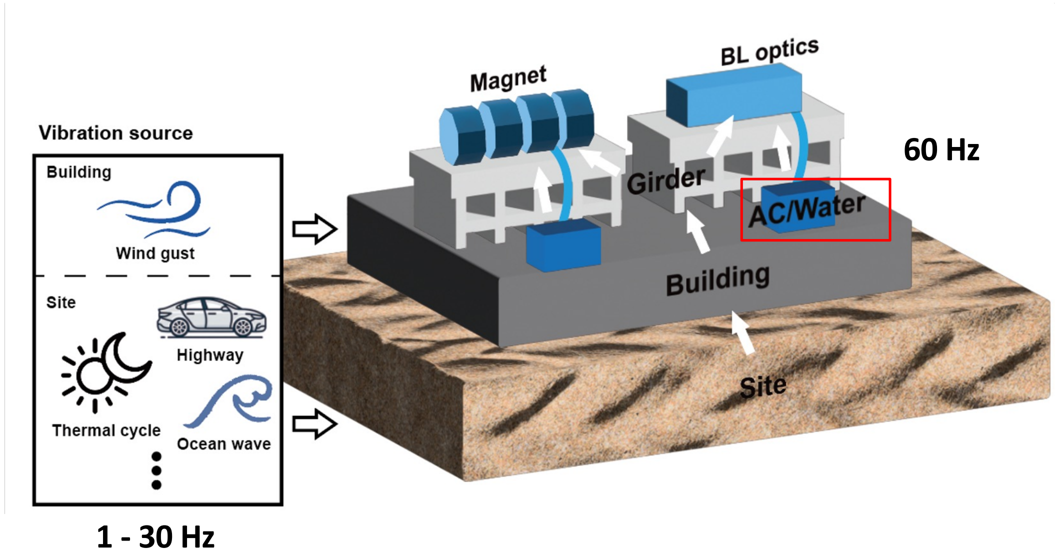
❖ **Overview of vibration amplitude (RMS, 1-100 Hz)**

Facility name	APS	BNL	SPRING 8	SSRF	IHEP	PLS-II 9C/2D	4GSR
Day rms (nm)	11.0	135.3	2.5	444.0	9.0	15.9 / 85.49* 15.4 / 34.39*	70 nm (1 Hz)** 11 nm (2 Hz)
Night rms (nm)	9.8	29.1	1.8	102.0	8.1		

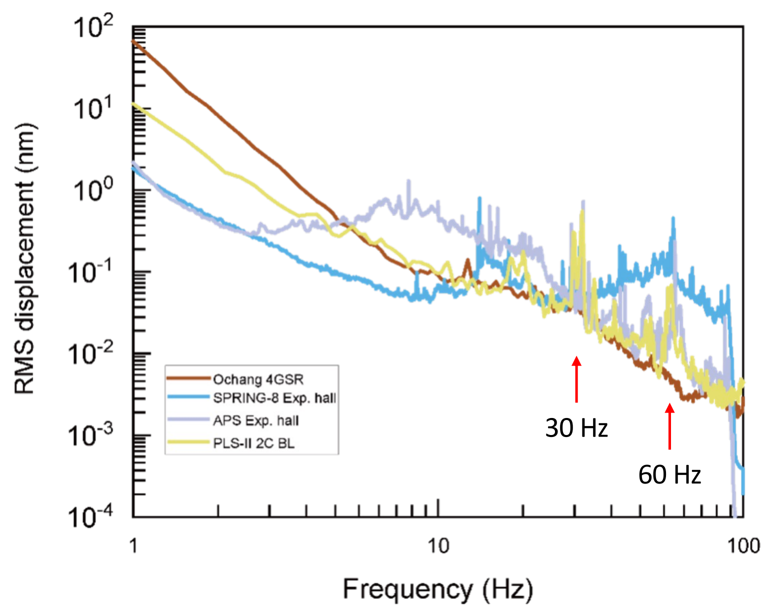
https://vibration.desy.de/overview * Measured over 4 repetitions. **Dr. Gwang-Wook Hong from PAL** ** On construction site

Compare vibration level with other SR facility

❖ **Vibration source and propagation**



❖ **Vibration comparison of SR facility**



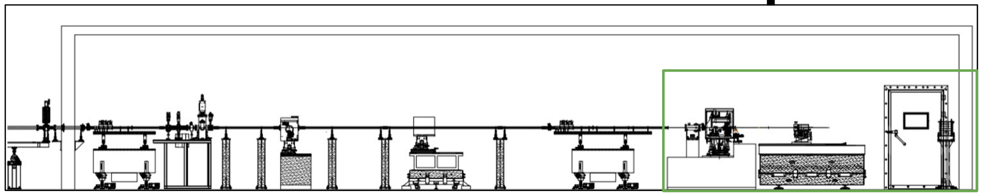
❖ **Overview of vibration amplitude (RMS, 1-100 Hz)**

