Magnetic Coherent Diffraction of Domain Excitations in Sr_2IrO_4 Iridate

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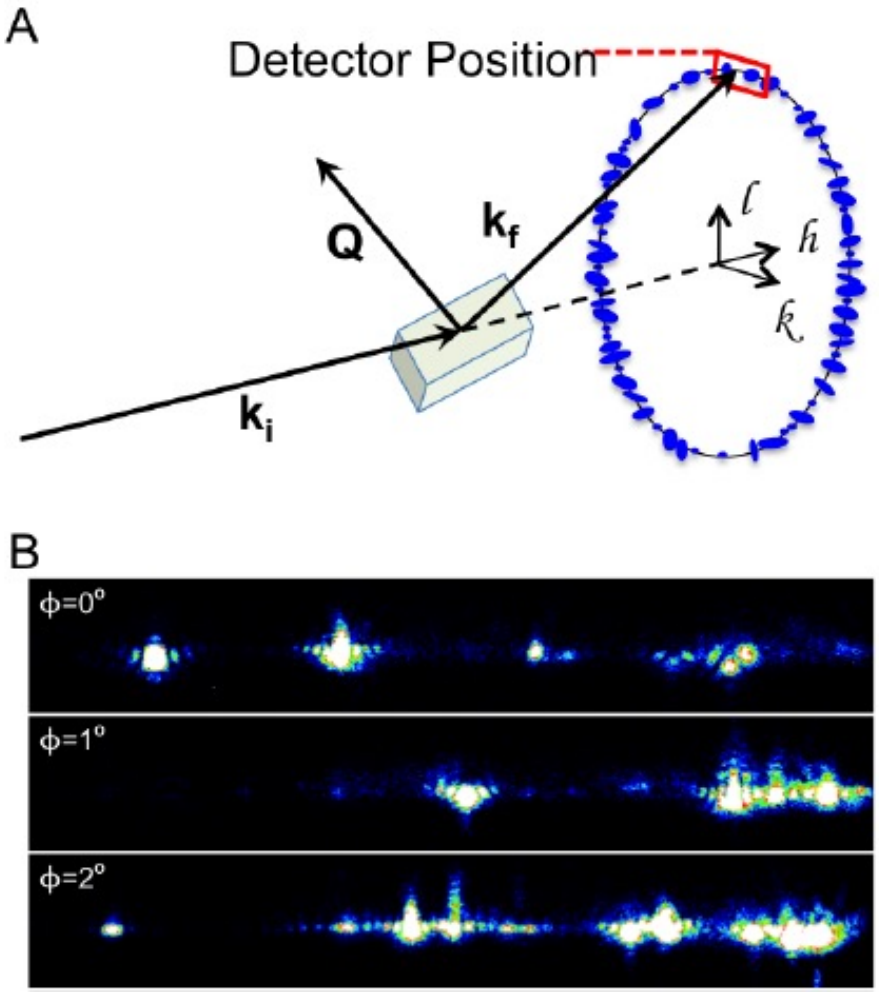
Workshop on
"XFEL Applications in Material Sciences and Nanotechnology"
Polish Academy of Science,
Warsaw, Poland
December 2024

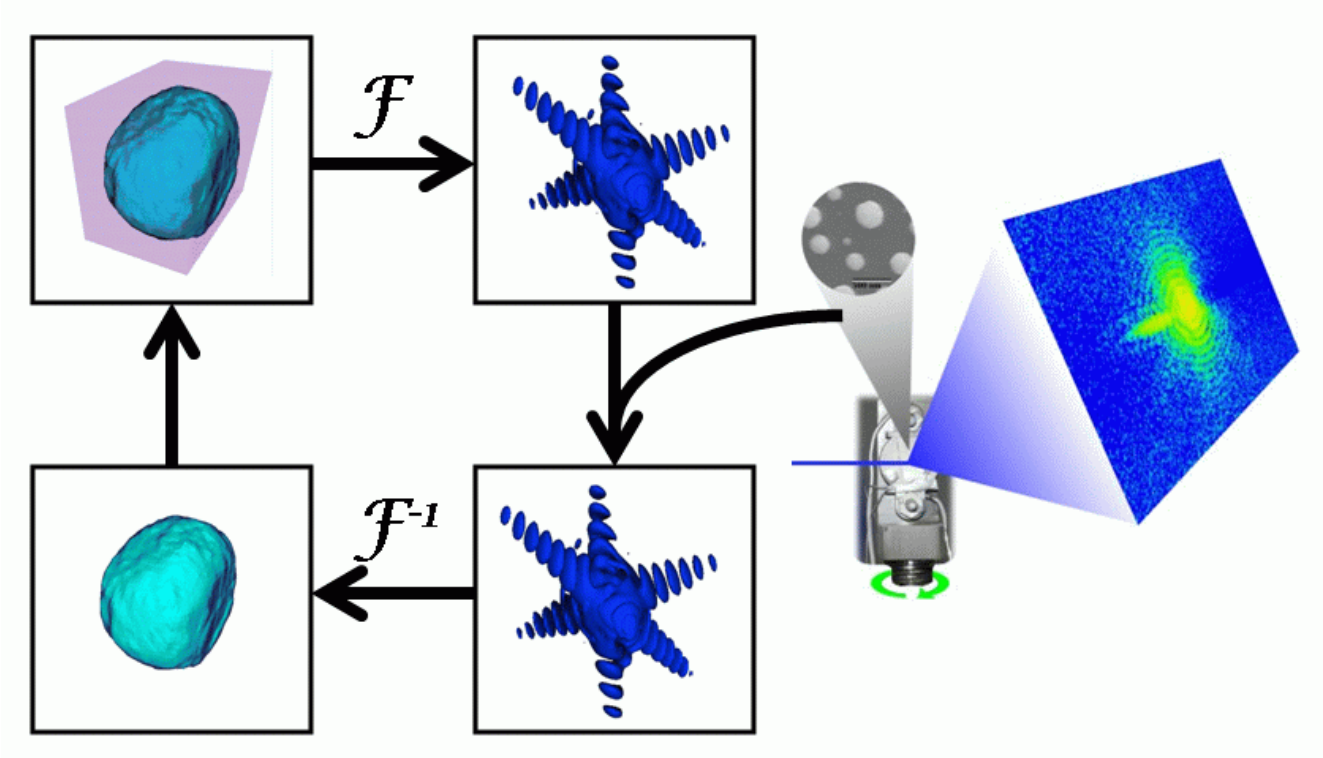
Magnetic Coherent X-ray Diffraction

- Bragg Coherent Diffraction Imaging
- Sensitivity to strain
- Phase domain structures
- Domain counting rule
- Antiferromagnetism of Sr_2IrO_4
- Pump-probe XFEL experiment
- Phase domain model of data
- Migration of magnetic domains



