深圳综合粒子设施研究院
Institute of Advanced Science Facilities, Shenzhen

The Design of Hard X-ray Spectroscopy Beamlines in Shenzhen Innovation Light source Facility (SILF)

Chunzhen Yang, Dr.
Environmental Science and Chemistry Group
Contact: yangcz@mail.iasf.ac.cn
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Synchrotron Radiation light sources

Guangdong-Hong Kong-Macao Greater Bay Area

Guangming Science City

Hong Kong-Shenzhen Innovation and Technology Park

Shenzhen Innovation Light-source Facility (SILF)

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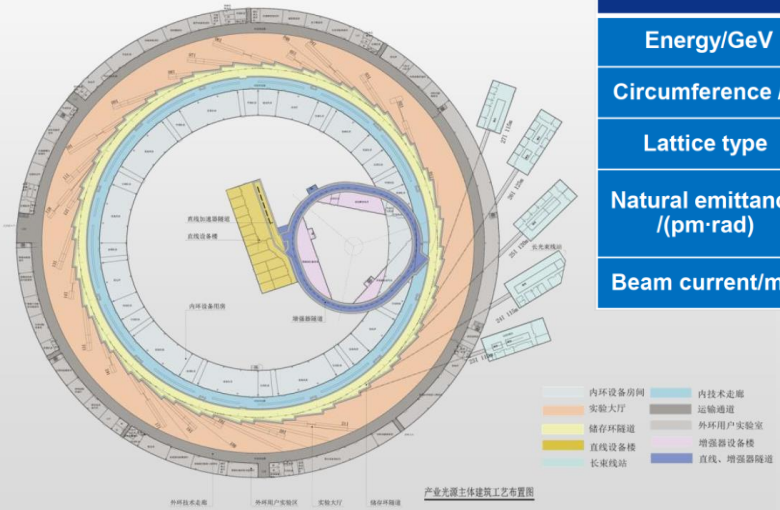
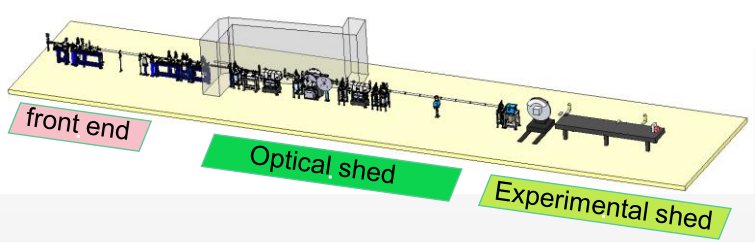
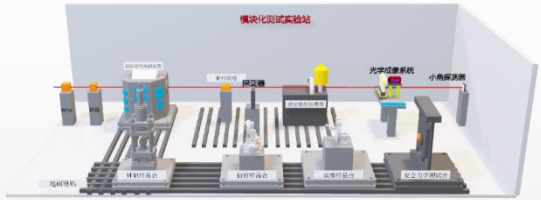
SILF is a fourth-generation diffraction-limited synchrotron radiation with an electron energy of **3 GeV** and low emittance of **<100 pm·rad**, and it provides photons with a broad range of energy from **4 meV to 160 keV**.



Parameter	Value
Energy/GeV	3.0
Circumference /m	700
Lattice type	7BA
Natural emittance /(pm·rad)	~100
Beam current/mA	200- 300

Beamlines





marine resources | Rare earth material

Next generation semiconductor | Green chemistry

....

未来产业

Future industry

(3 beamlines) (4 beamlines)

新兴产业

Biomedical Section | Electric Circuit Section

Advanced Manufacturing Section | Advanced Material Section

(3 beamlines) (3 beamlines)

Emerging industry

SILF

Major needs

重大需求

carbon fiber

nuclear material

special equipment

.....

Future development

发展预留

Hard X-ray Spectroscopy Beamlines

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Environmental Science and Chemistry Group

	Beamlines	Front End	Energy (keV)	Mono-chromator	Key features	Experiments
1	X-ray coupled TEM Beamline X射线电子束联用线站	Wiggler	4.8 – 30	DCM	✓ Time resolved QXAFS ✓ Both high time resolution and high space resolution	✓ XAFS ✓ QXAFS ✓ XAFS-TEM ✓ TEM-EELS
2	Environmental Science Beamline 环境能源线站	IVU22	2.05 – 16	DCM	✓ High detection limit ✓ High space resolution ✓ Element mapping image	✓ μ-XRF ✓ μ-XRD ✓ μ-XANES
3	High Resolution Hard X-ray Beamline 高分辨硬X射线谱学线站	IVU24	4 – 20	DCM&HRM	✓ High energy resolution for electronic structure analysis ✓ 磁性材料测量	✓ HERFD-XAS ✓ RIXSXES/XRS ✓ HAXPES

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X-ray coupled TEM Beamline

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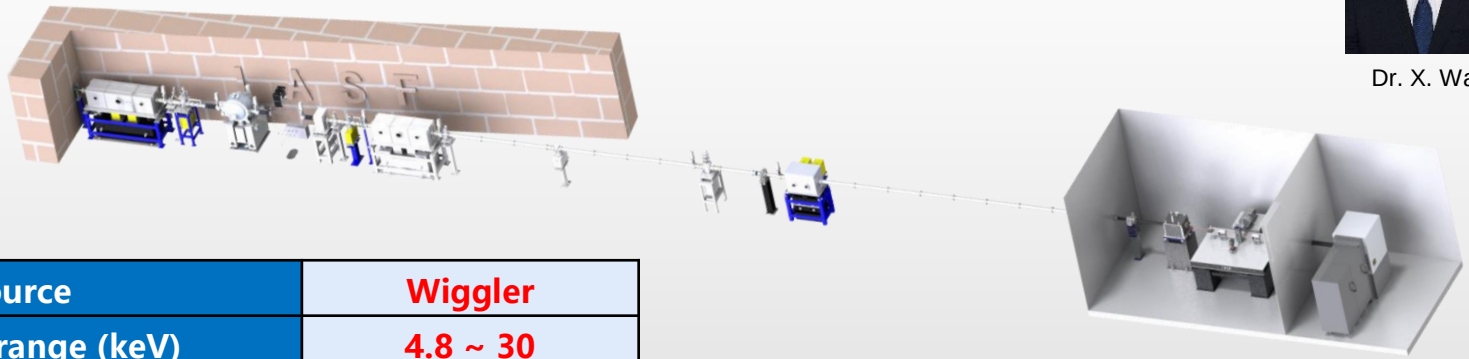
1. Key features

- Time-resolved XAFS
- X-ray coupled TEM analyses


Dr. X. Wang


Dr. M. Shu



Light source	Wiggler
Energy range (keV)	4.8 ~ 30
Energy resolution	~10^{-4}
Flux at 10 keV (ph/s)	10^{12}~10^{13} ph/s
Spot size at sample (μm^2)	0.3×0.3 (EH1) 2×0.3 (EH2)
Key features:	100 ms

Methodology

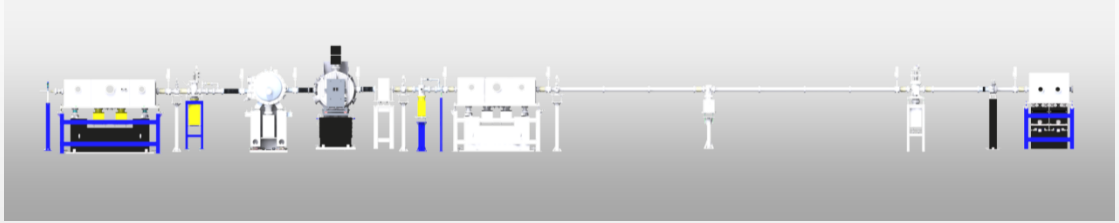
- XAFS-TEM
- QXAFS
- XAFS
- EELS

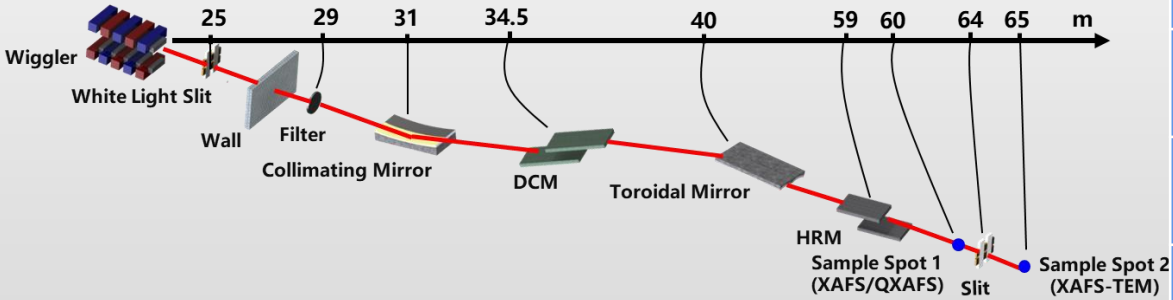
Application Fields

- Catalysis
- Battery
- Environment
- Archaeology

X-ray coupled TEM Beamline

2. Beamline Optics





Source	Wiggler, 50 mm, 40 period, 1.9 T
Angle acceptance	500×100 (μrad, H×V)
Collimating Mirror	Rh, Pt
Monochromator	Si(111)，Si(311)
Focusing Mirror	Rh, Pt
Harmonic Reject Mirror	Si, Rh, Pt

