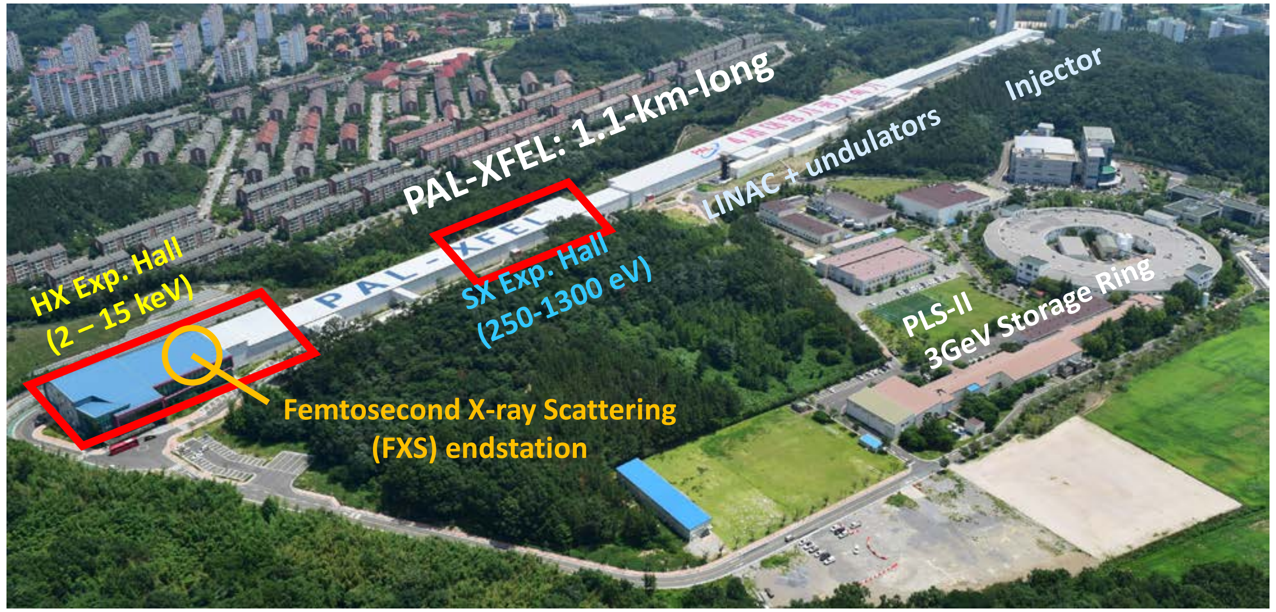
Ultrafast photoinduced dynamics of physical properties in condensed matter

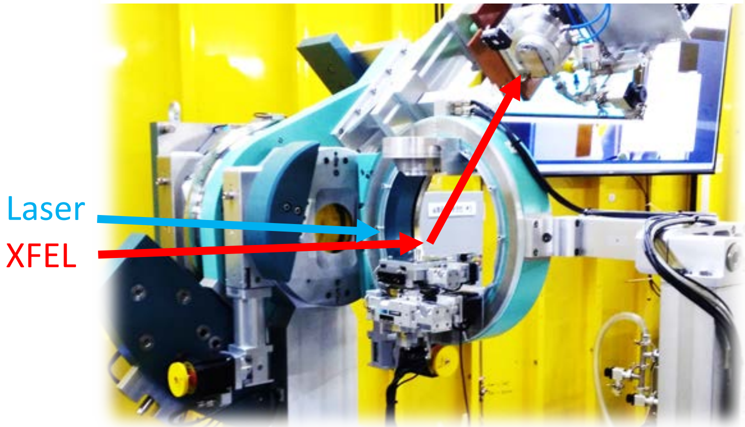
Sae Hwan Chun (FXS endstation, XFEL beamline div.)

November 14, 2023

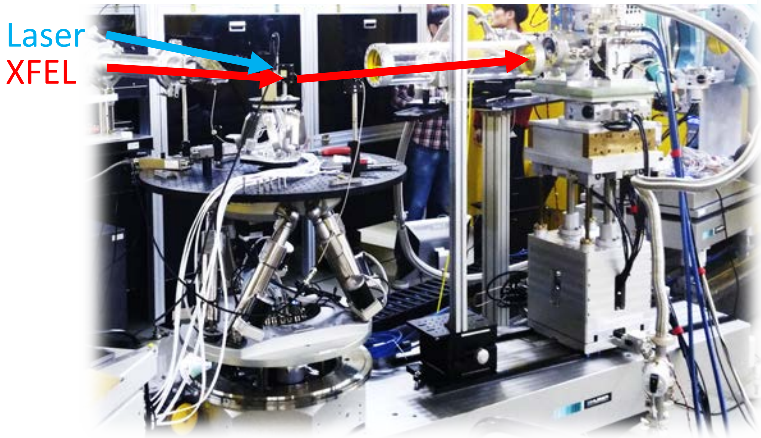
FXS endstation: a hard X-ray endstation for investigation of condensed matter physics



- 4-circle diffractometer

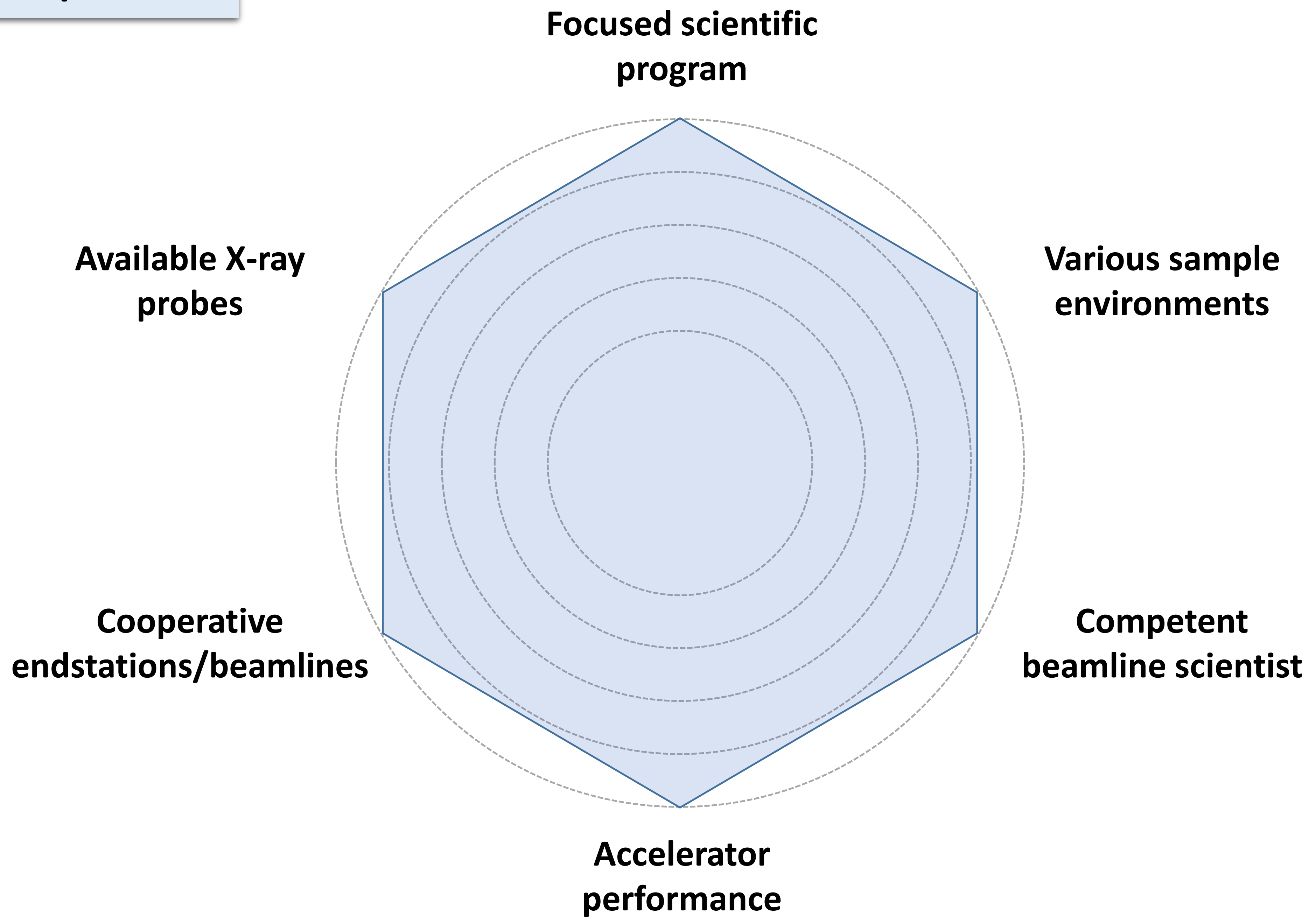


- 2-circle diffractometer



	X-ray photon energy (keV)	Focused beam size (μm)	X-ray flux (photons/pulse)	Rep. rate (Hz)	Available laser pump
XPP (LCLS)	4 – 25	≥ 3 (CRL)	≤ ~10^{12}	120	✓ 800/400/266 nm ✓ OPA (478-590 nm) ✓ THz, Mid-IR
BL3-EH2 (SACLA)	4 – 20	≥ 2 (CRL)	≤ ~10^{11}	60	✓ 800/400/266/200 nm ✓ OPA
FXS (PAL-XFEL)	2.2 – 15	≥ 10 (CRL)	≤ ~10^{11}	60	✓ 800/400/266 nm ✓ OPA (240-15000 nm)
FXE (EuropeanXFEL)	6 – 20	≥ 8 (CRL)	≤ ~10^{12}	1128, 564, 376, …	✓ 800/400/266 nm ✓ TOPAS (UV – Mid-IR)
Bernina (SwissFEL)	4.5 – 8	≥ 5 (CRL/KB)	≤ ~10^{12}	100	✓ 800/400/266 nm ✓ OPA (240 – 14000 nm) ✓ THz