I. K. Robinson, Polish Acad Sci 2024

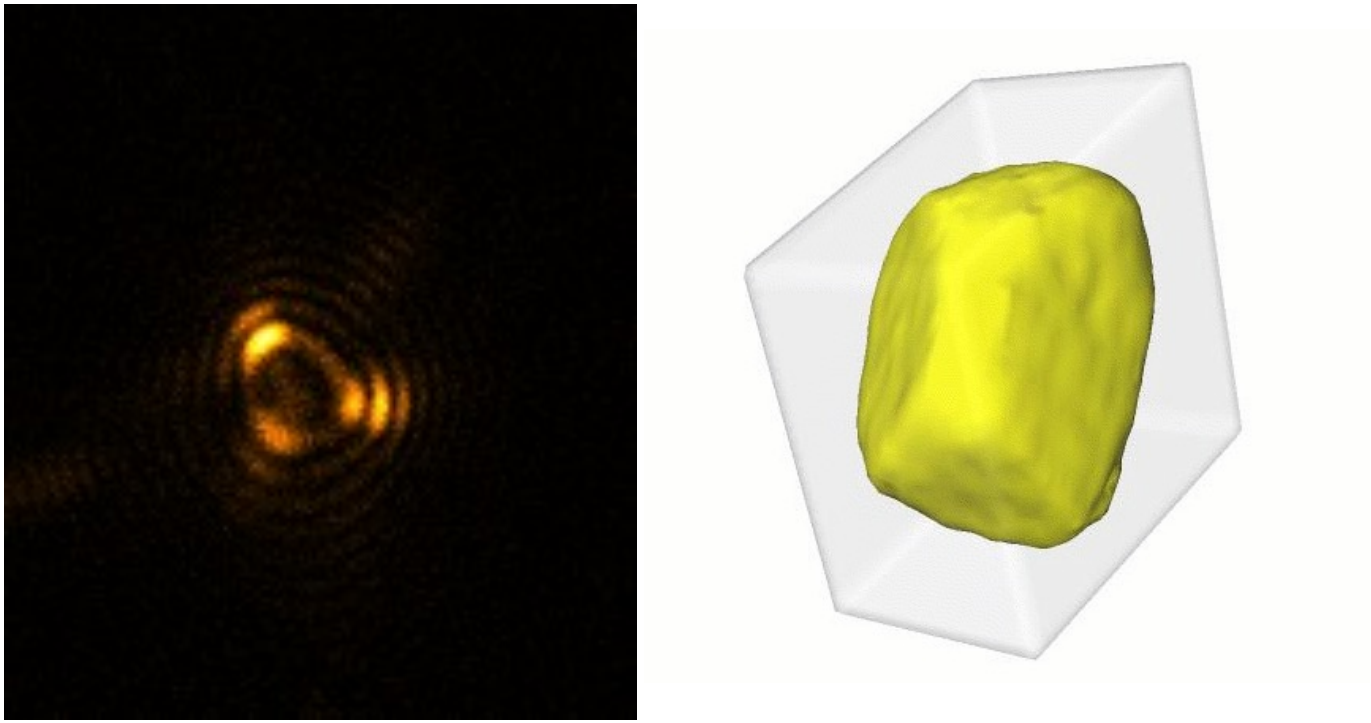
Generic “Error Reduction” method



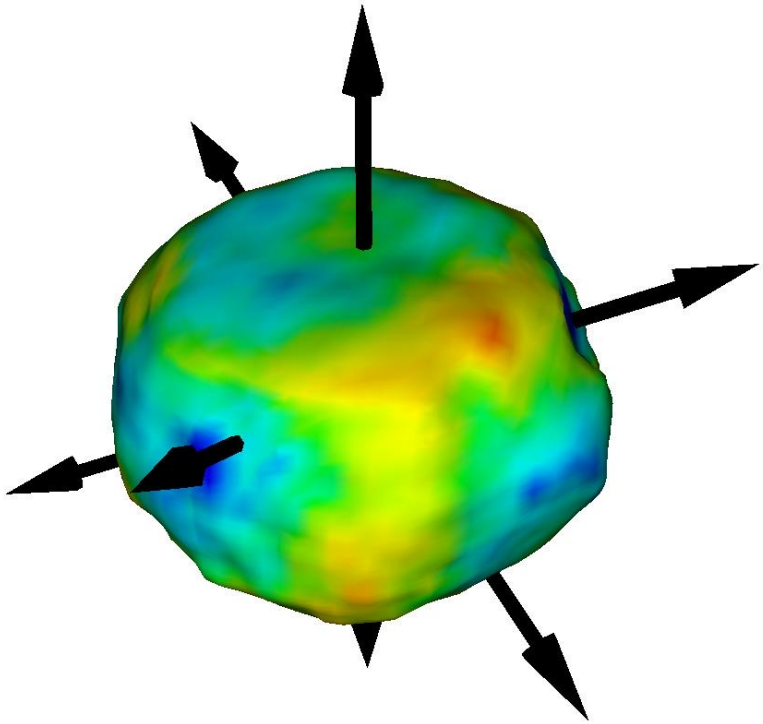
J. R. Fienup Appl. Opt. 21 2758 (1982)
R. W. Gerchberg and W. O. Saxton Optik 35 237 (1972)

Gold nanocrystal reconstruction

showing support used for 20 HIO followed by 10 ER



Phase isosurface of residual strain



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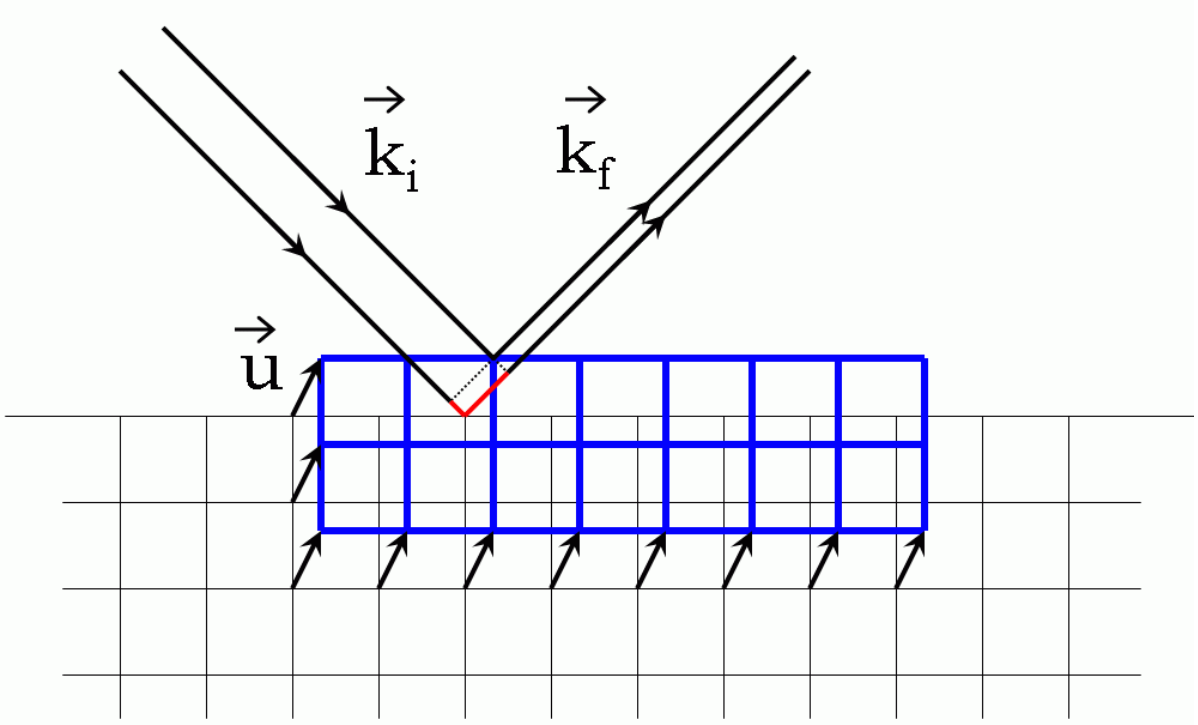
Sensitivity to strain