X-ray coupled TEM Beamline

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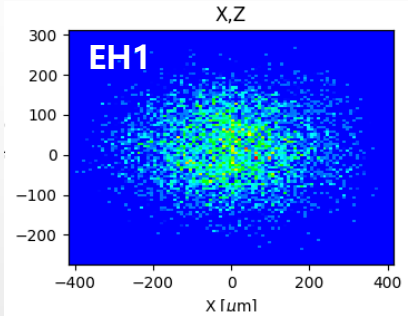
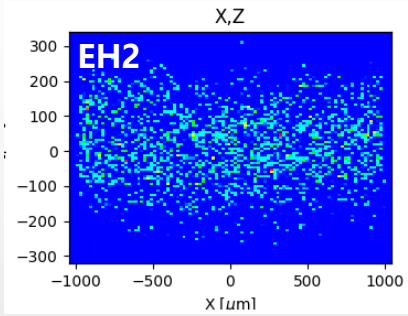
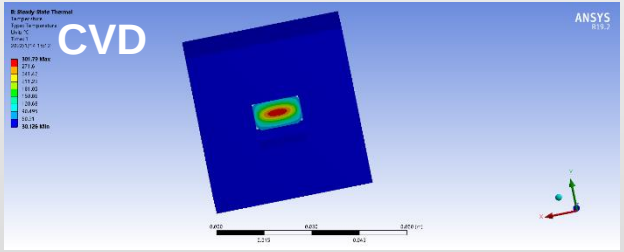
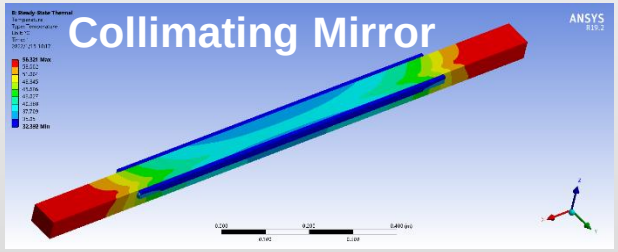
3. X-ray tracing and thermal analyses

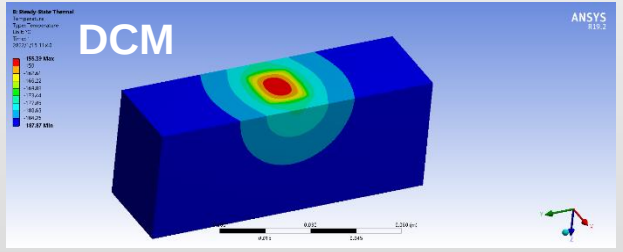




Sample Spot	EH1	EH2
Position (m)	60	65
Energy (keV)	10	10
Size (μm², FWHM, H×V)	216.55×193.40	1939.98×278.17
Divergence(μrad², FWHM, H×V)	969.15×127.58	345.21×112.65
Flux (phs/s/0.1% bw)	1.56E+13 (10 keV)	6.00E+12 (10 keV)







OE	CVD	CM	DCM
Power (W)	158	304	551
Power Density (W/mm²)	3.81	0.018	2.19

X-ray coupled TEM Beamline

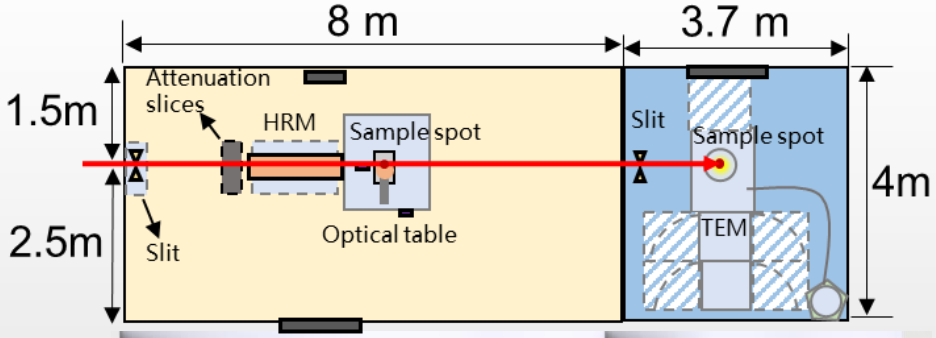
4. Experimental Hutch

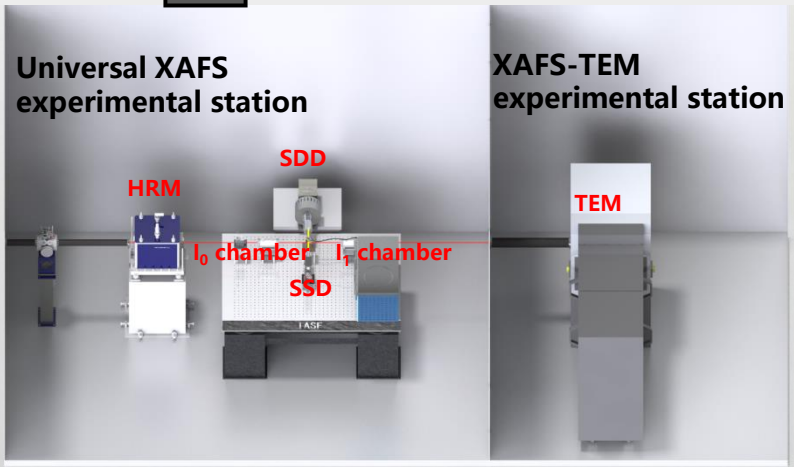
EH 1: Universal XAFS hutch

- ✓ Transmission XAFS
- ✓ Fluorescence XAFS
- ✓ Time solved XAFS

EH 2: TEM hutch

- ✓ XAFS-TEM
- ✓ HR-TEM
- ✓ EELS





X-ray coupled TEM Beamline

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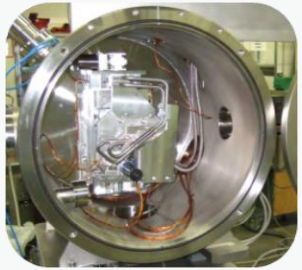
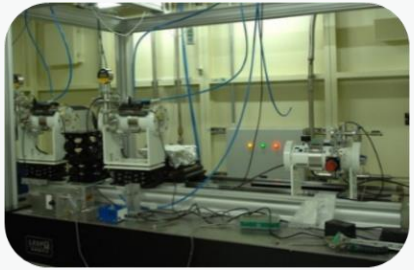
5. Detectors and Instruments

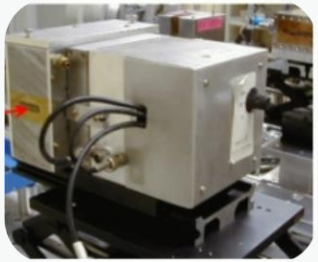


Channel-cut Monochromator

In-situ XAFS

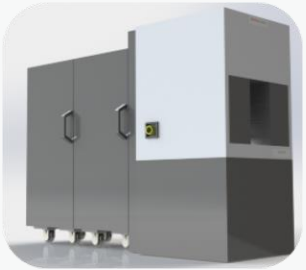


Ionization chamber

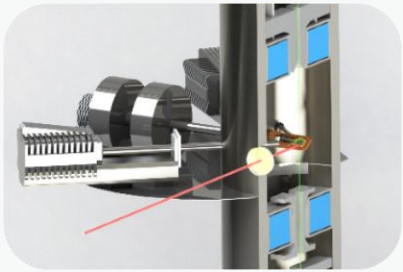


Lytle chamber

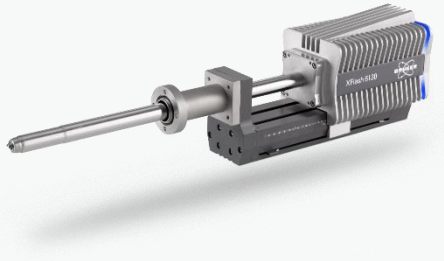
Solid state detector



TEM



XAFS-TEM



Silicon drift detector

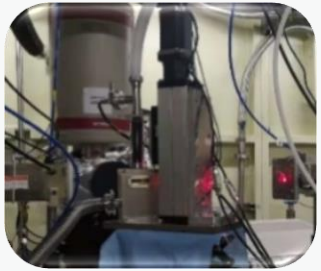
Sample holder

6. User Facilities

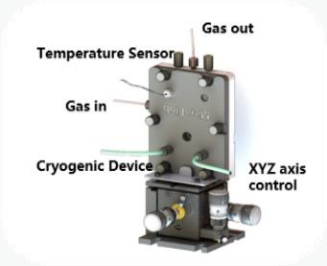
X-ray coupled TEM Beamline was equipped with universal XAFS and TEM test, and a diversity of in situ XAFS devices for catalytical reaction, battery property test, and combined test by XAFS-TEM.