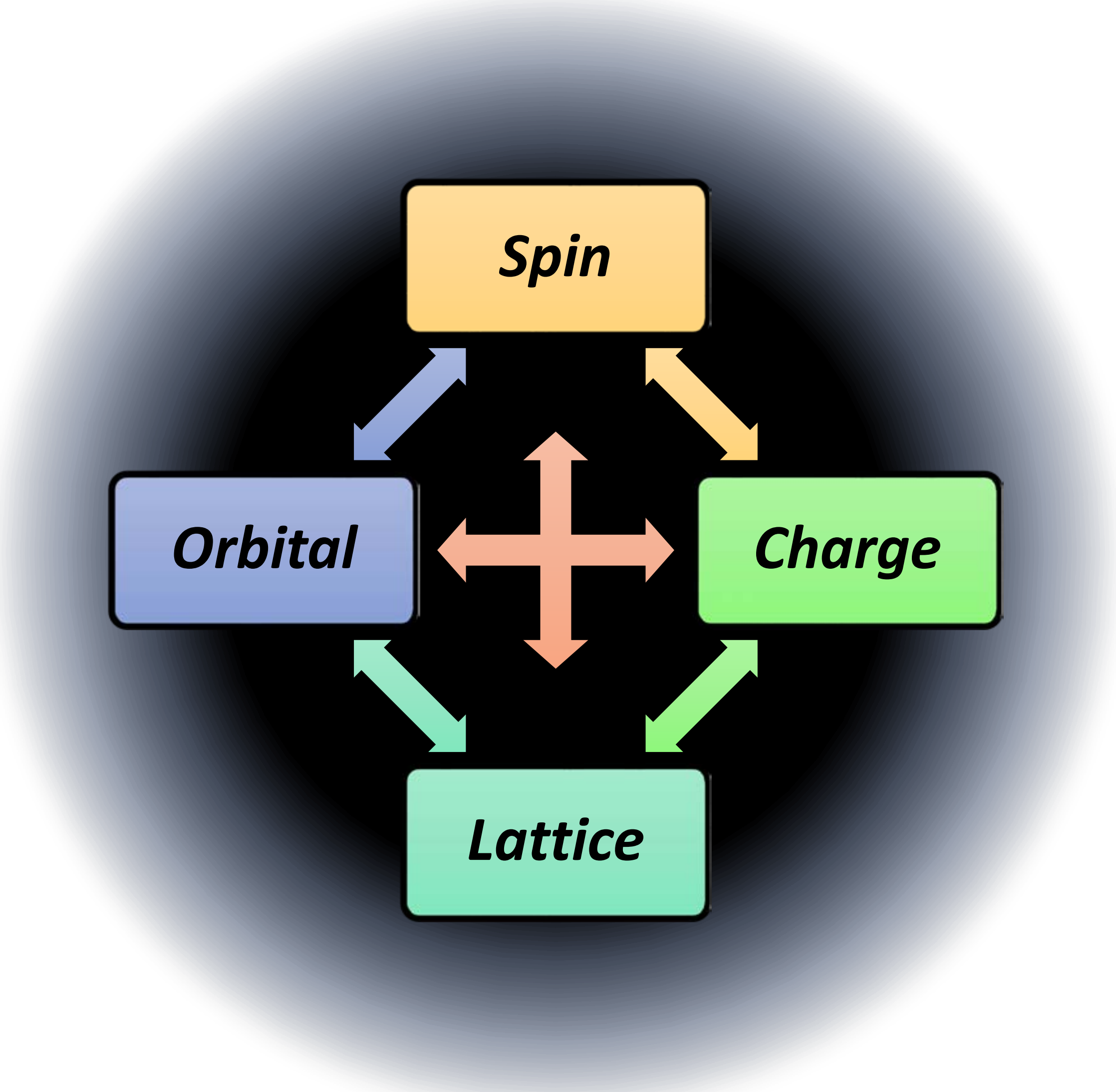
Strategies for the competence



Focused research on quantum materials

❖ **Condensed matter**

- Featuring entanglement of fundamental physical degrees of freedom (i.e., spin, orbital, charge and lattice) with inter-coupling one another mediated by the electrons



Inter-couplings mediated by electrons

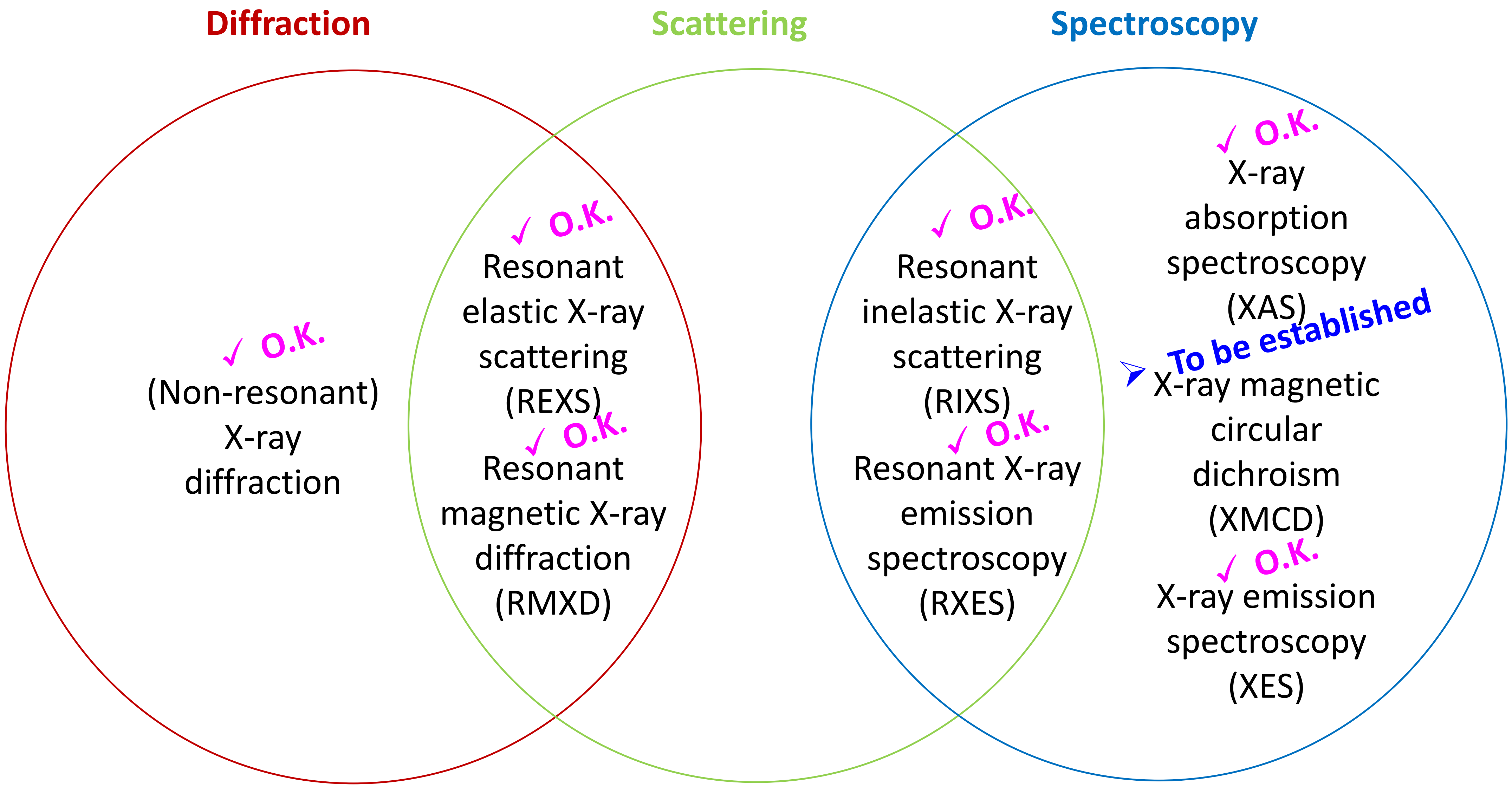
❖ **Quantum materials**

- High Tc superconductivity
- Quantum spin liquid
- Colossal magnetoresistance
- Multiferroics
- …

❖ **Resonant X-ray scattering**

- A powerful experimental technique to probe ground and excited states associated with spin/orbital/charge degrees of freedom