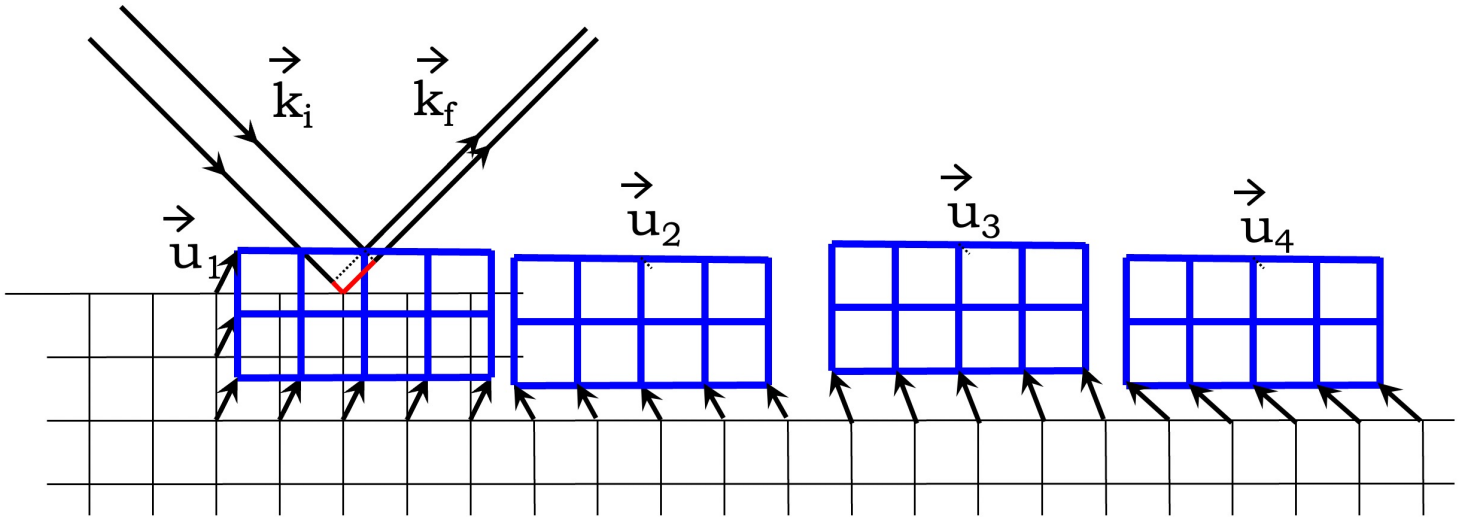
$$\Delta\phi = \mathbf{k}_f \cdot \mathbf{u} - \mathbf{k}_i \cdot \mathbf{u} = \mathbf{Q} \cdot \mathbf{u}$$



I. K. Robinson, Polish Acad Sci 2024

Sensitivity to domain offsets

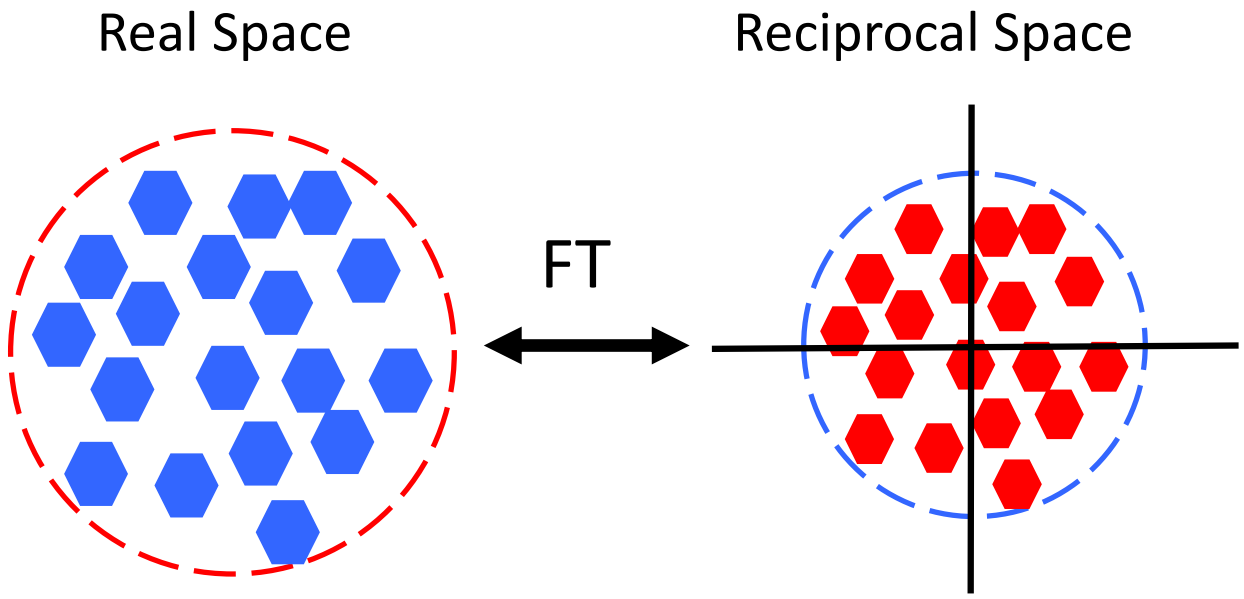
$$\Delta\phi = \mathbf{k}_f \cdot \mathbf{u} - \mathbf{k}_i \cdot \mathbf{u} = \mathbf{Q} \cdot \mathbf{u}$$



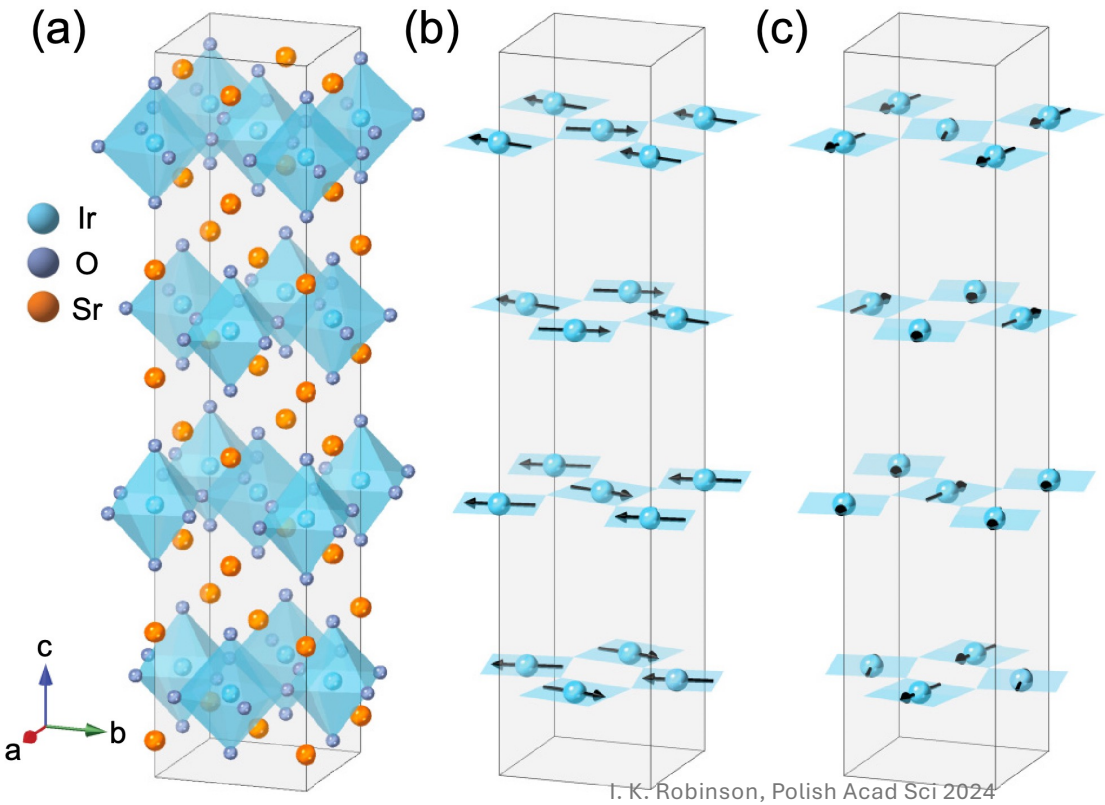
I. K. Robinson, Synchrotron Radiation News (2024)