Multi-environmental test

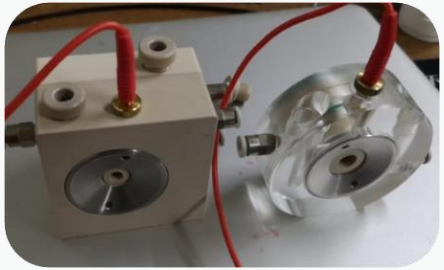
Thermo catalytic operando cell



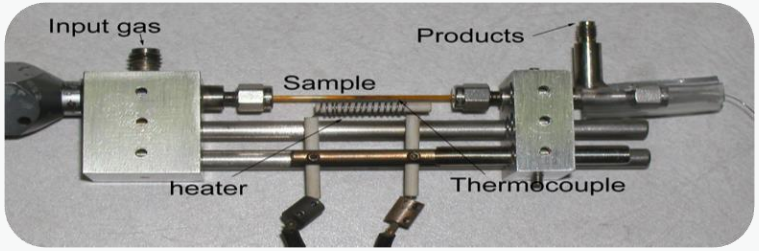
In situ cryogenic device



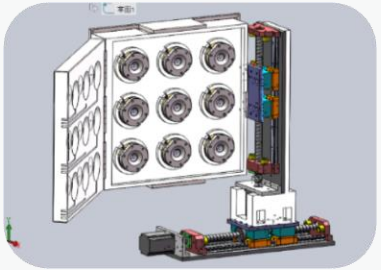
In situ battery cell



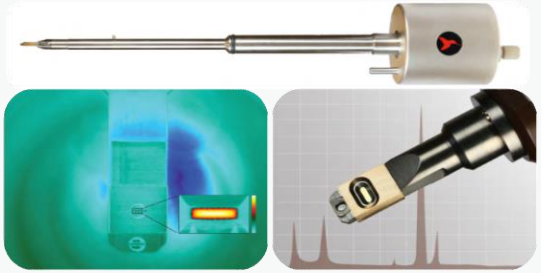
In situ electrochemical cell



Thermo catalytic cell



Automated in-situ XAFS battery test system

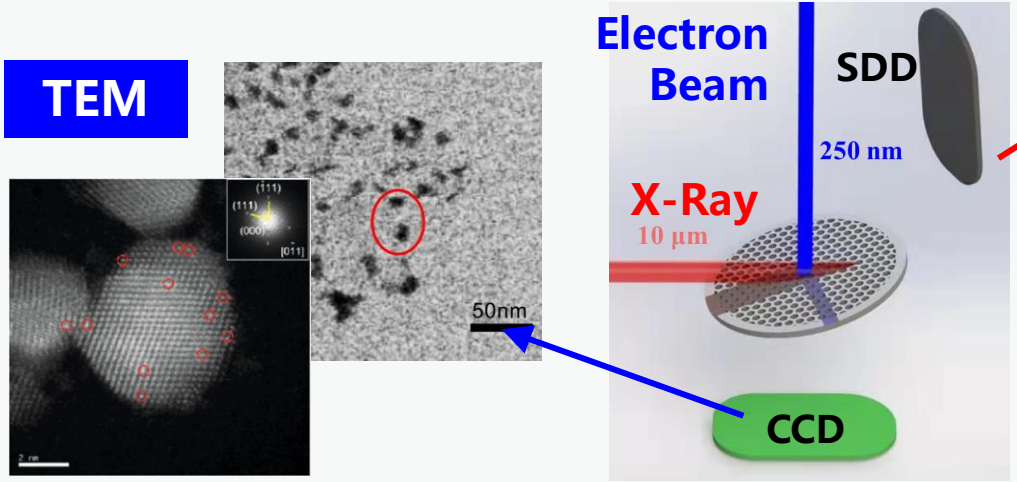


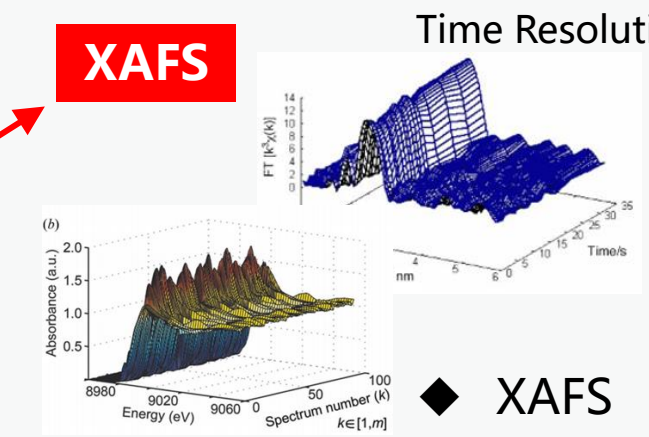
In-situ sample holder

X-ray coupled TEM Beamline

7. Unique features

- Obtain the microscopy morphology ,element distribution and the valence state, local coordination structure of samples at the same time

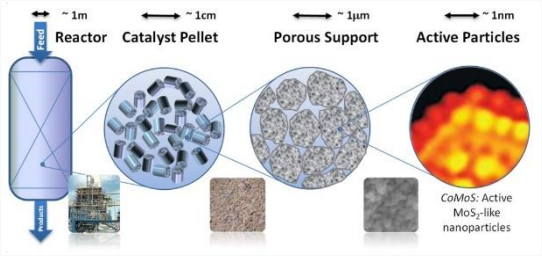




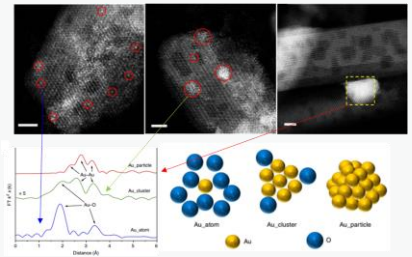
- XAFS
- QXAFS
- XAFS&TEM

8. Potential applications

- Focus on the structure and chemical properties of catalysis, material science, electrode material, etc., in order to understand and design better materials

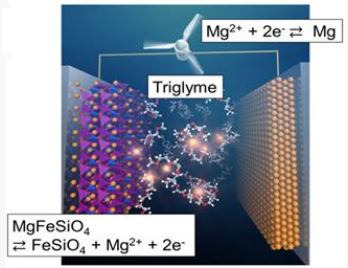


Morphology of industrial catalysts



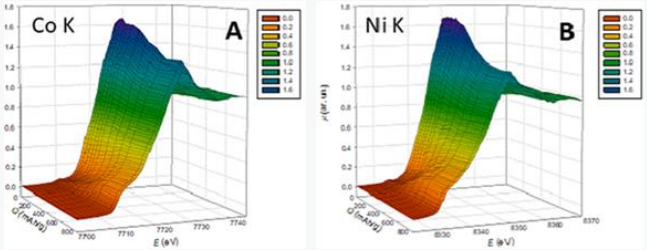
Relationship of structure & activity

Li-ion battery

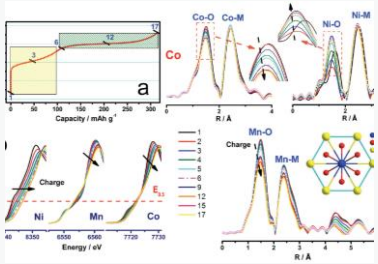


fuel cell

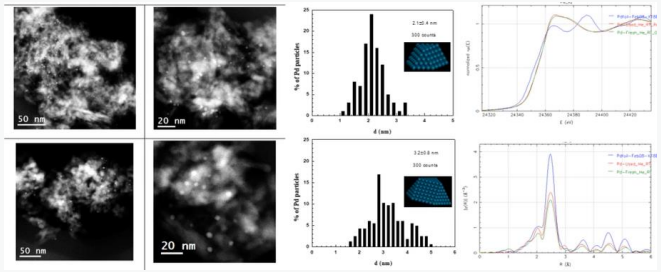
- Understanding the affection of environment (temperature, pression, voltage, charge time, etc.) to control a better operated conditions



QXAFS for electron chemistry



QXAFS for supercharge



XAFS-TEM for catalysts

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Environmental Science Beamline

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1. Key features

- high spatial resolution
- ultra-sensitive element detection


Dr. M. WANG Dr. X. LIN

Light source	Undulator
Energy range (keV)	2.05 ~ 16
Energy resolution	~10^{-4}
Flux at 2.5 keV (ph/s)	10^{12} ph/s
Spot size at sample (μm^2)	~600×600 (EH1) ~0.5×0.5 (EH2)
Key features	Space resolution: < 0.5 μm Detection limit: ppb Cryogenic system: 10 k

Method
μ-XRF, XRF, TXRF, XFCT
μ-XANES, XANES
μ-EXAFS, EXAFS
μ-XRD, XRD

Applications
Environmental science
Energy materials
Life sciences
Geological science