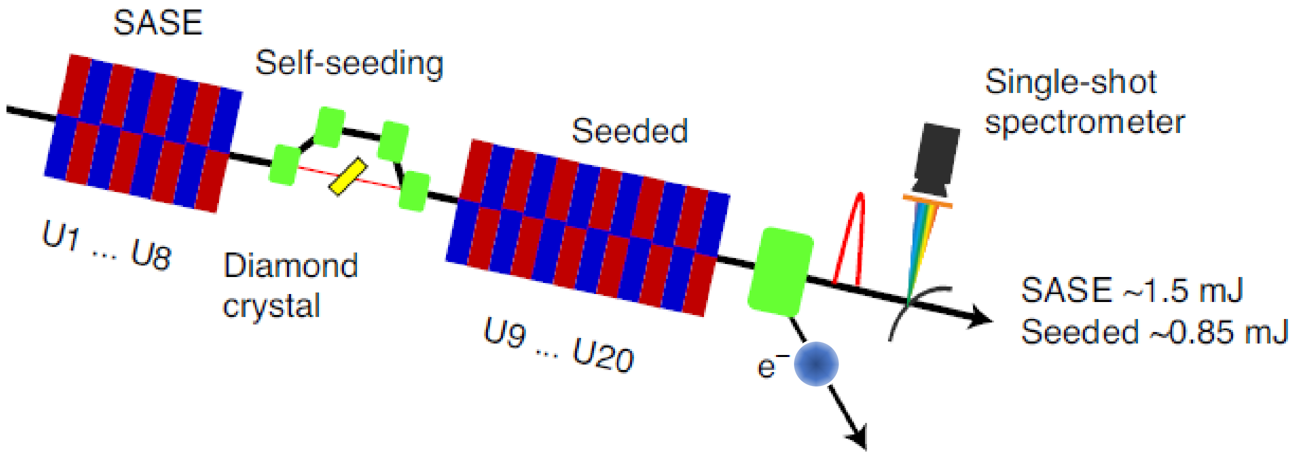
Towards diversifying X-ray probes

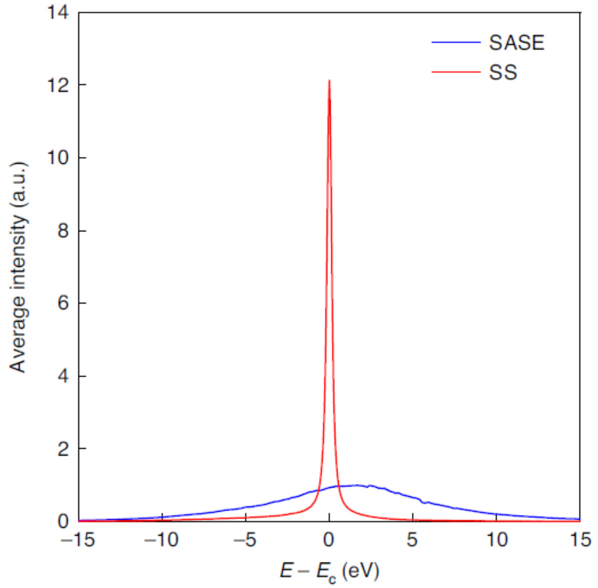


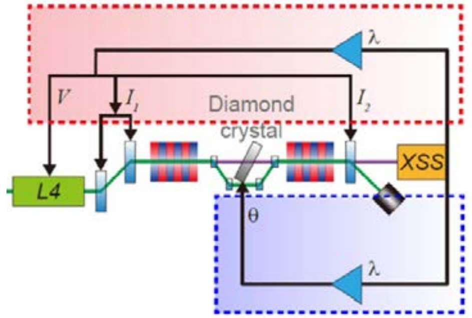
Resonant X-ray emission spectroscopy using self-seeded X-ray pulses

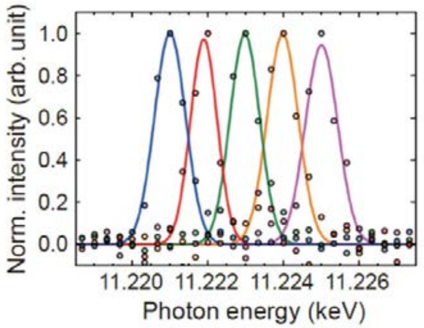
- **Self-seeded X-ray pulses with energy tunability**

I. Nam *et al.*, *Nat. Photon.* **15**, 435 (’21)



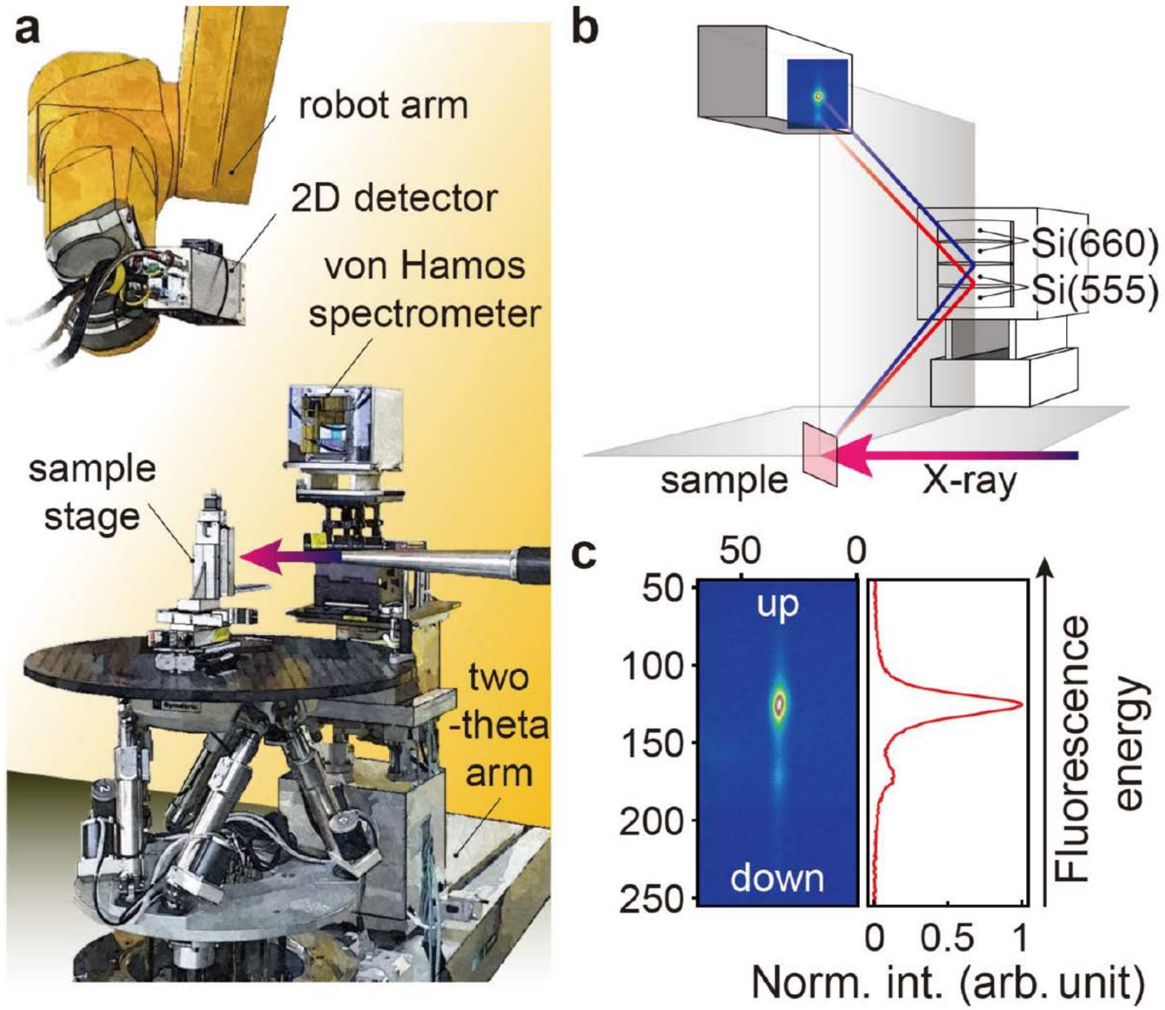






- **von Hamos-type X-ray emission spectrometer**

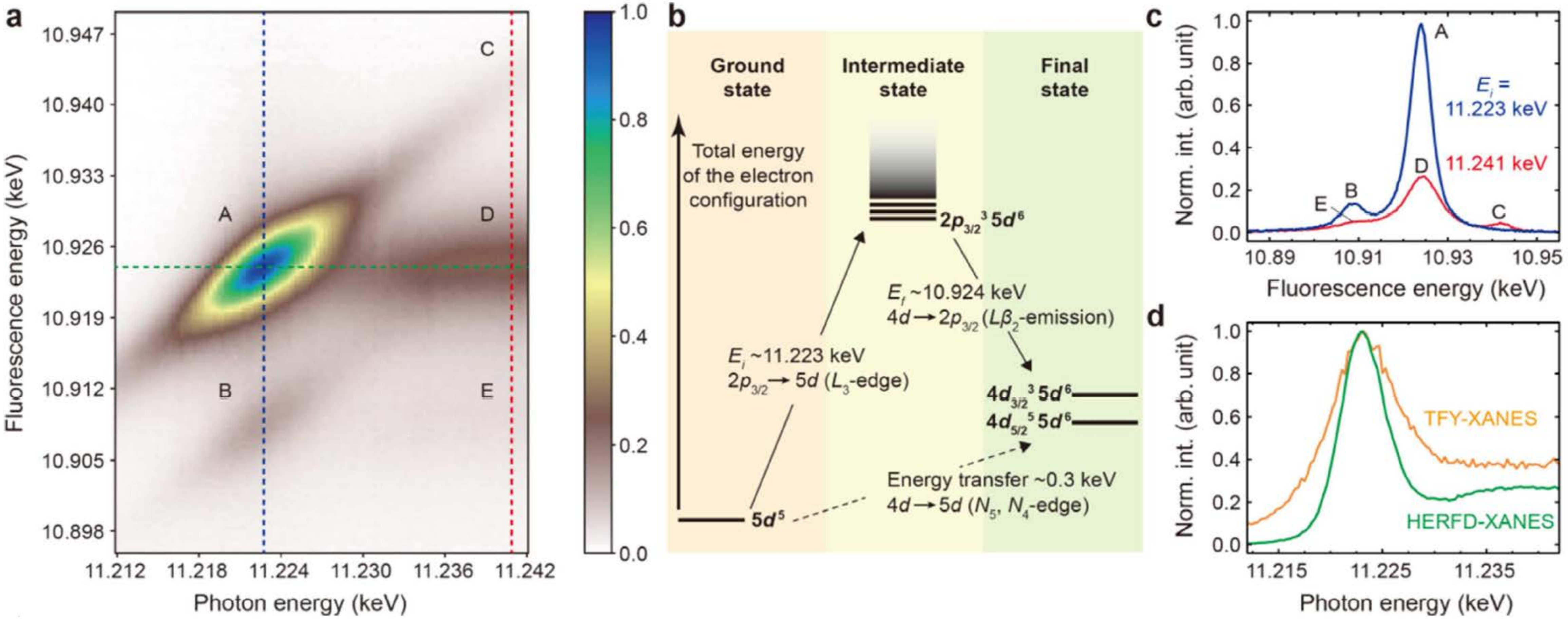
T.-K. Choi, ***SHC*** *et al.*, *J. Synchrotron Rad.* (’23)