Domain Counting by Coherent Diffraction

Ian Robinson et al, J. Superconductivity and Novel Magnetism (2019)



Sr_2IrO_4 has “214” Layered square planar structure like $La_{2-x}Sr_xCuO_4$ superconductors



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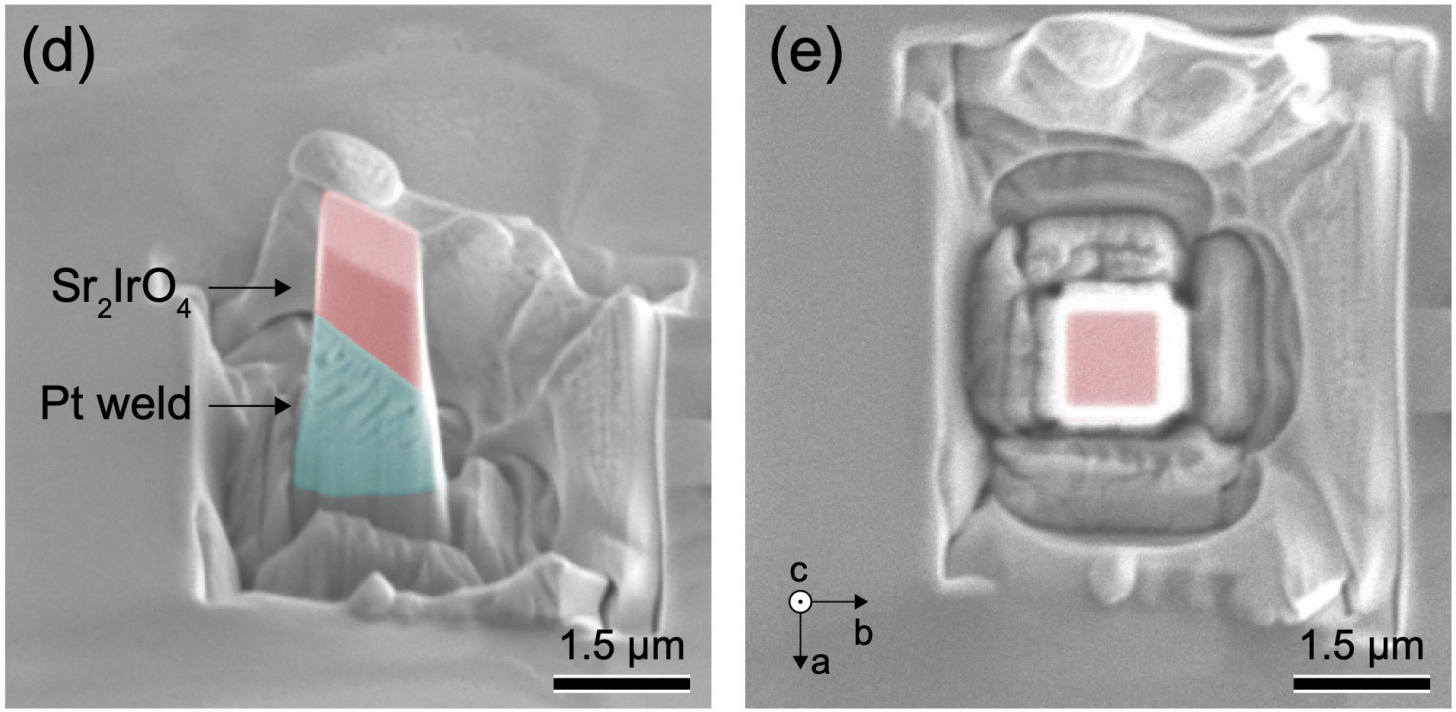
Strong AFM peaks at
106 first domain
016 second domain
108 second domain

pseudo tetragonal unit cell

resonance at Ir L_3 11.215 keV

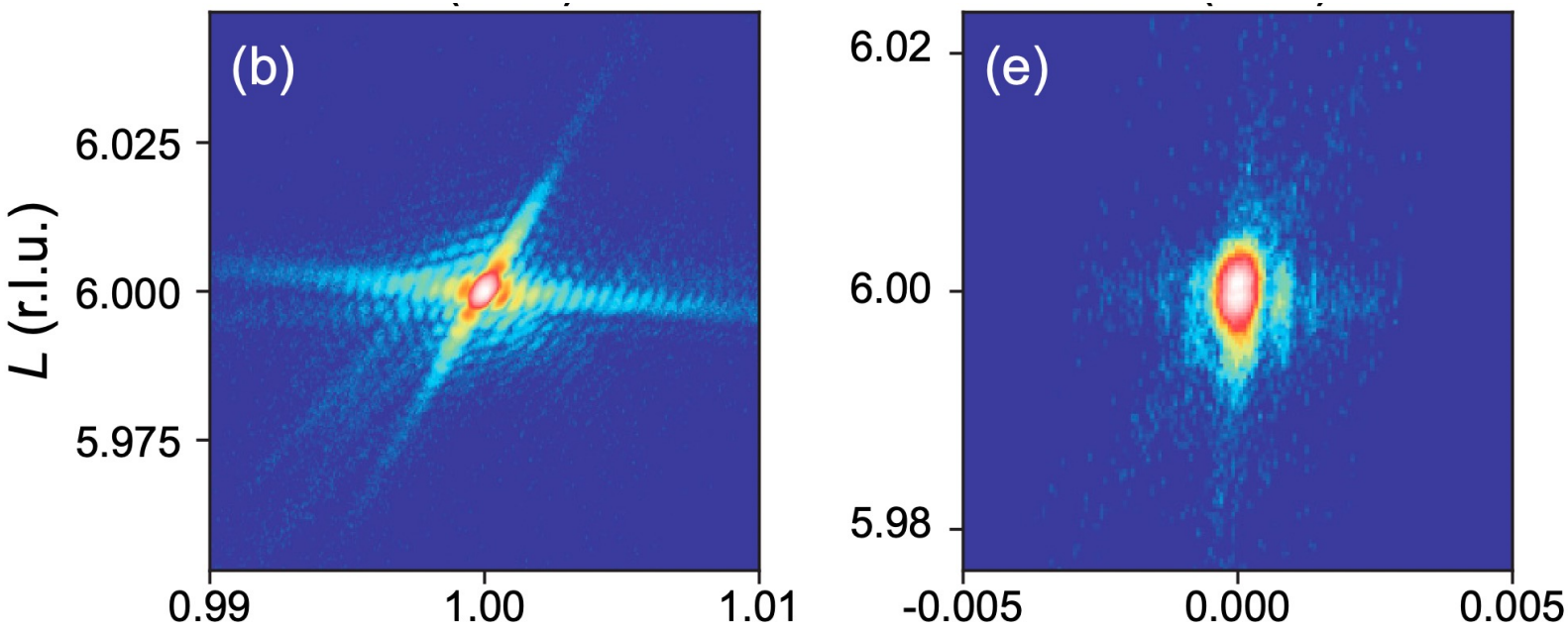
FIB sample preparation (Kim Kisslinger CFN BNL)