Environmental Science Beamline

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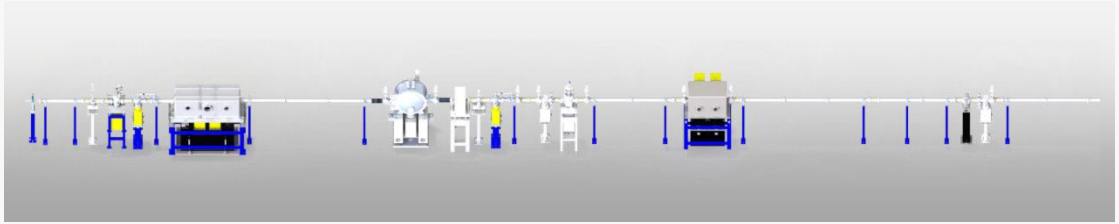
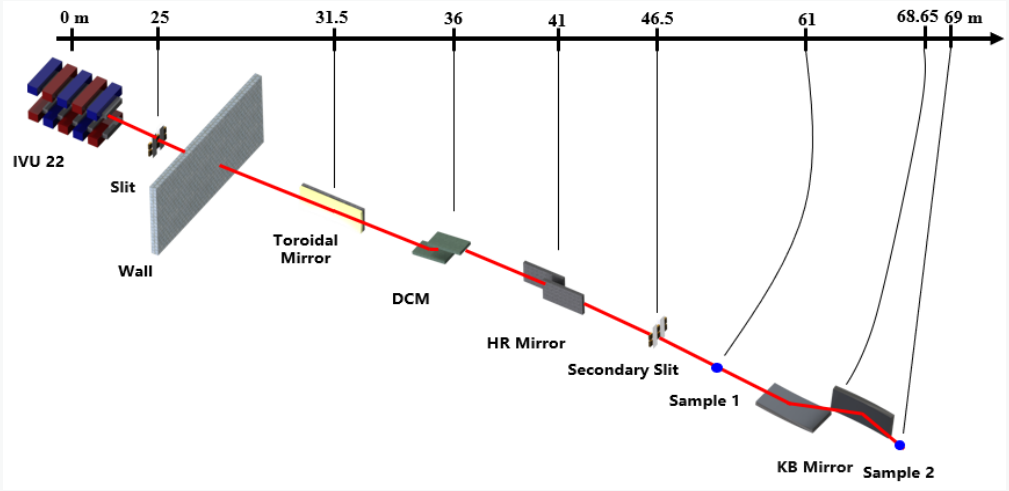
2. Beamline Optics





Source	IVU22, λ=22mm, B_{max}=1.04T, Gap_{min}=5 mm, L=4.5m
Angle acceptance (μrad)	45×45(H×V)
Toroidal Mirror	Rh 3mrad Vertical collimation Horizontal focus
Monochromator	Si(111), Si(311)
KB Mirror	Rh 4mrad
Harmonic Reject Mirror	Cr(2.05~3.5 keV), Ni(3.0~35.5 keV), Rh(9~15 keV),

Environmental Science Beamline

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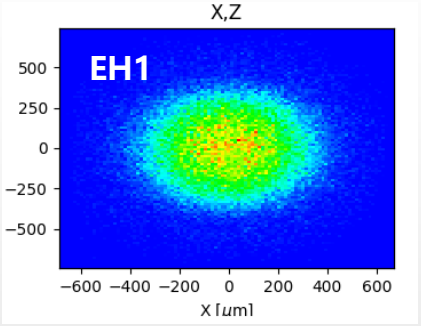
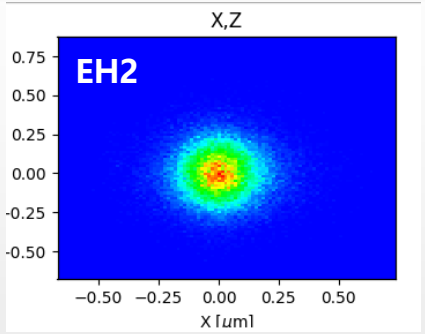
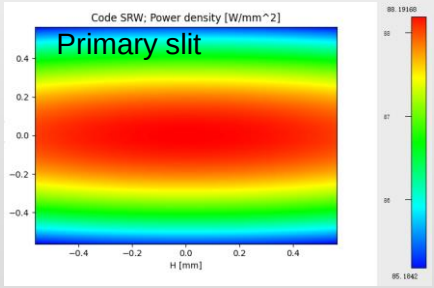
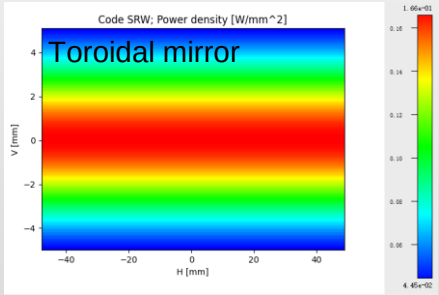
3. X-ray tracing and thermal analyses

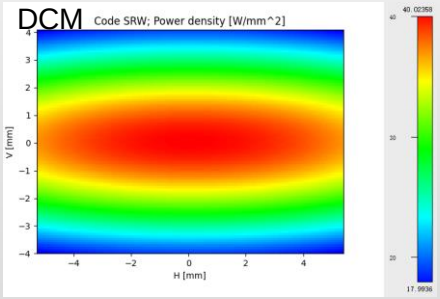




Sample Spot	EH1	EH2
Position (m)	60	69
Energy (keV)	2.5	2.5
Size (μm², FWHM, H×V)	462.30×475.9	0.23×0.31
Divergence(μrad², FWHM, H×V)	35.33×0.63	2258.74×1122.12
Flux (phs/s/0.1% bw)	2.70E+13 (2.5 keV)	4.67E+12 (2.5 keV)







OE	Primary slit	Toroidal Mirror	DCM
Absorbed Power (W)	2473	18	70.27
Power Density (W/mm²)	88.19	0.17	40.02

Environmental Science Beamline

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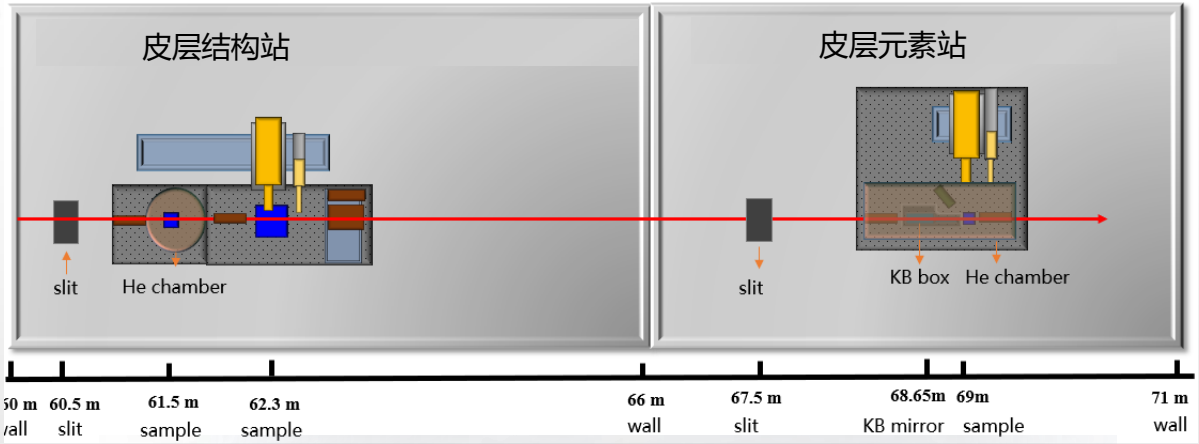
4. Experimental Hutch