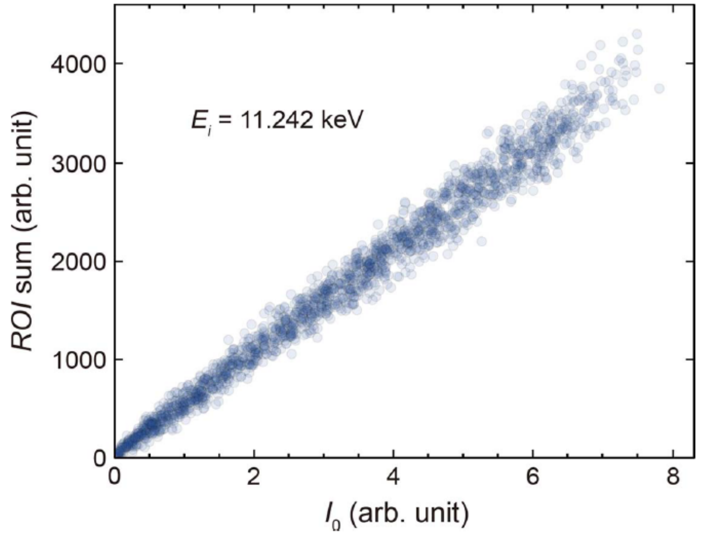


PAL POHANG ACCELERATOR LABORATORY

Resonant X-ray emission spectroscopy

T.-K. Choi, ***SHC*** *et al.*, *J. Synchrotron Rad.* ('23)



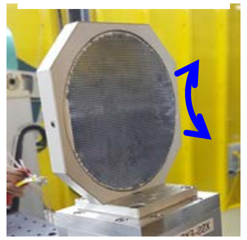


POHANG ACCELERATOR LABORATORY

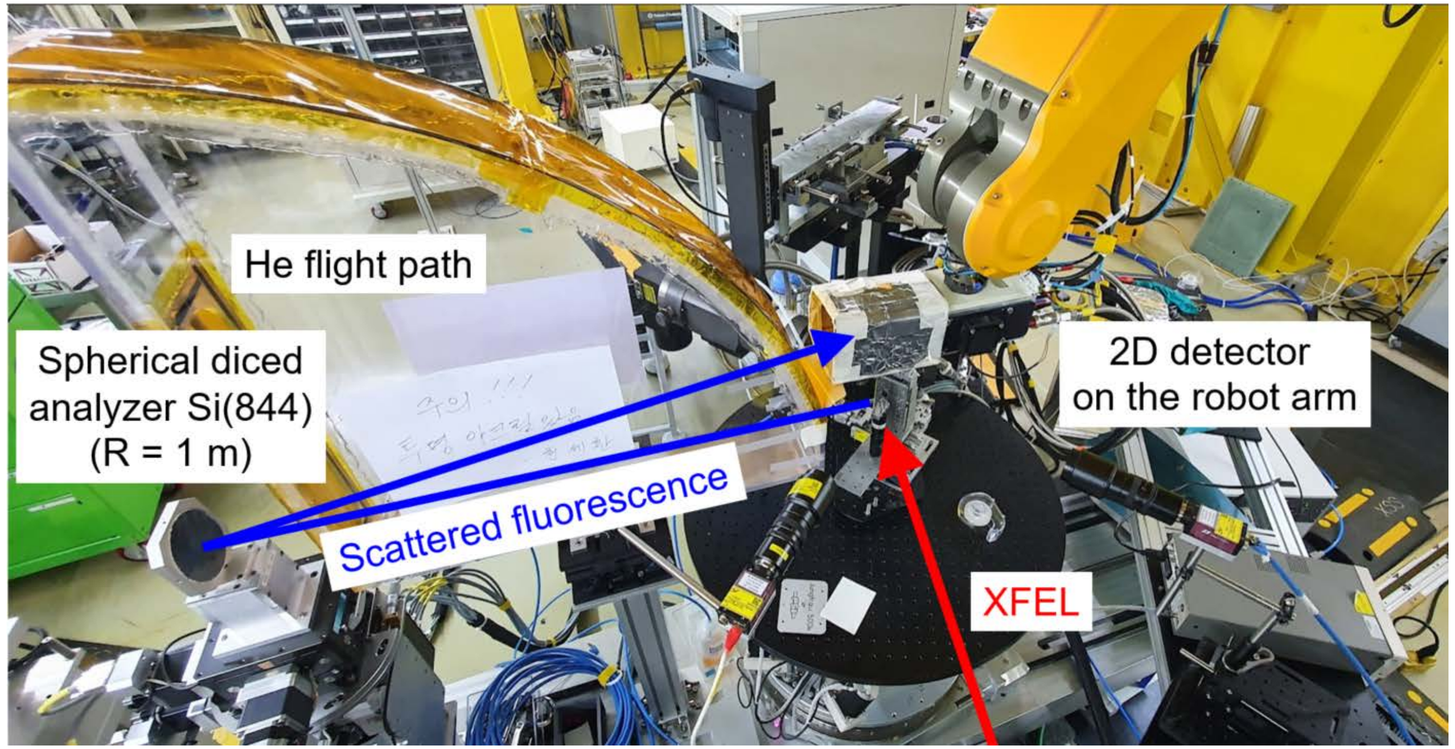
Resonant inelastic X-ray scattering (RIXS)