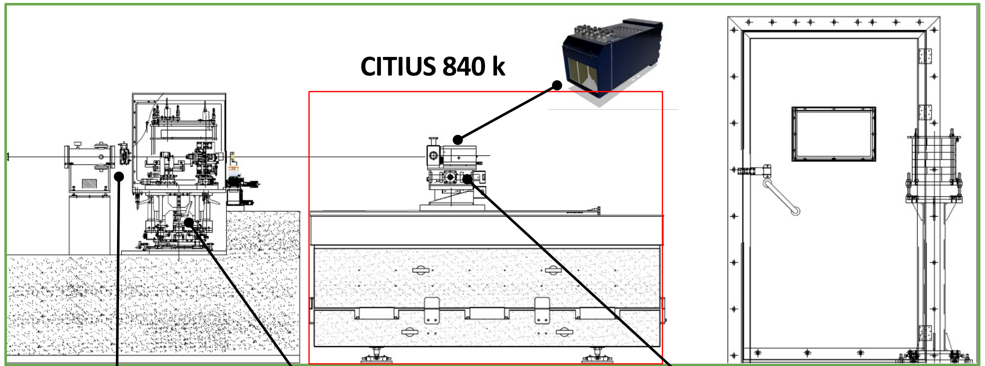
Facility name	APS	BNL	SPRING 8	SSRF	IHEP	PLS-II 9C/2D	4GSR
Day rms (nm)	11.0	135.3	2.5	444.0	9.0	15.9 / 85.49*	70 nm (1 Hz)**
Night rms (nm)	9.8	29.1	1.8	102.0	8.1	15.4 / 34.39*	11 nm (2 Hz)

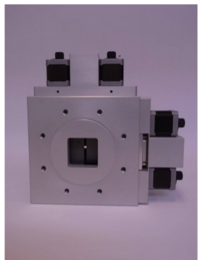
https://vibration.desy.de/overview * Measured over 4 repetitions. **Dr. Gwang-Wook Hong from PAL** ** On construction site