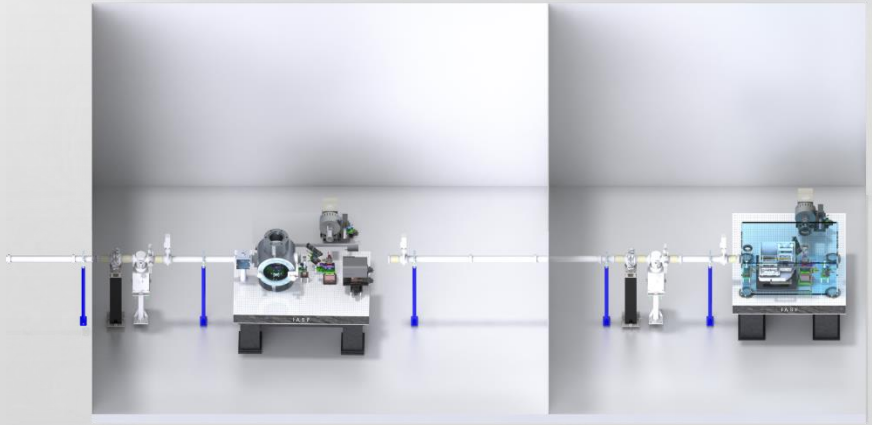
EH 1: micro spot size

- ✓ XRF
- ✓ TXRF
- ✓ confocal-XRF
- ✓ XFCT
- ✓ XRD
- ✓ XAFS



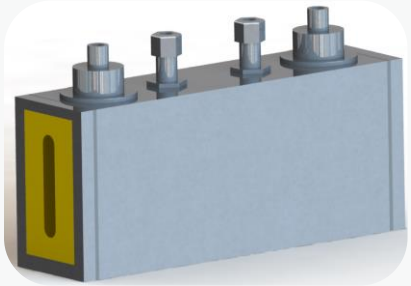
EH 2: sub-micro spot size

- ✓ μ-XRF
- ✓ μ-TXRF
- ✓ μ-XFCT
- ✓ μ-XAFS



5. Detectors and Instruments

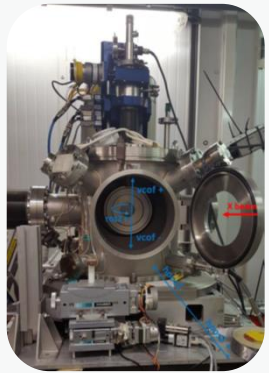
ion-chamber



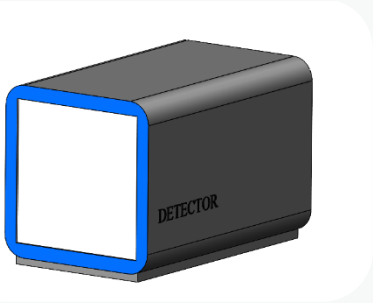
36 elements Ge SSD

Polycapillary optics

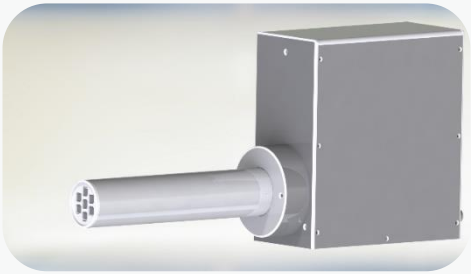
He/N_2/vacuum chamber



Eiger XRD detector

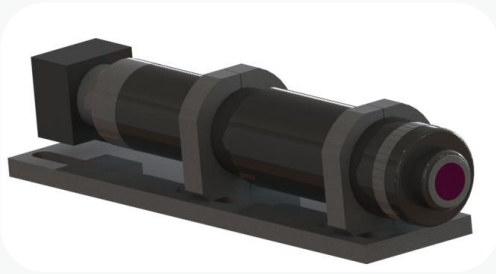


7 elements SDD



7D high precision sample stage

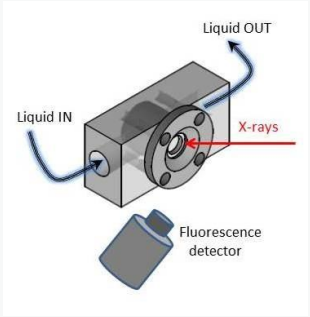
Optical camera



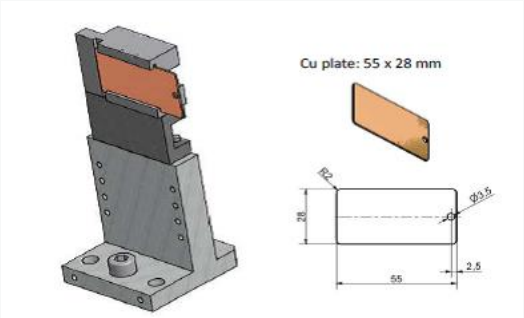
6. User Facilities

LHe/LN_2 cryostat

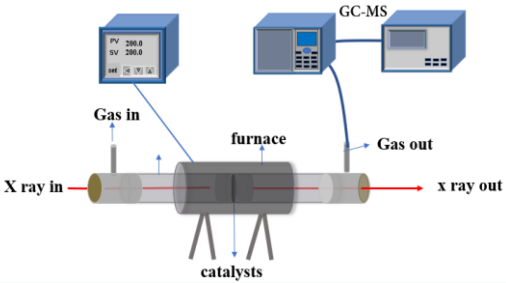
Liquid cell



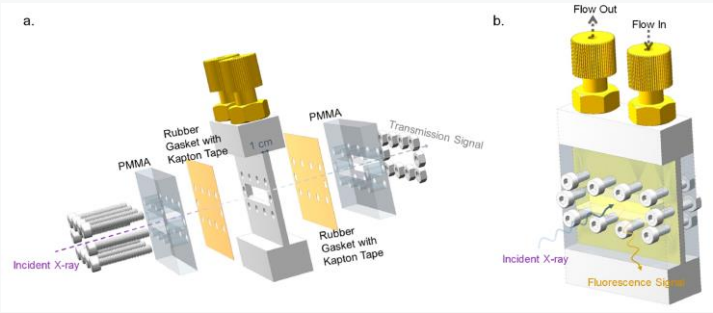
Solid sample holder



In situ catalytic system

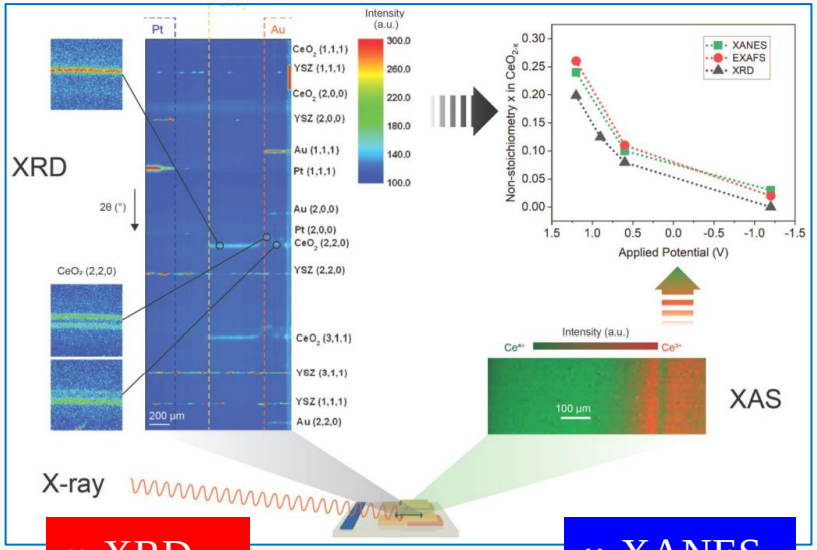


gas cell



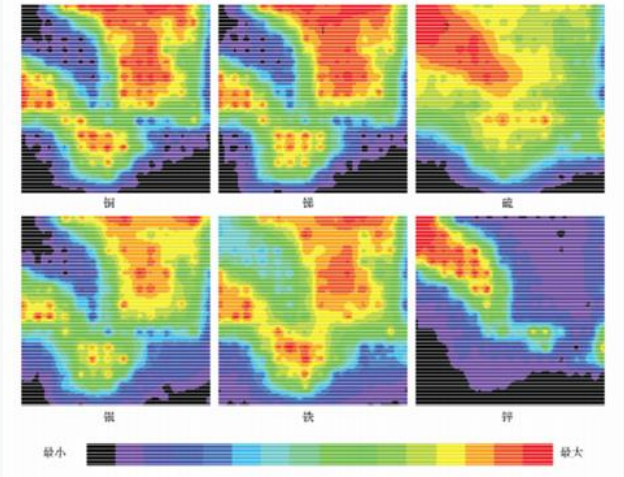
7. Unique features

- Obtain the chemical composition, element distribution and crystal structure simultaneously



μ-XRD

μ-XANES

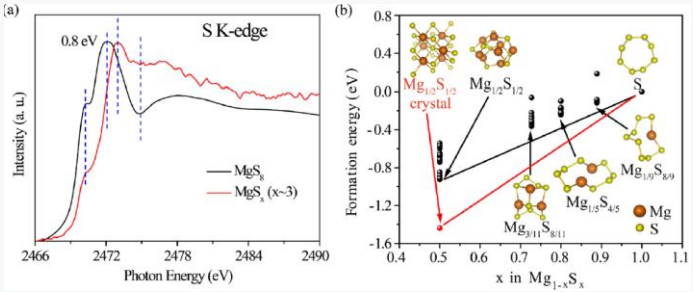


μ-XRF

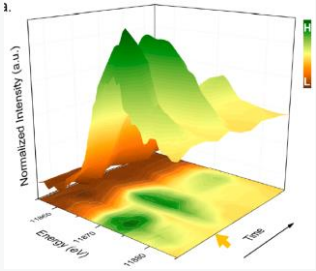
8. Potential applications

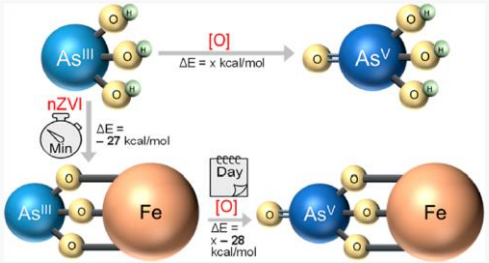
valence states, local Structure

- Investigation of the Capacity Degradation Mechanism in S- containing Batteries

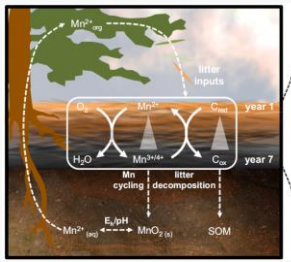


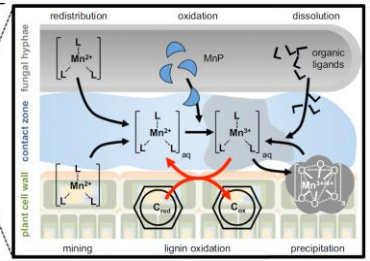
- Trace Key Mechanistic Features of catalysis reaction