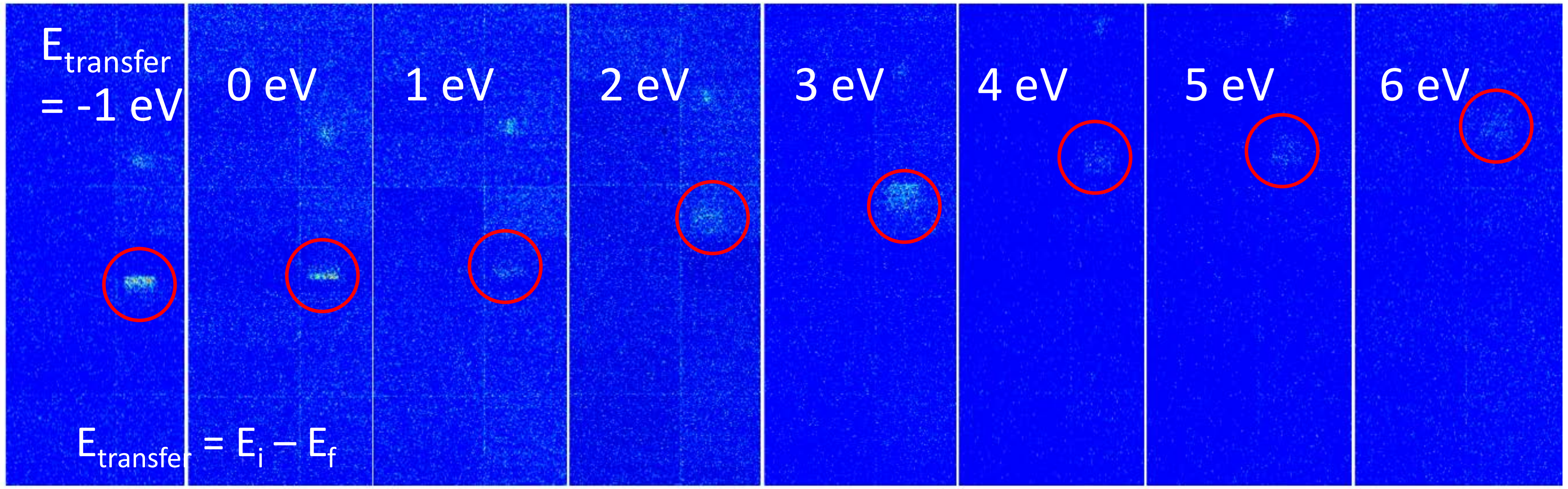
- **Johann-type spectrometer**

Si (844) spherical analyzer

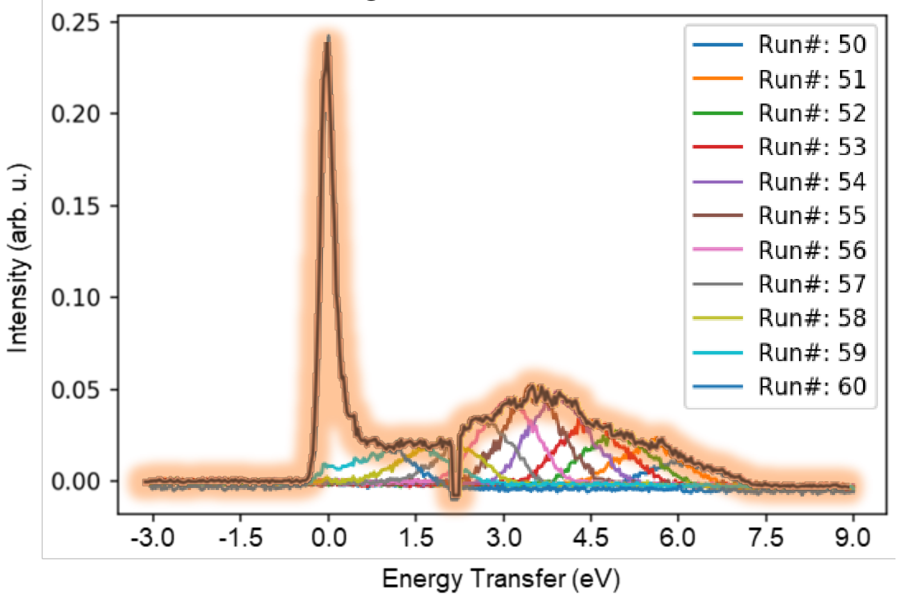


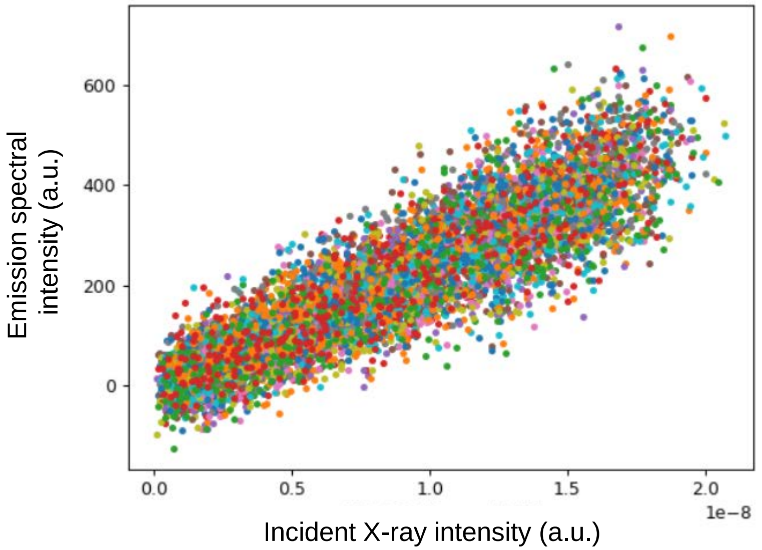
Bragg angle changed





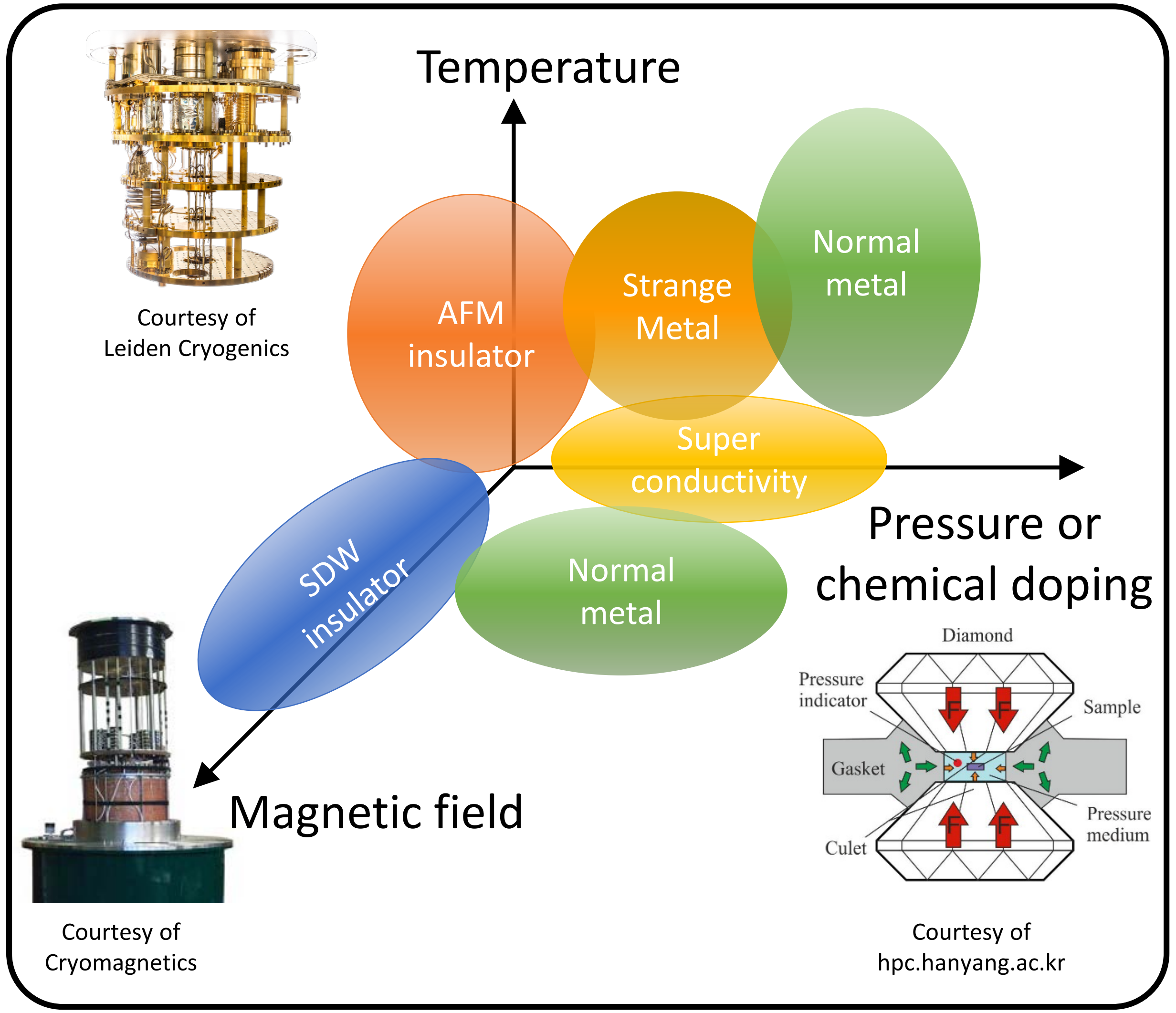
- **RIXS data of an Ir-based complex near the Ir L_3 absorption edge**





Sample environments for extreme conditions

- **Phase diagram of a cuprate in thermal equilibrium**



Courtesy of Leiden Cryogenics

Courtesy of Cryomagnetics

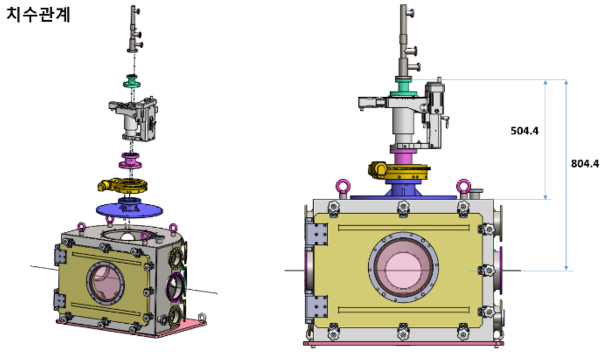
Courtesy of hpc.hanyang.ac.kr

- **High temperature sample holder**

- **Cryostream-type cryostat** (40 – 300 K)

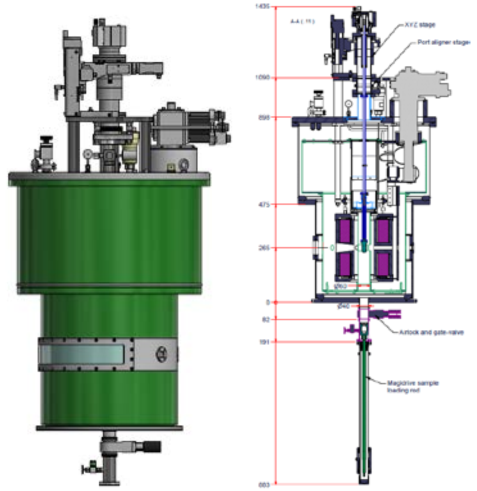
- **Low temperature diffraction setup for the tender X-ray regime**

in collaboration with Sogang Univ.

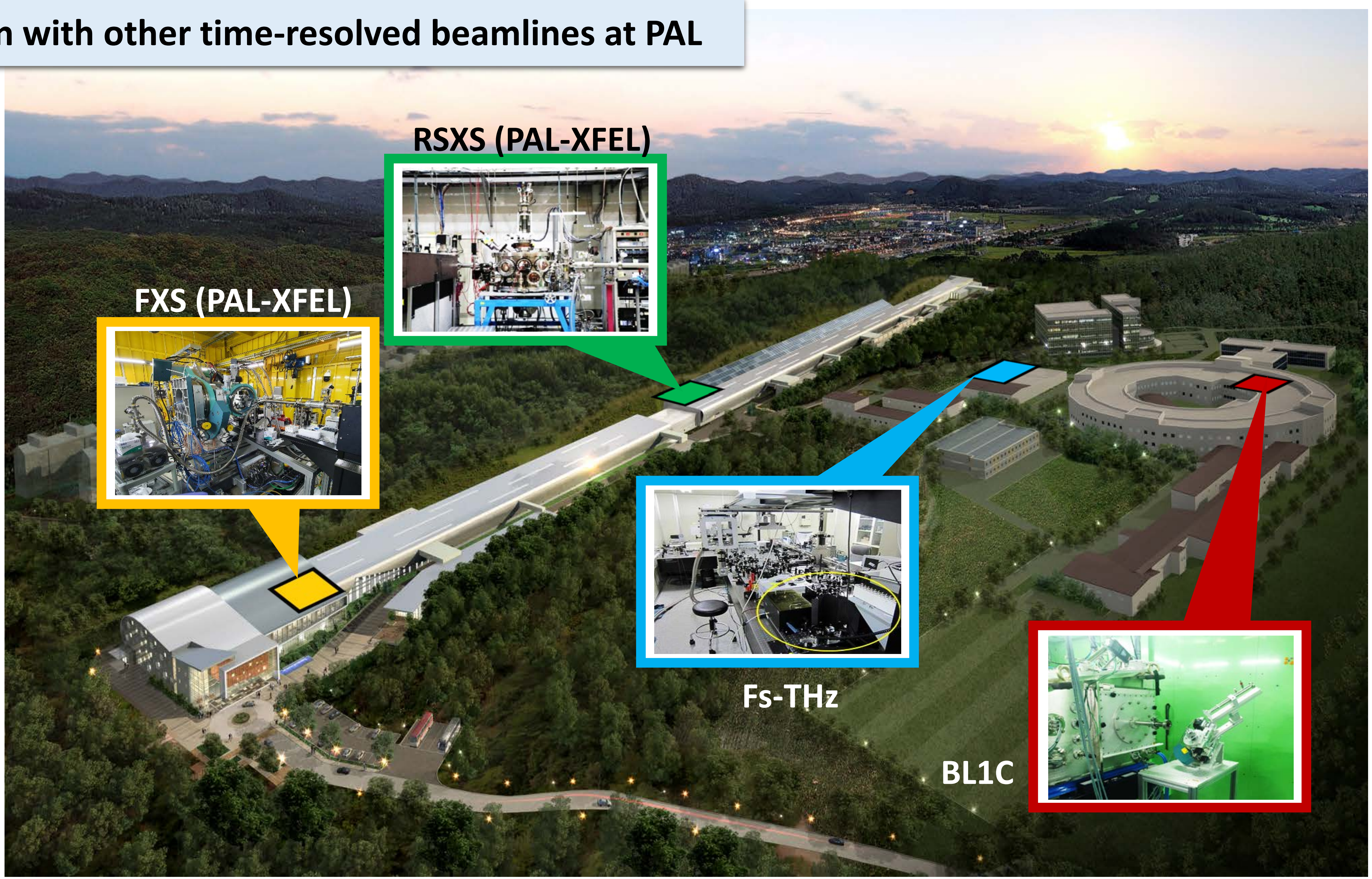


- **High field magnet** (9 T, 4 K)

in collaboration with Photon Science Center, POSTECH



Cooperation with other time-resolved beamlines at PAL



A collaborative research of condensed matter physics at the PAL-XFEL

RESEARCH ARTICLE

ADVANCED MATERIALS
www.advmat.de

4D Visualization of a Nonthermal Coherent Magnon in a Laser Heated Lattice by an X-ray Free Electron Laser