For MID-XFEL Jungfrau at 8m we made 5x5x5 μm and 4x4x4 μm crystals



I. K. Robinson, Polish Acad Sci 2024

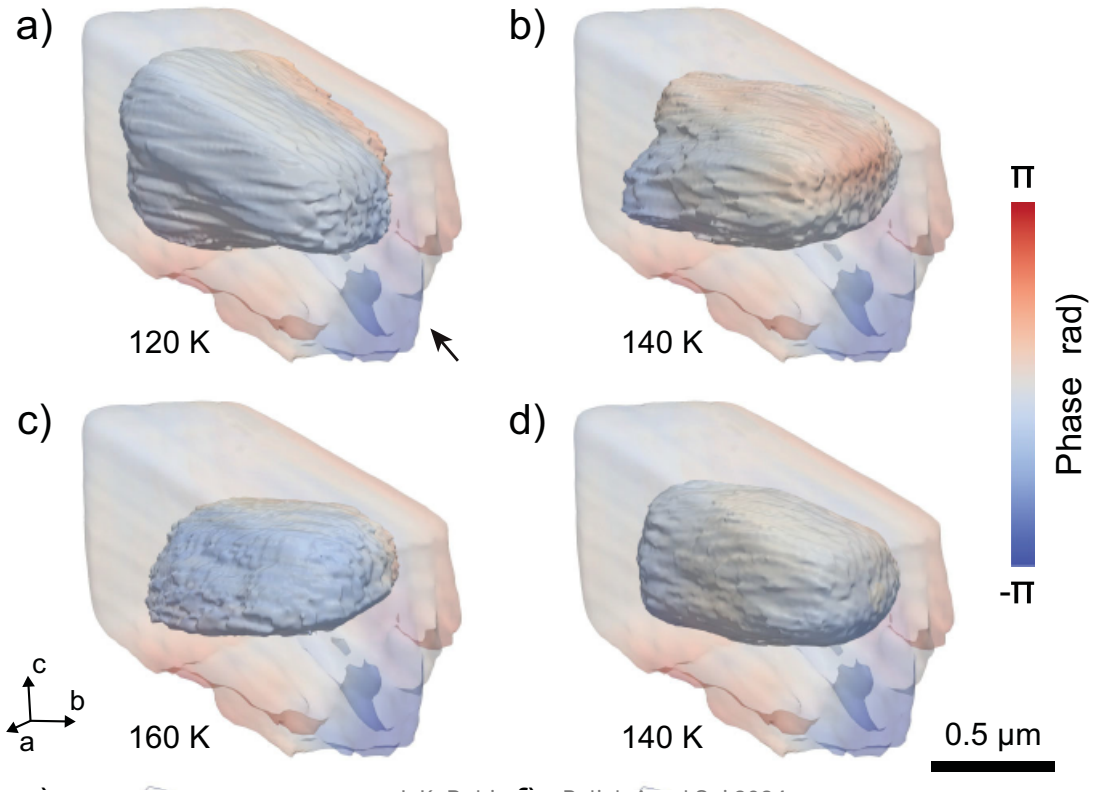
116 charge and 106 magnetic diffraction peaks Resonant on Ir L_3 at 11.215 keV



length (nm)	(116) peak	120 K	140 K	160 K
ξ_H	1153 ± 6	1137 ± 4	1158 ± 4	1030 ± 13
ξ_K	970 ± 3	1019 ± 15	1083 ± 20	871 ± 54
ξ_L	902 ± 3	739 ± 2	610 ± 3	423 ± 9

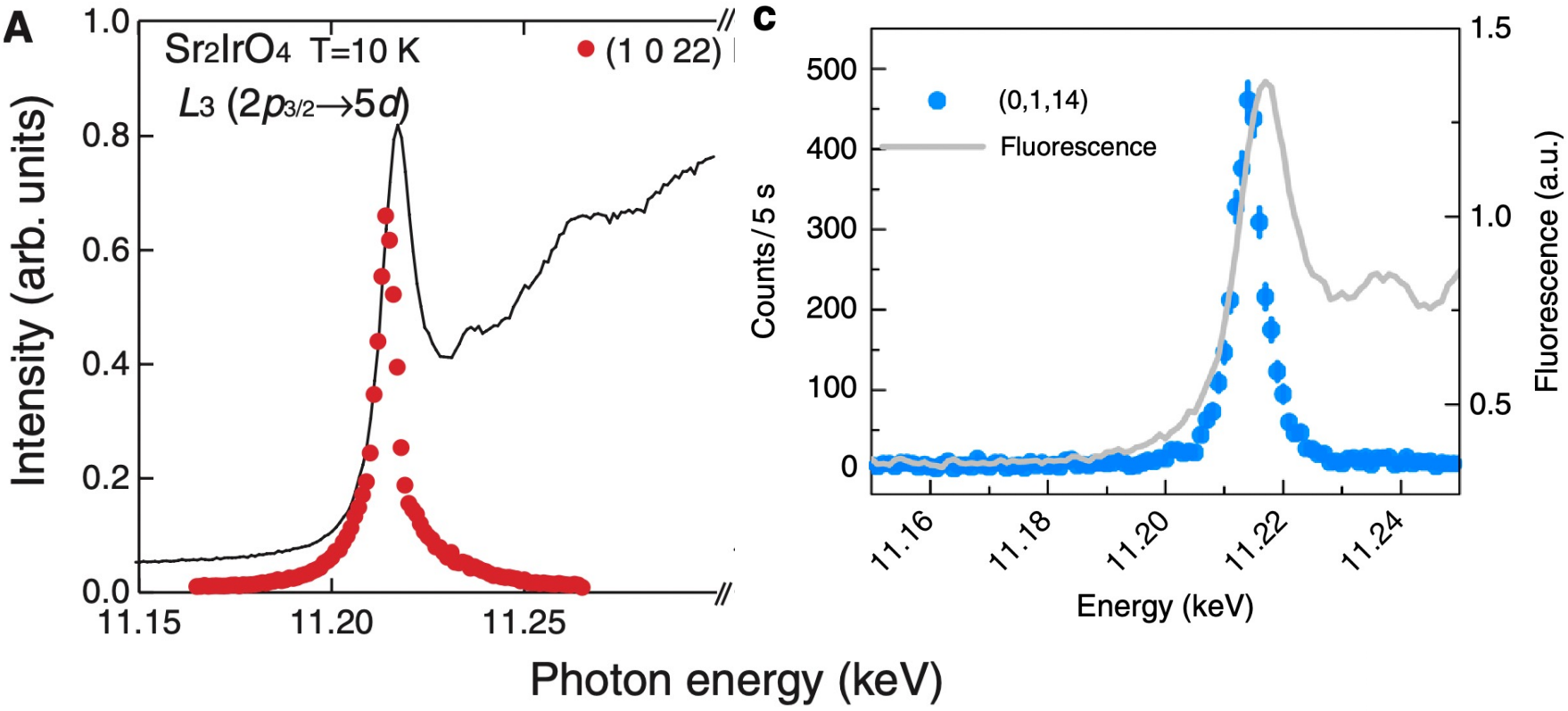
Magnetic BCDI images of single AFM domain