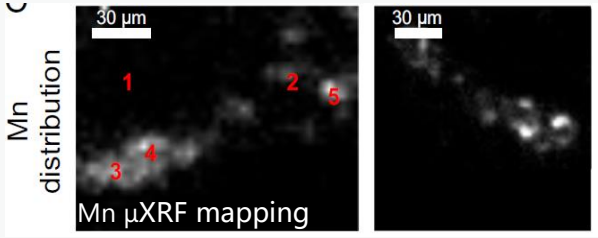


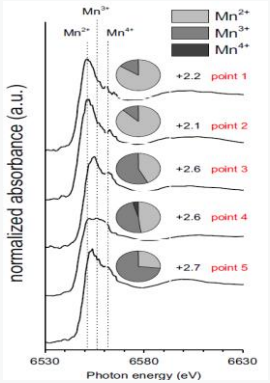


- Long-term litter decomposition controlled by manganese redox cycling in soil









Environmental Science Beamline

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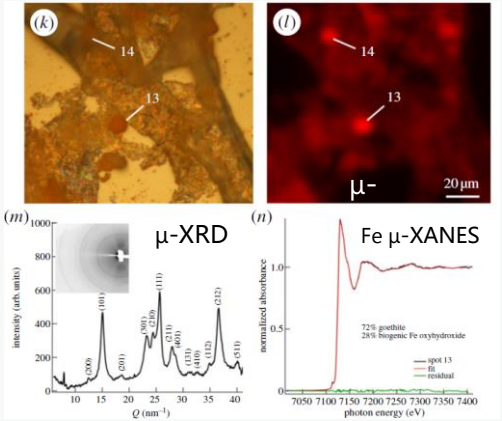
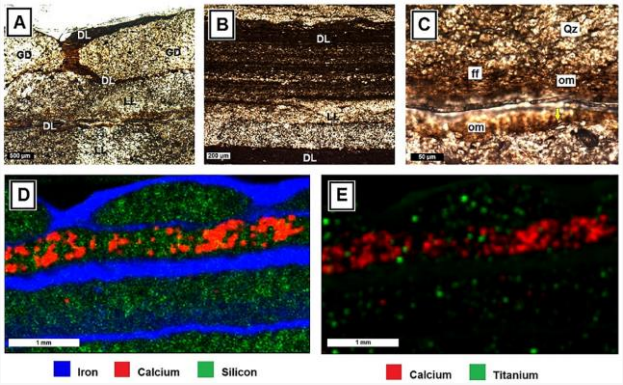
8. Potential applications

chemical composition， elements distribution

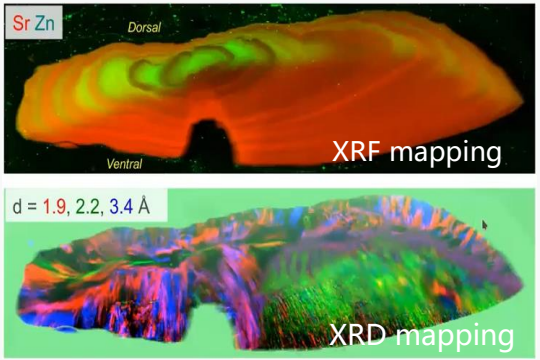
- A role for iron and oxygen chemistry in preserving soft tissues, cells and molecules from deep time



- the process of elemental migration associated with marine sediments and sedimentary rocks



- Date and understand the behavior of migratory fish



CONTENTS

High Resolution Hard X-ray Beamline

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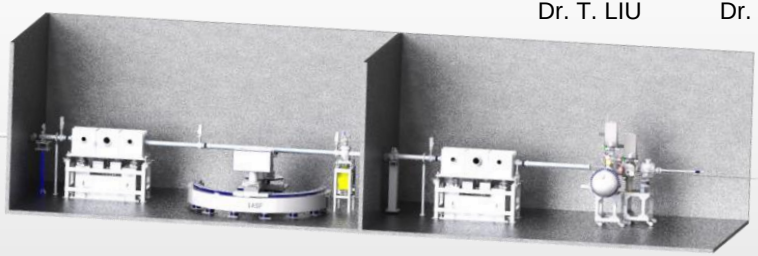
Institute of Advanced Science Facilities, Shenzhen

1. Key features

◆ High Energy Resolution

Dr. T. LIU

Dr. H. LI



Light source	Undulator
Energy range (keV)	4.0 – 20.0
Energy resolution	< 500 meV
Flux at 10 keV (ph/s)	10^{12}~10^{13} ph/s
Spot size at sample (μm^2)	~ 6.0×3.0 (EH1) ~ 2.0×1.0 (EH2)
Key features	Photon in-Photon out Photon in-Electron out

Method
RIXS, XES
HERFD-XAS
XRS
HAXPES

Application
Rare Earth Materials
Magnetic Materials
Semiconductor
Ferroelectrics, Multiferroics

High Resolution Hard X-ray Beamline

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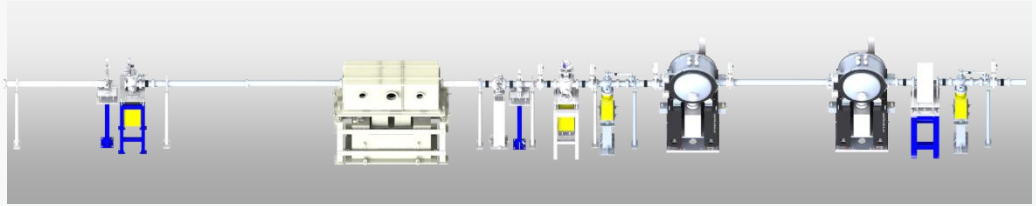
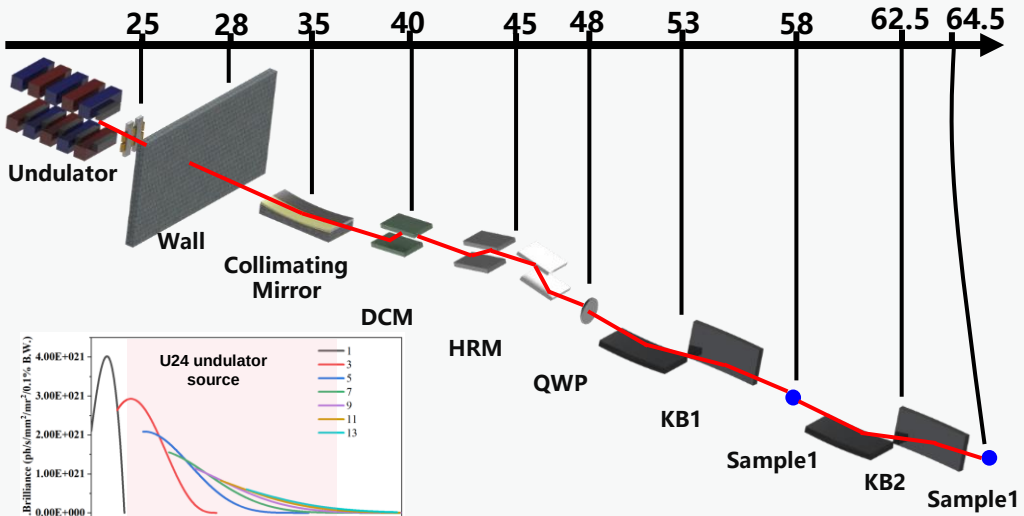
Institute of Advanced Science Facilities, Shenzhen

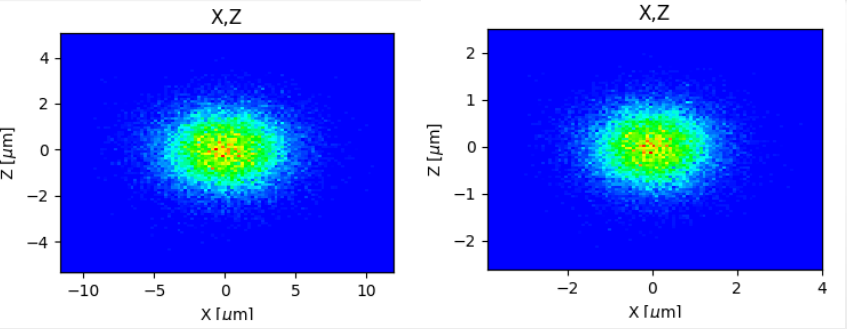
2. Beamline Optics



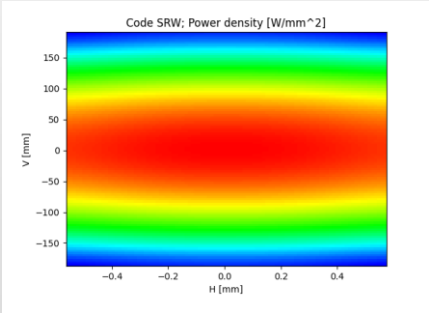


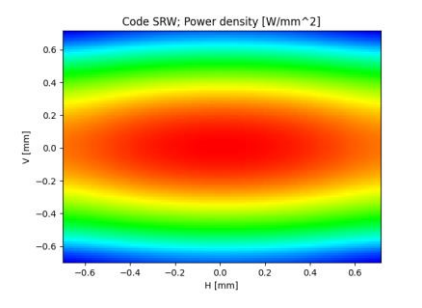
Optics		
Collimating Mirror	Shape	Plane elliptical
Primary Monochromator (DCM)	Type	LN2 cooled Double Crystal
	Energy range	4-20 keV
	Resolving power	< 2 eV
	Available reflections	Si(111), Si(311)
Secondary monochromator (HRM)	Type	Double channel-cut (+ - - +)
	Energy range	5-20 keV
	Resolving power	< 150 meV
	Available reflections	Si(400)
Phase retarder	Type	Single stage, Single crystal diamond
Kirkpatrick–Baez Mirror 1	Shape	Cylinder
	Energy range	4-9 keV (Si) 9-20 keV (Rh)
	Usage	Vertical & Horizontal focusing
Kirkpatrick–Baez Mirror 2	Shape	Cylinder
	Energy range	4-9 keV (Si) 9-20 keV (Rh)
	Usage	Vertical & Horizontal focusing