*Hoyoung Jang, Hiroki Ueda, Hyeong-Do Kim, Minseok Kim, Kwang Woo Shin, Kee Hoon Kim, Sang-Youn Park, Hee Jun Shin, Pavel Borisov, Matthew J. Rosseinsky, Dogeun Jang, Hyeongi Choi, Intae Eom, Urs Staub, and Sae Hwan Chun**

Adv. Mater. **2023**, 2303032

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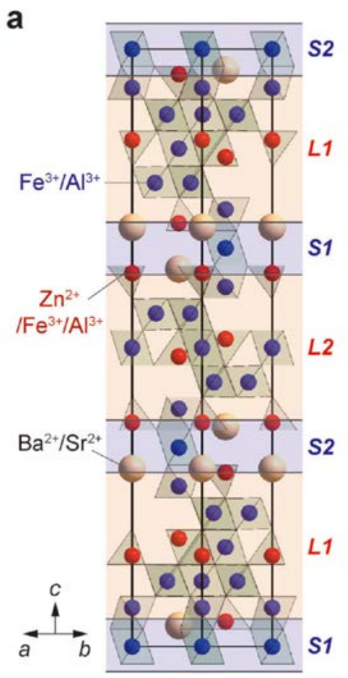
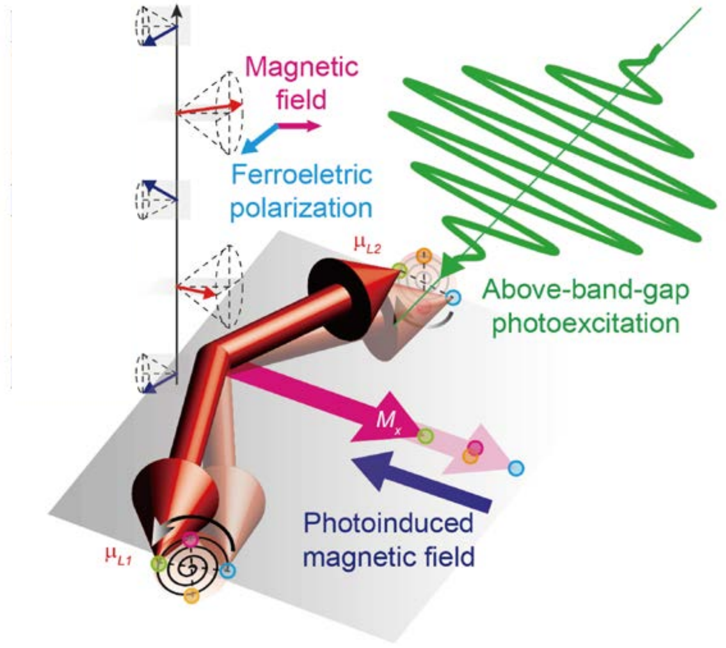


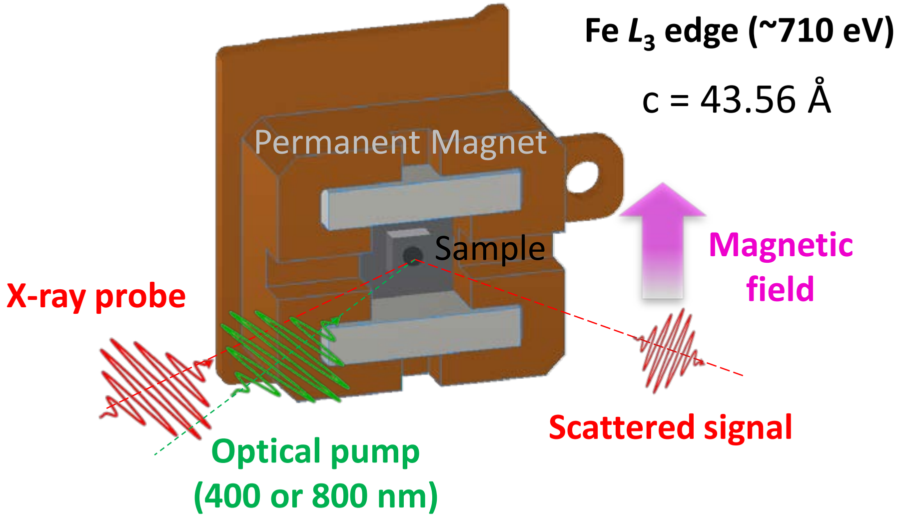


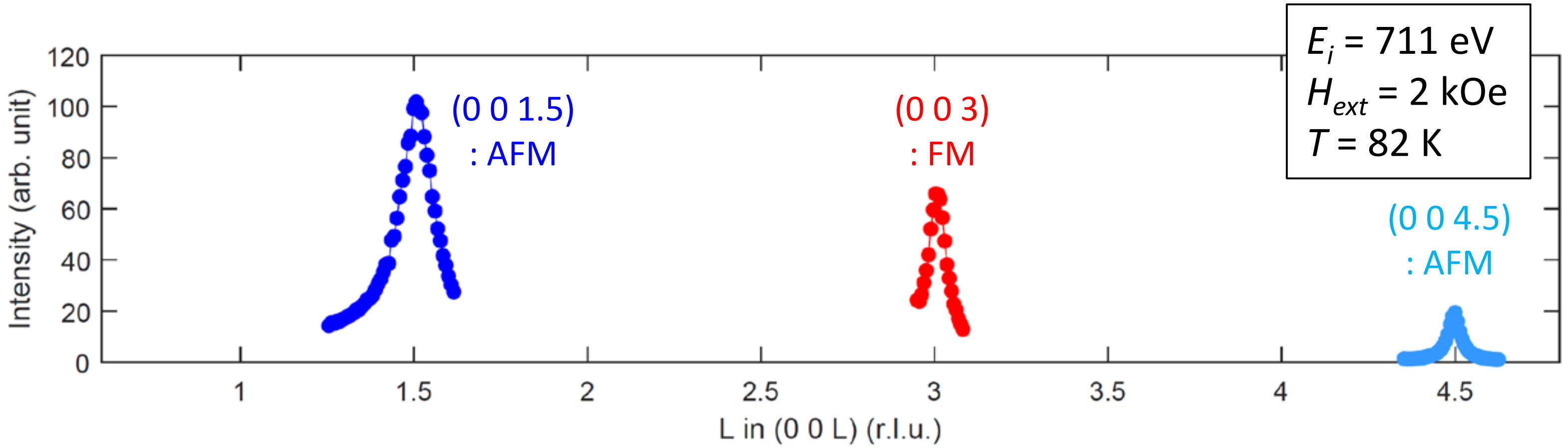
Time-resolved resonant magnetic X-ray diffraction

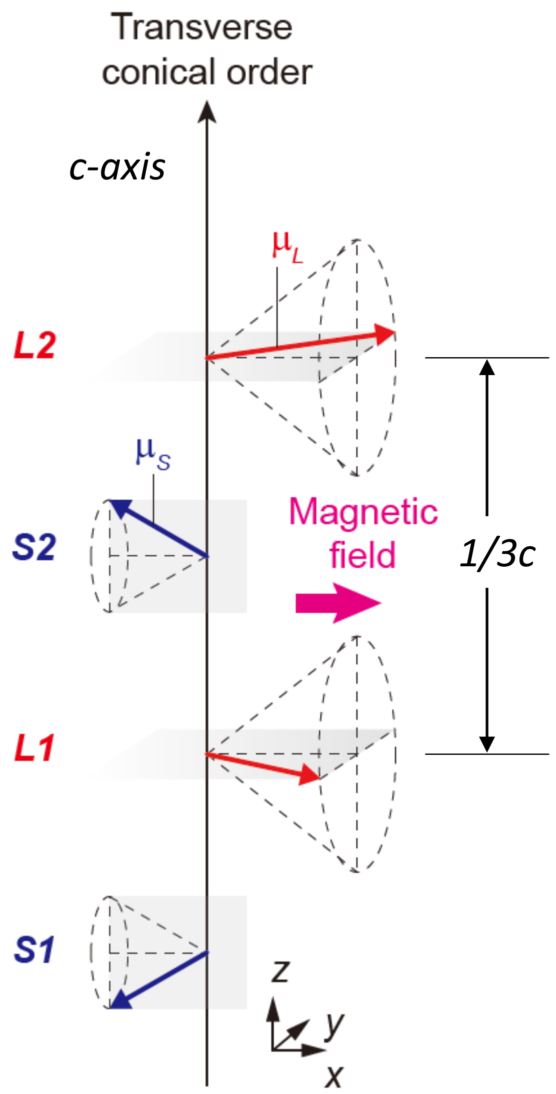
Y-type hexaferrite: $Ba_{0.5}Sr_{1.5}Zn_2(Fe_{0.92}Al_{0.08})_{12}O_{22}$