Anisotropy of Antiferromagnetic Domains in a Spin-orbit Mott Insulator
Longlong Wu et al Physical Review B 108 L020403 (2023)



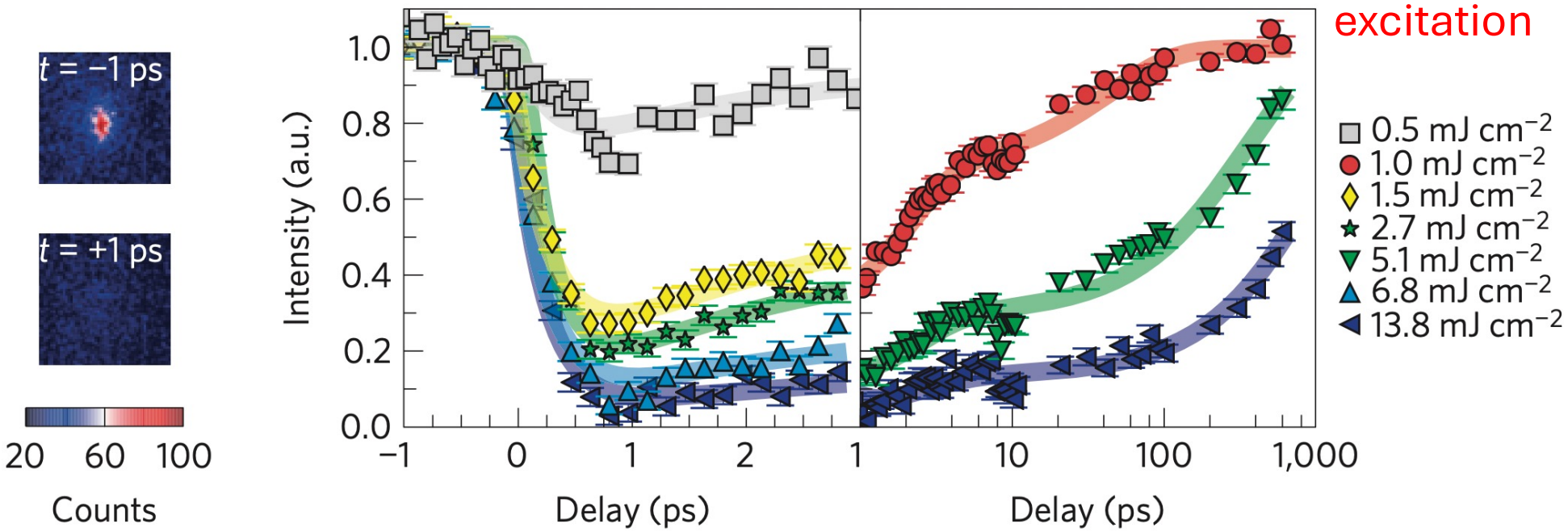
Magnetic Bragg peak resonance at 11.215 keV

B.J. Kim et al Science (2009); K. Finkelstein Nat Comm (2018)



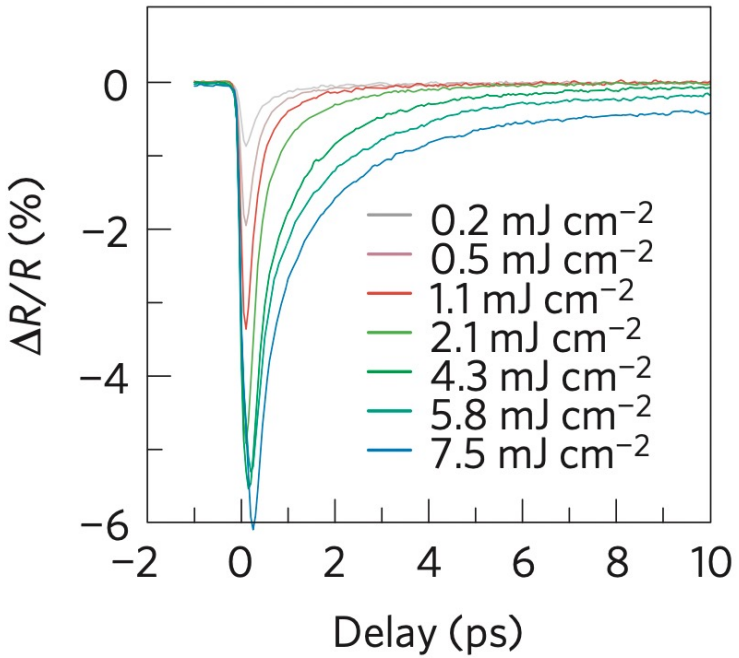
Ultrafast energy- and momentum-resolved dynamics of magnetic correlations in the photo-doped Mott insulator Sr_2IrO_4 [XPP LCLS]
M. P. M. Dean et al Nature Materials 15 601 (2016)

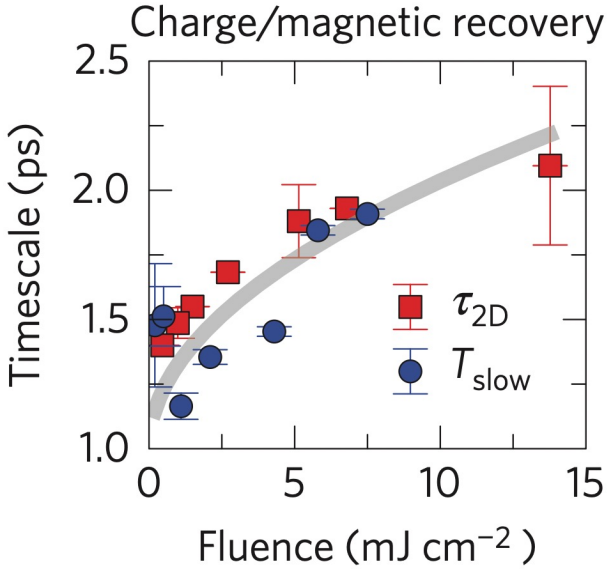
800 nm laser excitation



(−3 −2 28) magnetic Bragg peak (backscattering at 12.215 keV).