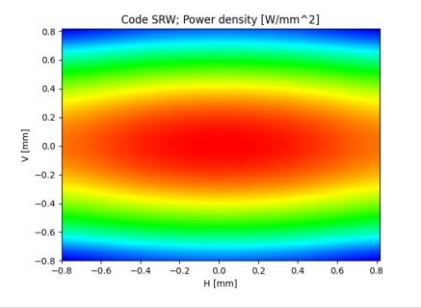
3. X-ray tracing and thermal analyses



Sample Spot	EH1	EH2
Position (m)	58	64.5
Energy (keV)	10	10
Size (μm², FWHM, H×V)	5.65×2.29	1.73×1.13
Divergence(μrad², FWHM, H×V)	105.82×45.90	328.81×92.69
Flux (phs/s/0.1% bw)	1.19E+13 (10 keV)	8.77E+12 (10 keV)







OE	Primary Slit	Collimating Mirror	DCM
Absorbed Power (W)	2673.64	12.95	84.50
Power Density (W/mm²)	48.38	12.40	18.80

High Resolution Hard X-ray Beamline

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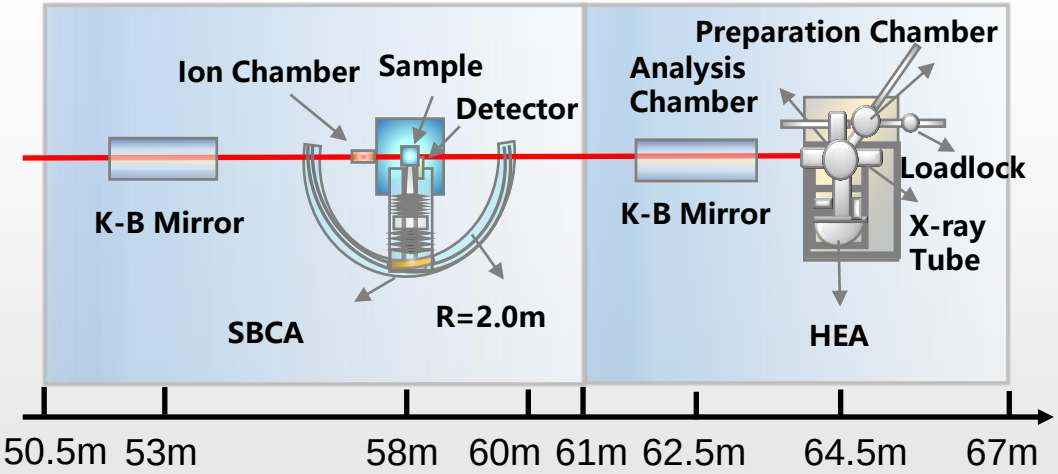
4. Experimental Hutch

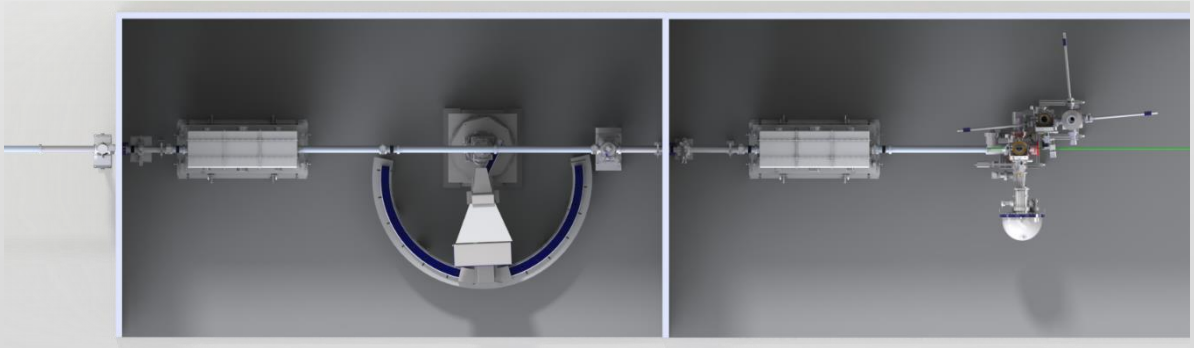
EH 1:

- ✓ HARFD-XAS
- ✓ RIXS/XES
- ✓ XRS



EH 2:

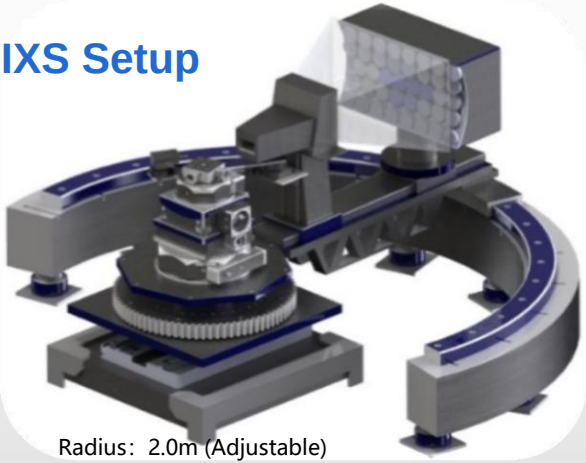
- ✓ HAXPES
- ✓ Off-line HAXPES



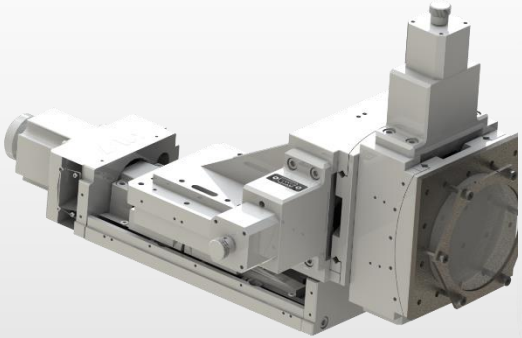
High Resolution Hard X-ray Beamline

5. Detectors and Instruments

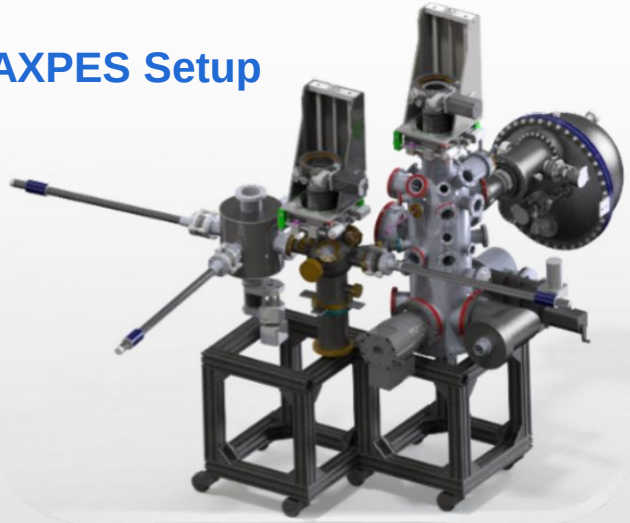
IXS Setup

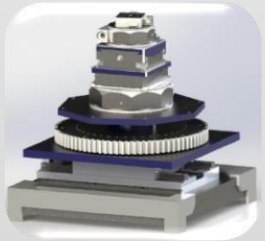


Radius：2.0m (Adjustable)

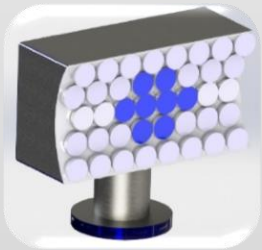


HAXPES Setup



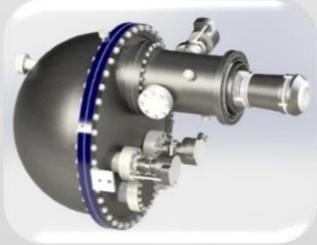


Sample Stage



SBCA

1D&2D Detector



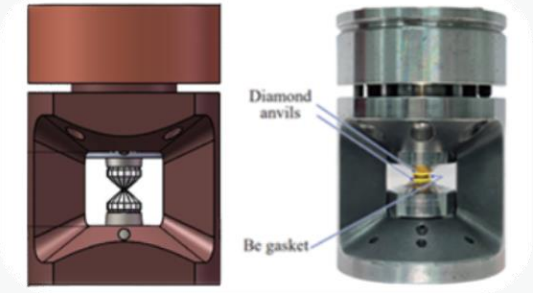
HEA

Ion Gun

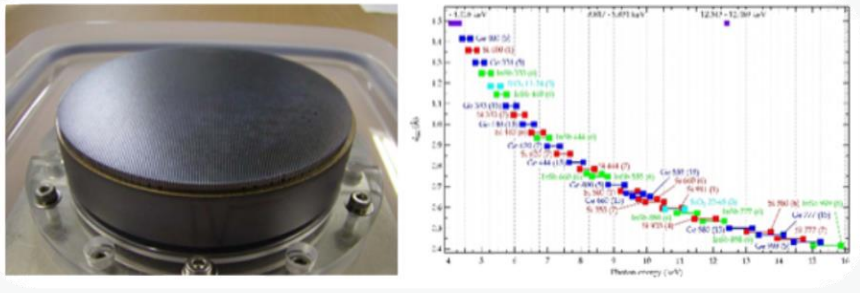
UHV chamber

6. User Facilities

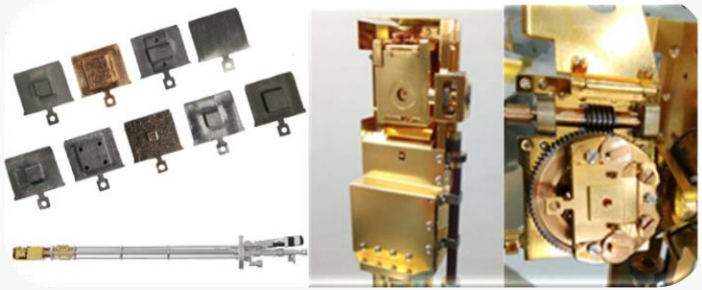
- This beamline will be equipped with unique sample environments (high dc magnetic fields, low/high temperatures, high pressure).