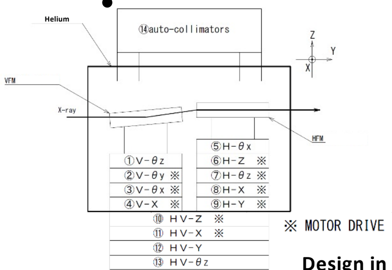
Experimental set up and operation mode

❖ Overview of EH2 - Beam path and detector stage





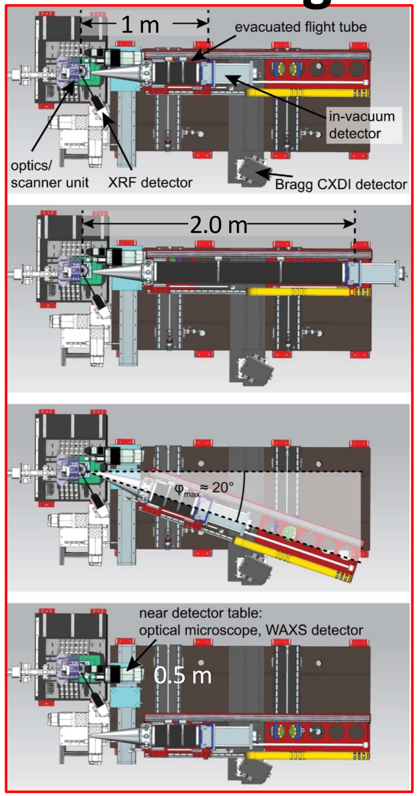




Design in Progress

Xhuber XY-Stage 5102.50

Xhuber Z-Stage 5103.C40



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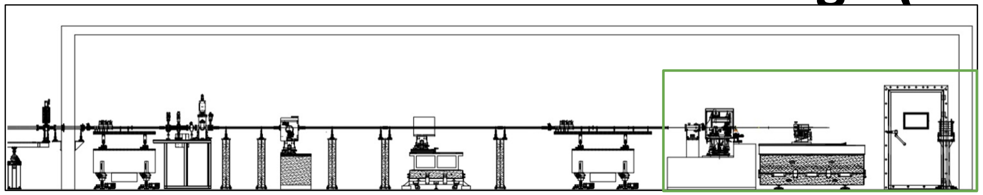
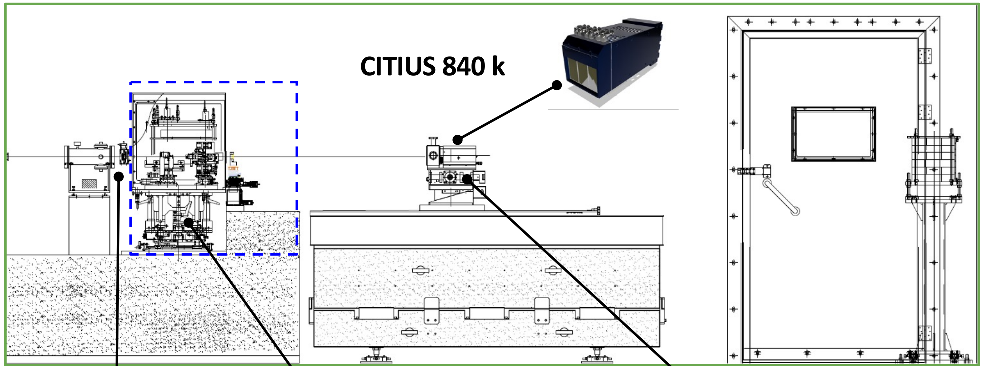
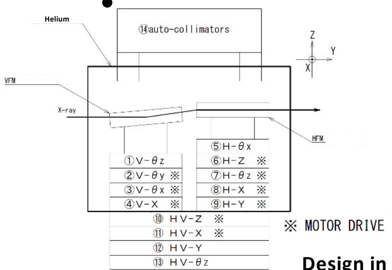
- **Working distance**
  : 50 mm (KB mirror)
- **Detector**
  : CITIUS 840 k, SDD 7 ch
- **Sample to detector**
  : 0.5 m - 2.0 m (On rail, up to 20∘)
  : 0.5 m - 4.2 m (On axis)
  : 0.5 m - 5.2 m (Up to 45∘)
- **Macro-nanoscale multiplexing 3D imaging**
  >100 um FOV, < 30 nm spatial resolution
- **High temperature env.**
  > 600 ℃ (Nano-chip mems)
- **In-situ/operando multiplexing imaging**
  < 10 min time step
- **Thermal stability:** ± 0.02 ℃ / h

Experimental set up and operation mode

❖ Endstation - KB mirror design (Design in progress)