RSXS instrument
@Soft X-ray beamline,
PAL-XFEL

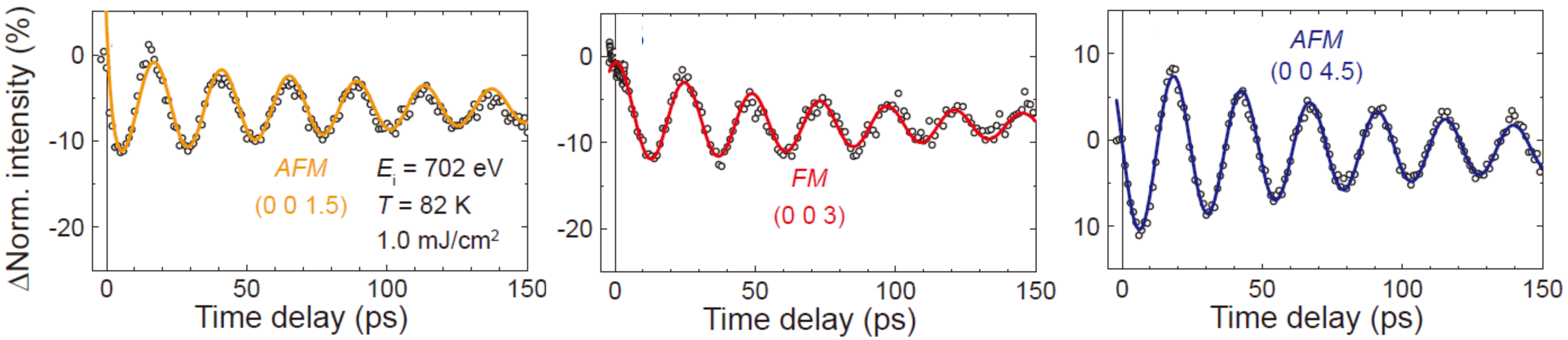
Dr. Hoyoung Jang

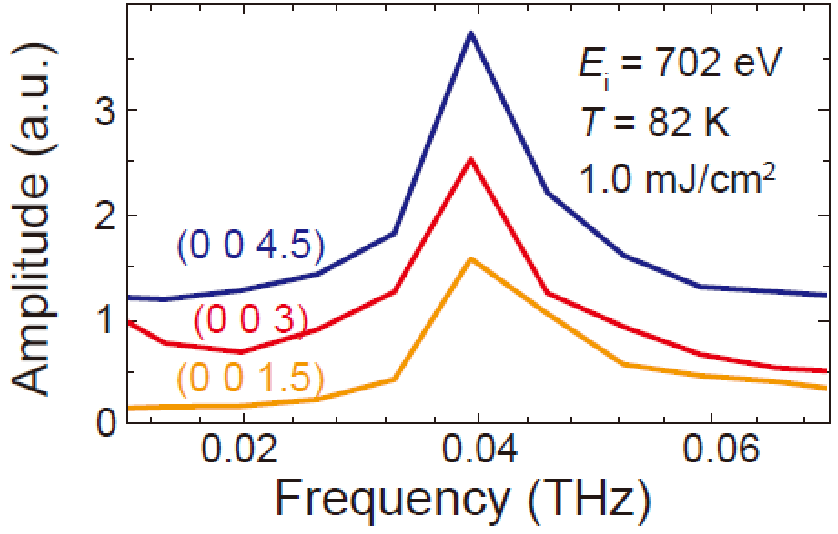




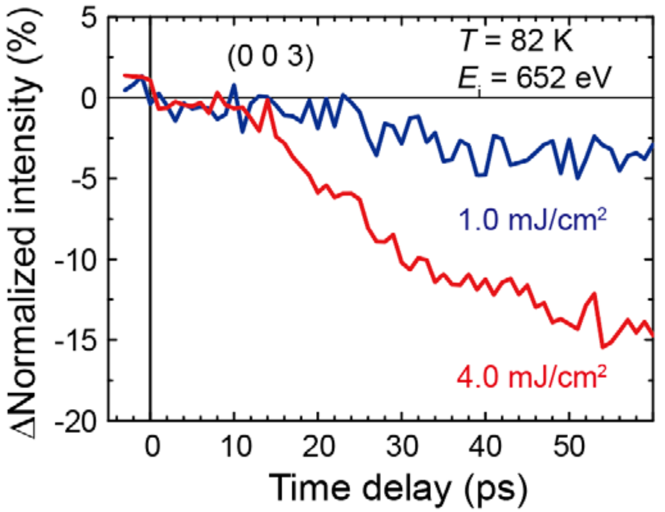


Observation of coherent magnon





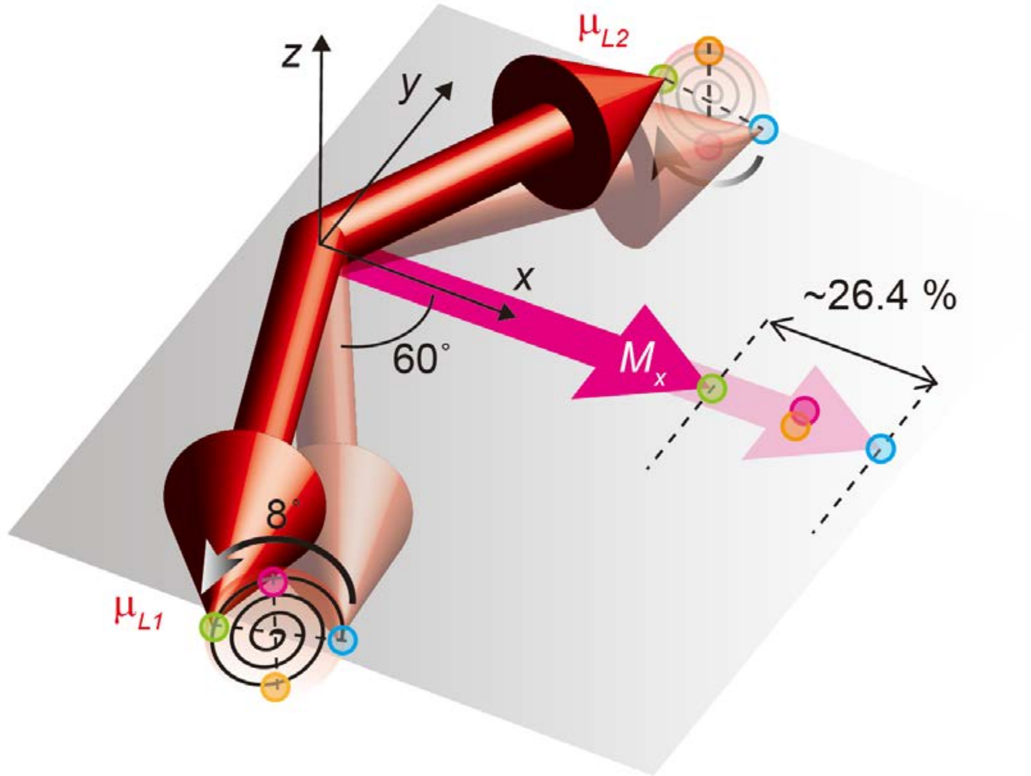
- **Non-resonant condition**

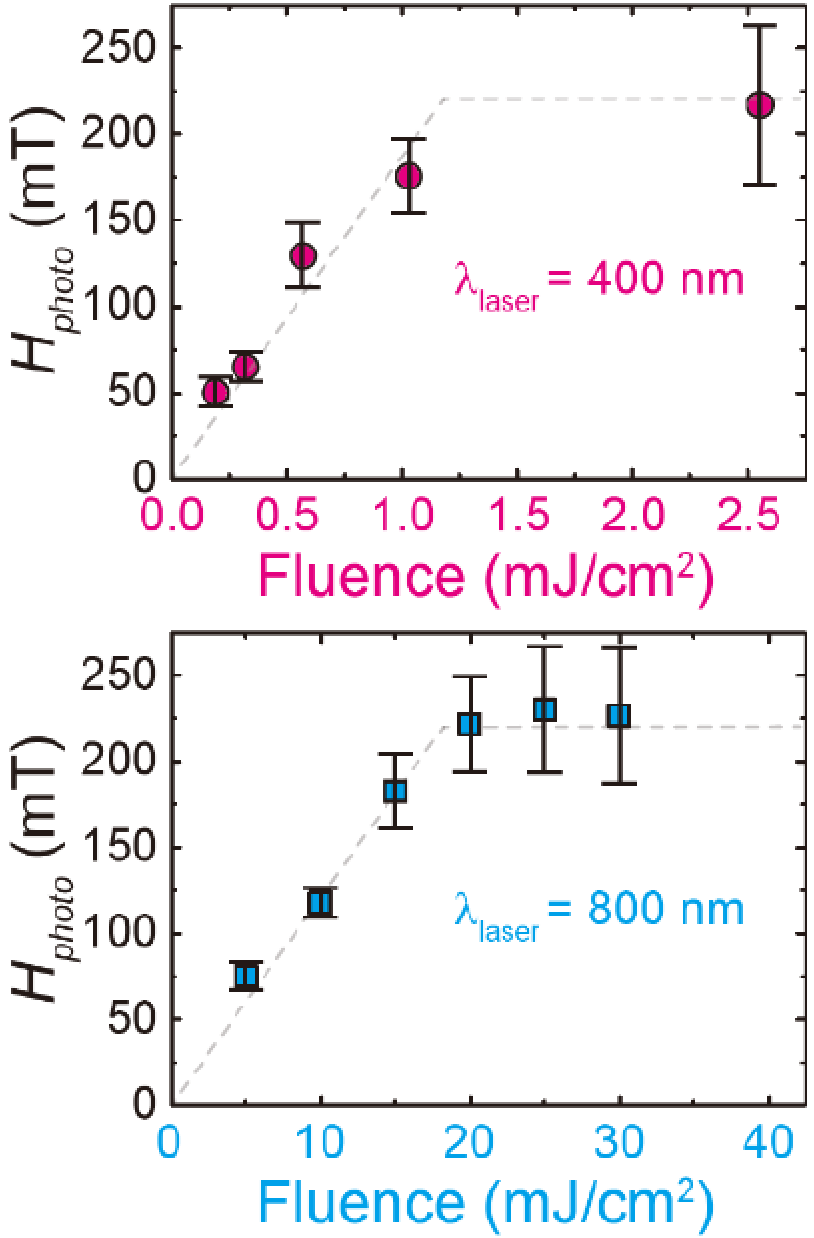


➢ *A coherent quasi-particle with 42 GHz (a period of 24 ps, ~0.17 meV)*

➢ *No oscillation observed in (0 0 3)*
→ not a coherent phonon

Large enhancement of the nonthermally photoinduced magnetic field via above-band gap photoexcitation





- *The above-band-gap photoexcitation is more efficient to create the photoinduced magnetic field.*
- *A way of identifying a nonthermal generation of the photoinduced magnetic field.*

Research highlight in 2023 (1)