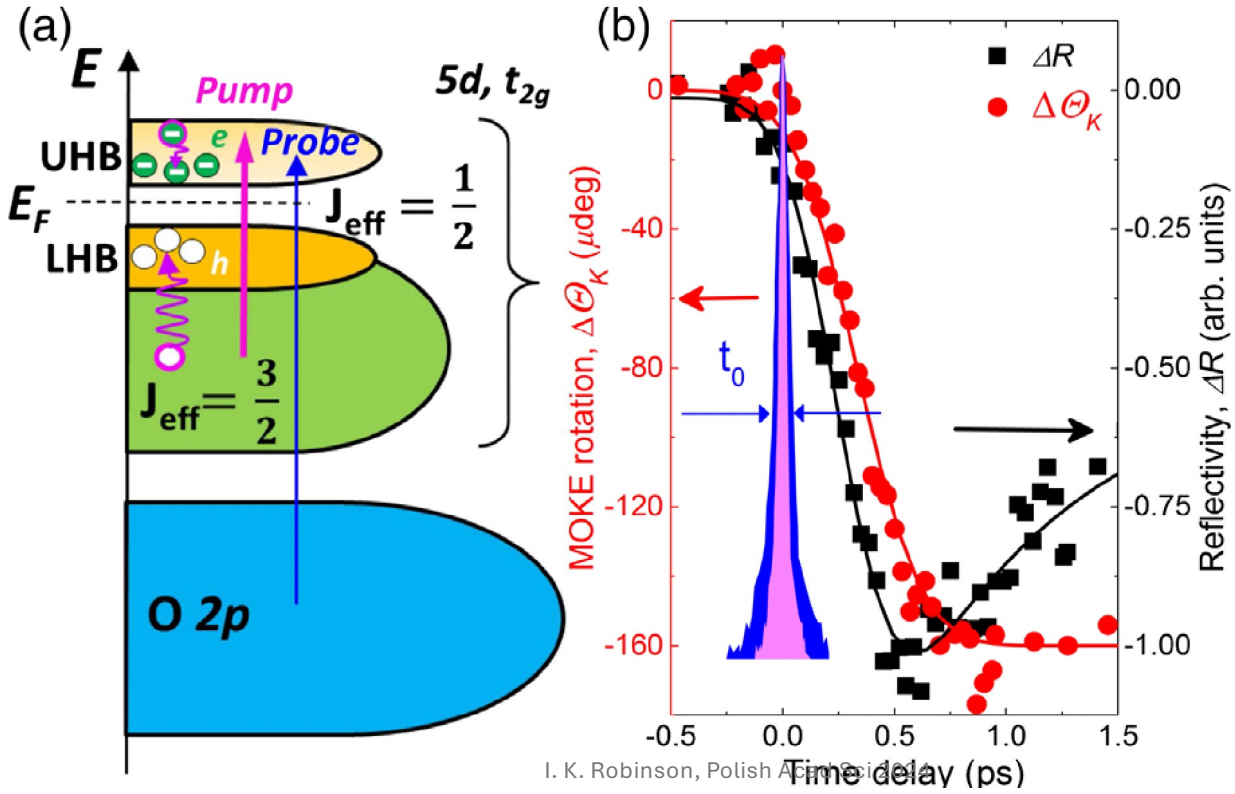
Ultrafast energy- and momentum-resolved dynamics of magnetic correlations in the photo-doped Mott insulator Sr_2IrO_4
M. P. M. Dean et al Nature Materials 15 601 (2016)





Laser reflectivity of AFM Demagnetisation by MOKE

Ultrafast Spin Dynamics in Photodoped Spin-Orbit Mott Insulator Sr_2IrO_4
D. Afanasiev et al Phys Rev X 9 021020 (2019)