Design in Progress

Xhuber XY-Stage 5102.50

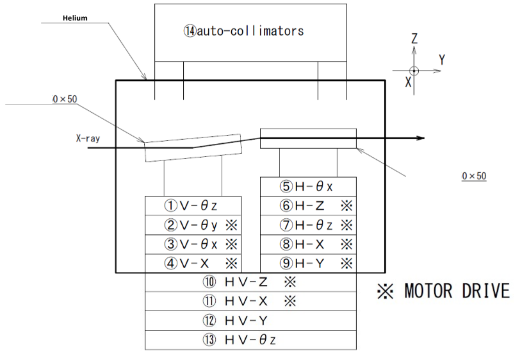
Xhuber Z-Stage 5103.C40

POHANG ACCELERATOR LABORATORY

- **JM 2000**

PLS-II 8C BL

- **KB motor configure for HXNP**

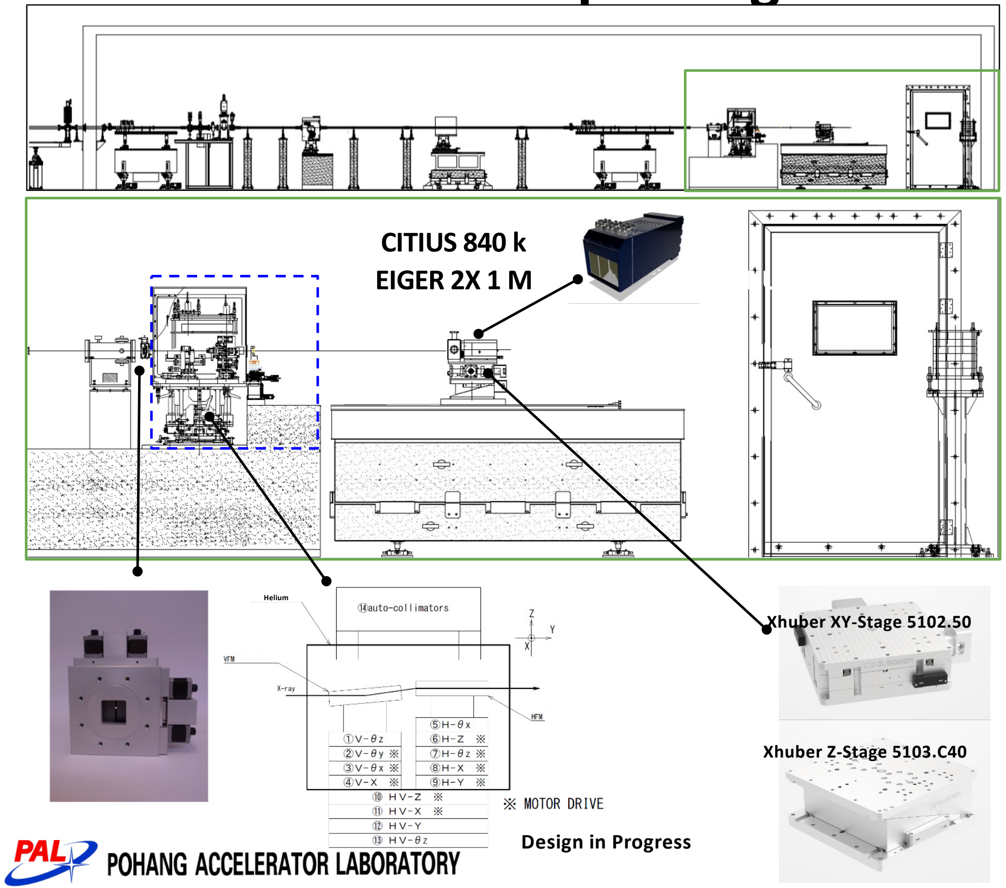


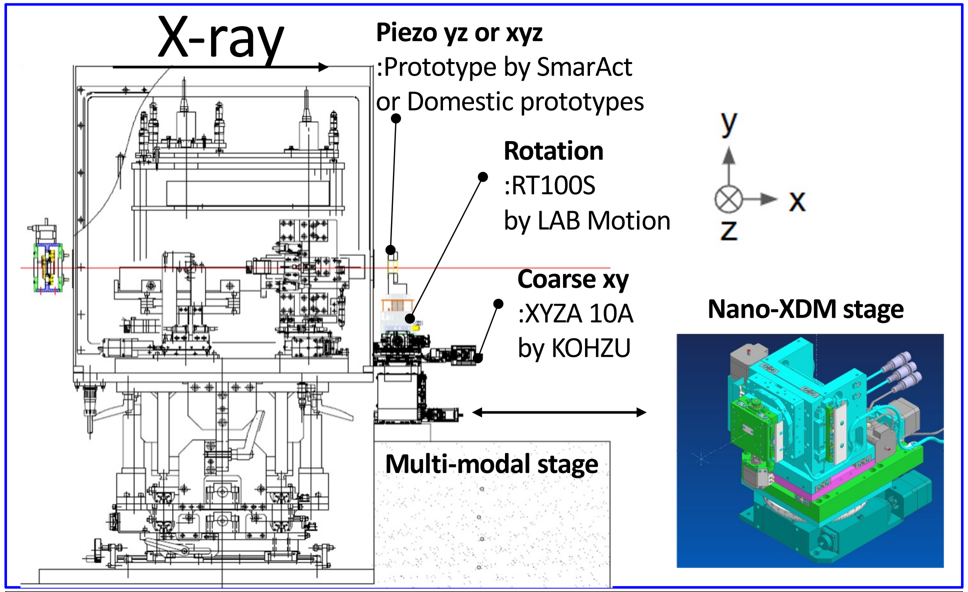
Design in Progress

- **Working distance**
  : 50 mm (KB mirror); Sample stage table size: 75 mm
- **Mirror length**
  : 300 mm(V) x 100 mm(H)
- **Laser interferometer system for verifying angular motion**
- **Helium purging chamber / thin wall**
- **Limit DOF for high stability**
  → Single coating(Pt)

Experimental set up and operation mode

❖ Endstation - Sample stage





- **Coarse xyz** → Travel range(X x Y x Z): 15 x 30 x 15 mm^3
- **Fast nanoscan stage(Domestically developed prototype)**
  → Travel range : 15 um x 15 um
  → Resonant frequency : > 3kHz; Position streaming rate: 25 kHz
- **Fast nanoscan stage(Prototype by SmarAct)**
  → Travel range : 15 um x 15 um
  → Resonant frequency : > 1kHz; Position streaming rate: 39 kHz
- **Rotation motor**: Air bearing rotation motor with slip ring
- **Sample position reader**: Laser interferometer(Design in Progress)