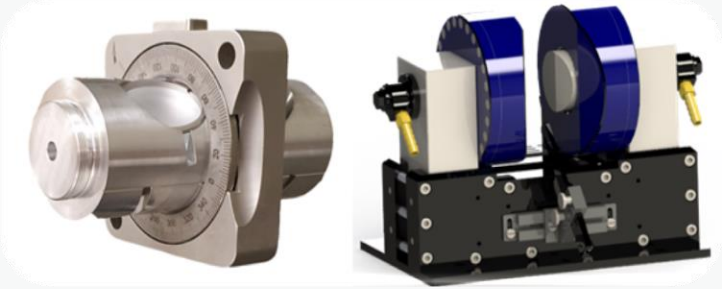
High Pressure sample holder



Available analysers



Manipulator head with Flag type sample holder compartment

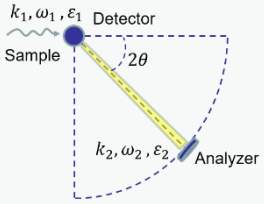


Phase retarder & Magnetic field generator

7. Potential applications

- Focus on the rare earth materials, magnetic materials, geologic materials et al.

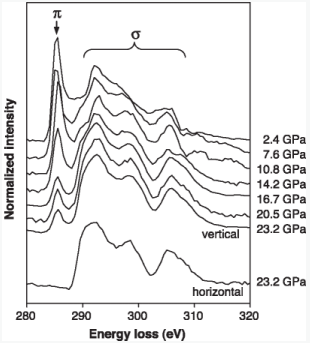
q dependence



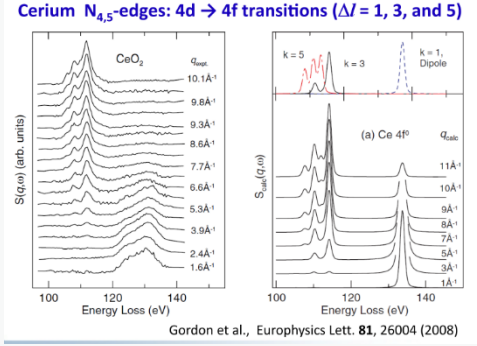
$$q = |k_1 - k_2| = |k| \sin 2\theta$$

Non-resonant

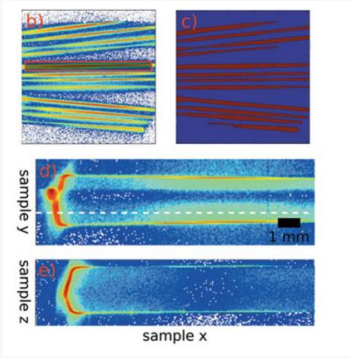
Inelastic x-ray Scattering



XANES-type XRS, light elements, High pressure

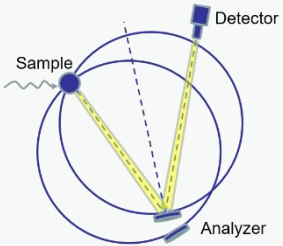


Q-dependence XRS, *l*-DOS



XRS Imaging, Direct tomography with chemical bond

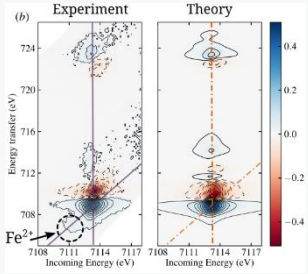
Energy dependence



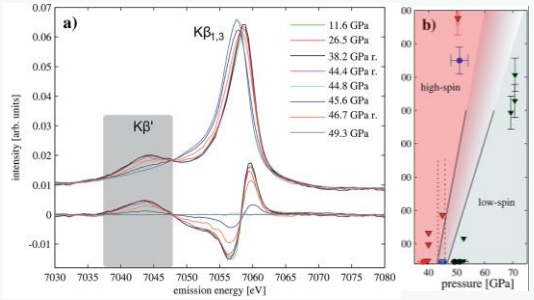
$$E = \frac{12398.4}{2\,\mathrm{d}\sin(90^0 - \theta)}$$

Resonant

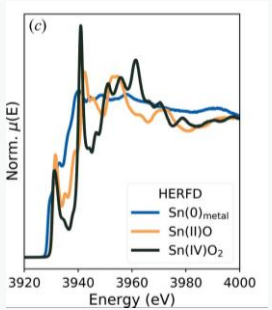
Inelastic x-ray Scattering



RIXS-MCD, Spin in the superamagnetic



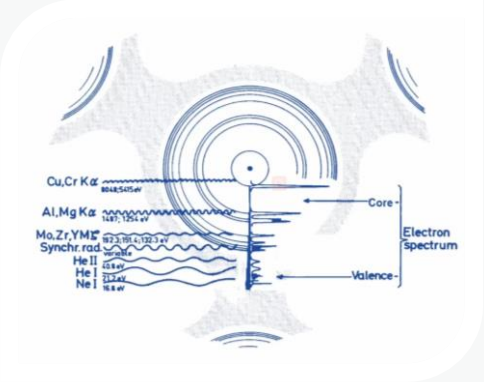
XES-MCD, Spin crossover in the earth materials



HERFD, fine edge structure

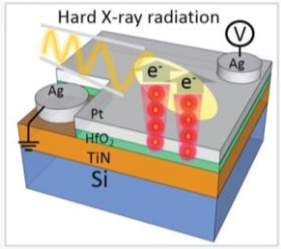
7. Potential applications

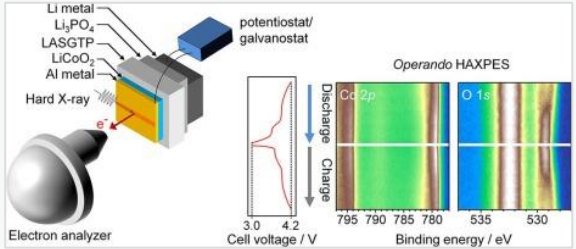
HAXPES :2-12keV

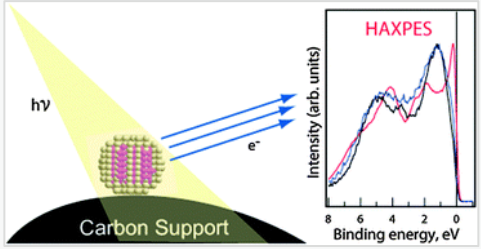


- *Probing Depth*
- *Chemical Analysis*
- *Electronic Structure*
- *Magnetic Ordering*

Industrial application

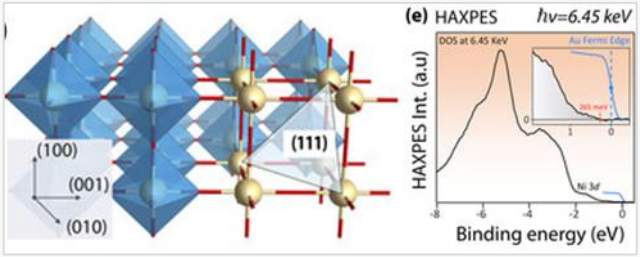


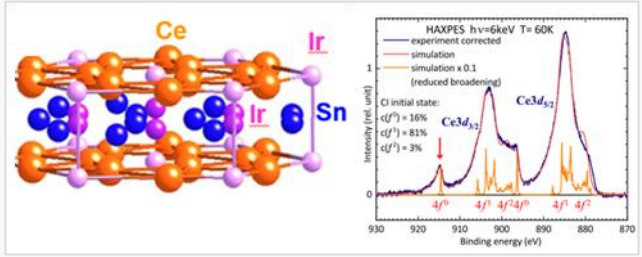




Microelectronics Battery Catalysts

Fundamental research





Strongly-correlated materials

Thank you for your attention !

Contacts: Dr. Yang

Email: yangchzh6@mail.sysu.edu.cn

Phone: 13070246505

IASF 深圳综合粒子设施研究院
Institute of Advanced Science Facilities, Shenzhen

深圳市光明区新湖街道
圳园路268号A3栋

268 Zhenyuan St, Building A3, Floor 3-6, Guangming District,
Shenzhen, Guangdong, P.R.China