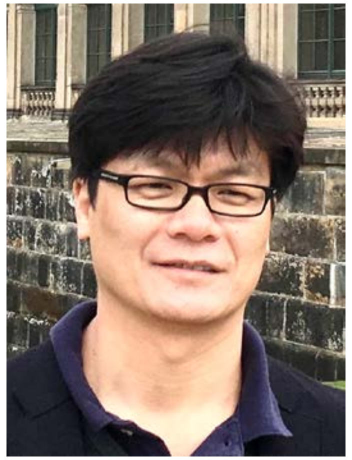
research papers

IUCrJ
ISSN 2052-2525
PHYSICS | FELS

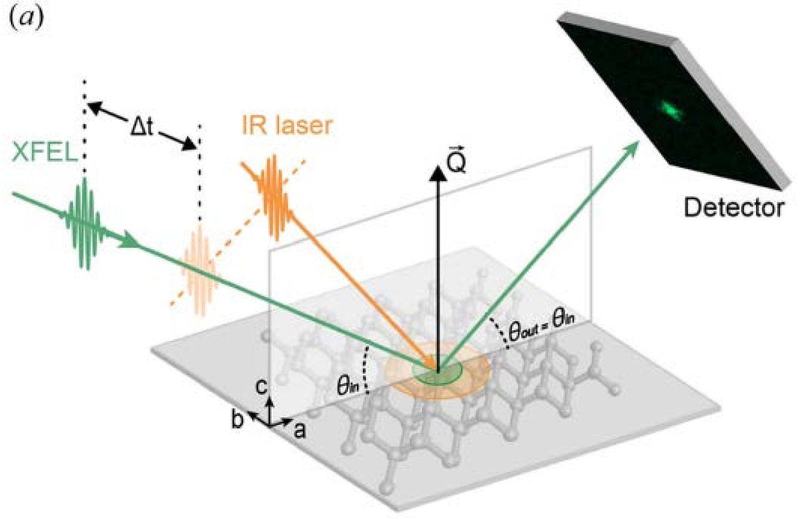
Received 3 July 2023
Accepted 11 September 2023

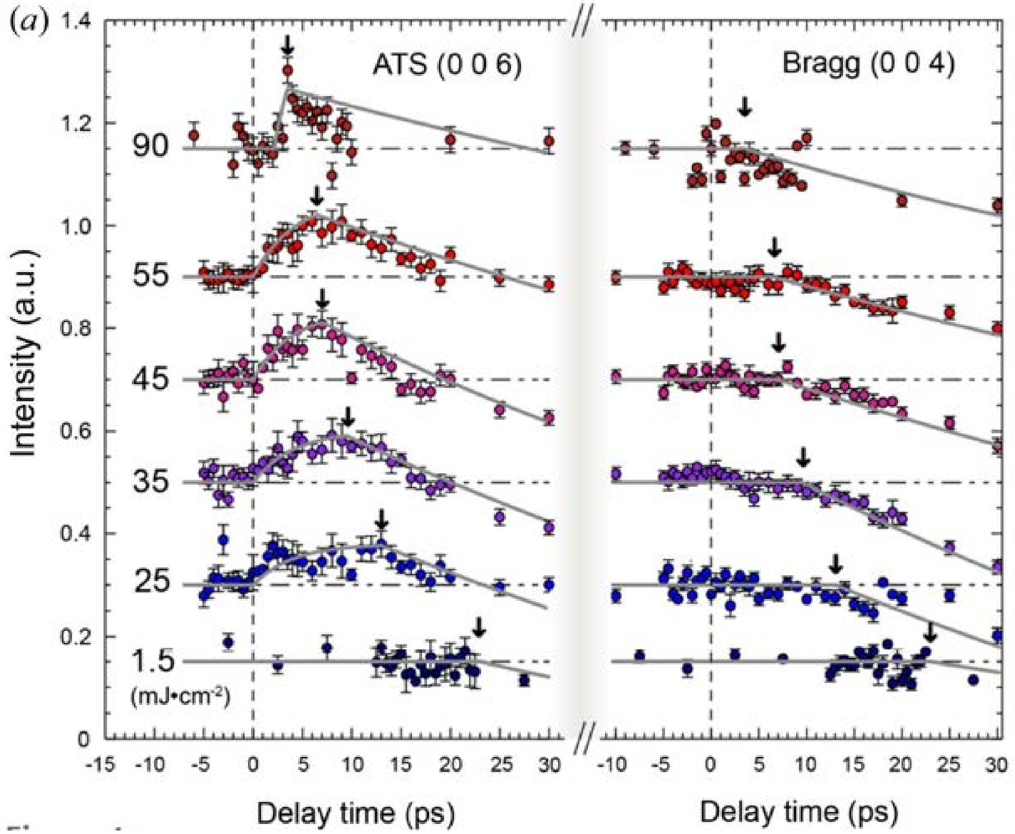
Observing femtosecond orbital dynamics in ultrafast Ge melting with time-resolved resonant X-ray scattering

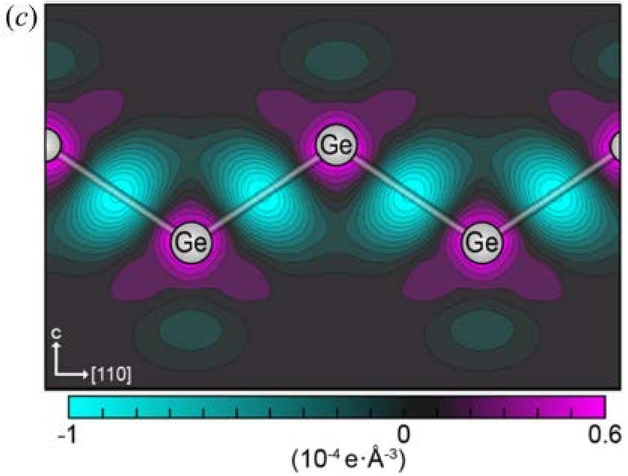
Heemin Lee,[a,b,c]‡ Je Young Ahn,[d]‡ Sae Hwan Chun,[c,e] Do Hyung Cho,[a,b] Daeho Sung,[a,b] Chulho Jung,[a,b] Jaeyong Shin,[a,b,c] Junha Hwang,[a,b,c] Sung Soo Ha,[f] Hoyoung Jang,[c,e] Byeong-Gwan Cho,[e] Sunam Kim,[e] Jaeku Park,[e] Daewoong Nam,[c,e] Intae Eom,[c,e] Ji Hoon Shim,[c,d] Do Young Noh,[f,g] Yungok Ihm[c,d]* and Changyong Song[a,b,c]*



Changyong Song (POSTECH)





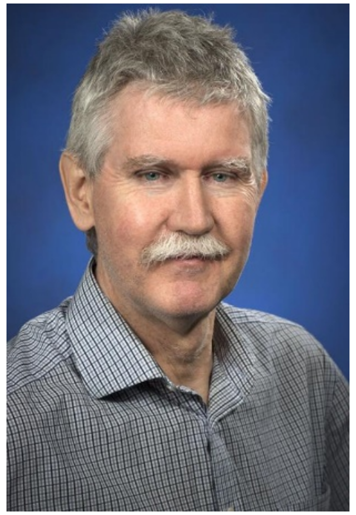


Research highlight in 2023 (2)

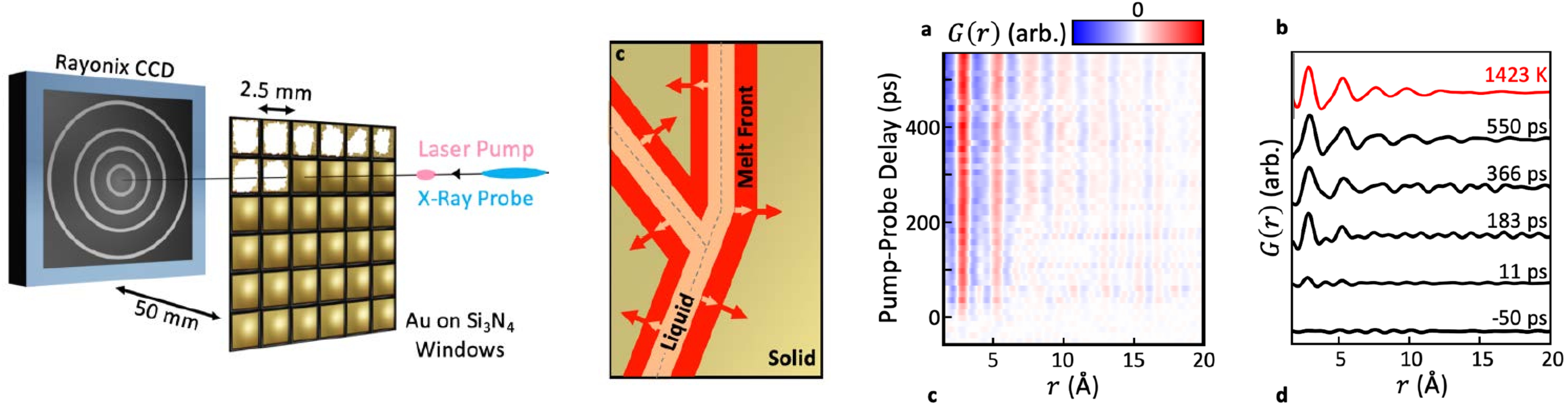
ICurJ in press (2023)

Emergence of liquid following laser melting of gold thin films

Ian K. Robinson[1,2], Jack P. Griffiths[1], Robert Koch[1], Tadesse A. Assefa[1], Ana F. Suzana[1], Yue Cao[3], Sungwon Kim[4], Dongjin Kim[4], Heemin Lee[5], Sunam Kim[6], Jae Hyuk Lee[6], Sang-Youn Park[6], Intae Eom[6], JaeHyun Park[6], Daewoong Nam[6], Sangsoo Kim[6], Sae Hwan Chun[6], Hyojung Hyun[6], Kyung-Sook Kim[6], Ming Lu[7], Changyong Song[5], Hyunjung Kim[4], Simon J. L. Billinge[1,8] and Emil S. Bozin[1]



Ian Robinson (BNL)



Thanks to:

Beamline staffs in PAL-XFEL