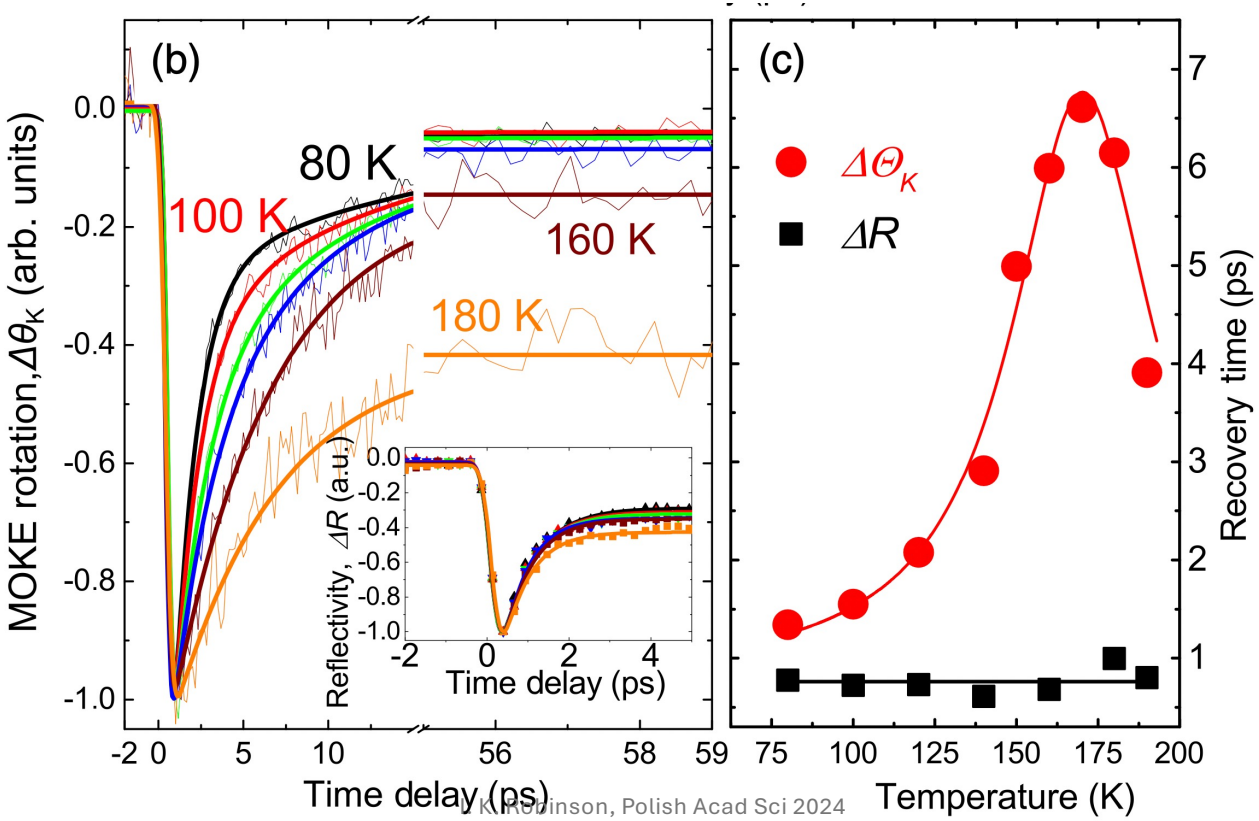


400 nm laser excitation

Laser reflectivity of AFM Demagnetisation by MOKE

Ultrafast Spin Dynamics in Photodoped Spin-Orbit Mott Insulator Sr_2IrO_4

D. Afanasiev et al Phys Rev X 9 021020 (2019)



Laser reflectivity of AFM Demagnetisation by MOKE

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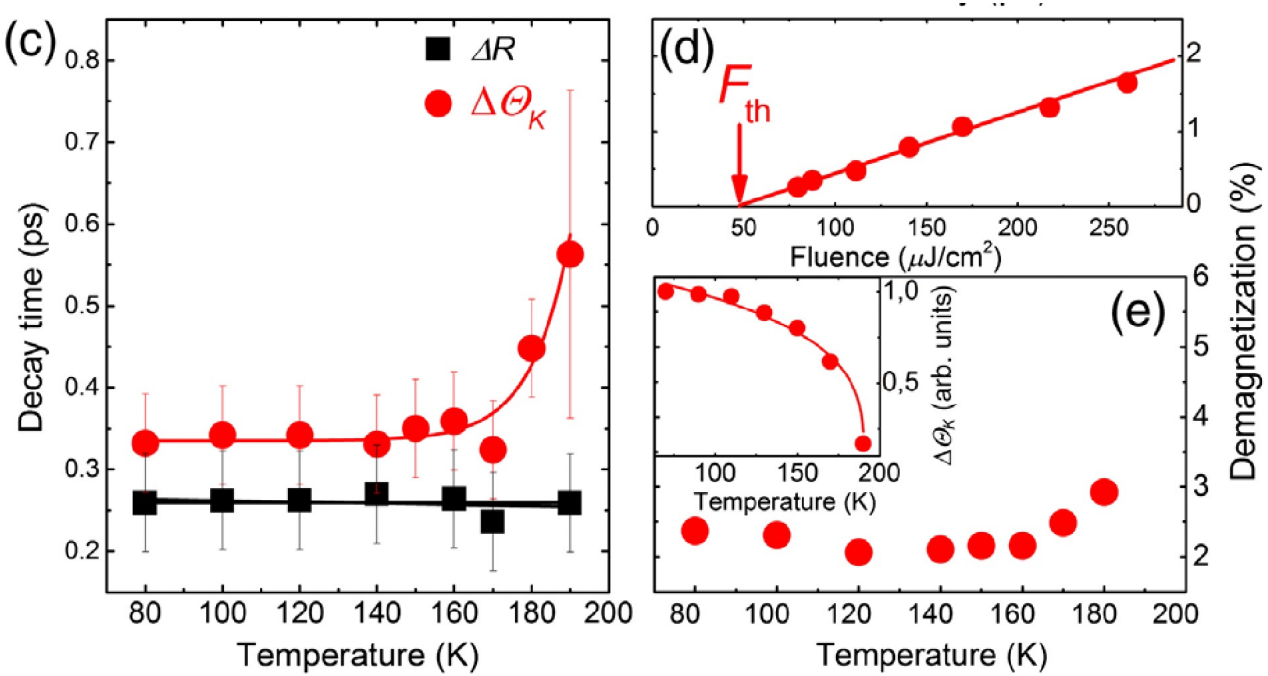
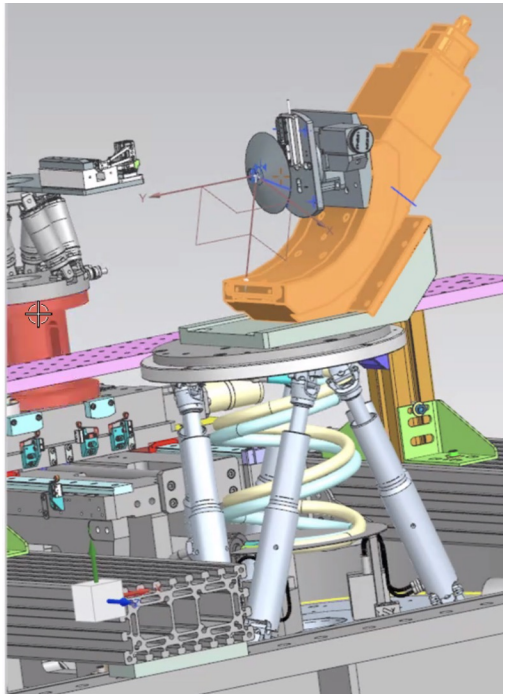


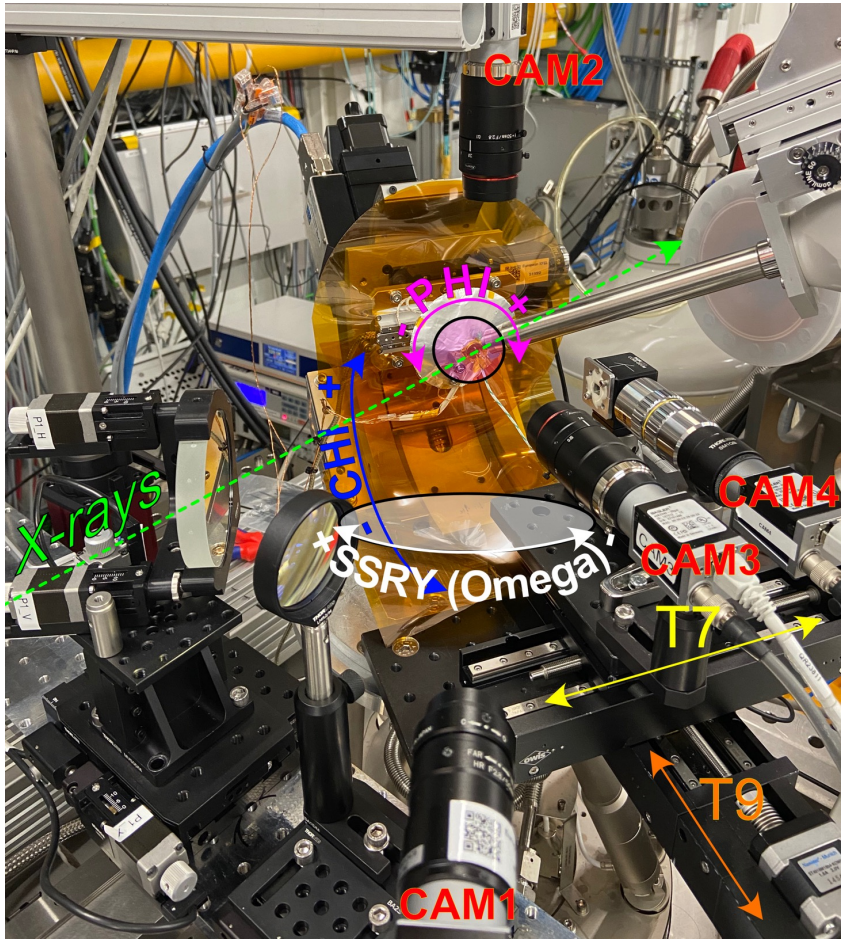
P3331 + P6156 experiments at MID of E-XFEL

- 2-day compensation beamtime (for cryo failure in April 2023)
- Challenging sample alignment
  - 5x5 μm crystal prealigned to 001 normal 100 parallel to edge
  - self seeding at exact resonant energy 11.215 keV
  - magnetic peaks only below 230K
  - (1 0 6) peak is tilted 51 degrees in 001/100 plane
  - spatial and temporal overlap of laser and 12 μm X-ray focus
- Pre-align on (2 0 12) charge peak at double the Bragg angle
- Planned to get 3D BCDI rocking curves vs PP delay and fluence

Set-up at MID E-XFEL April 2023 + April 2024

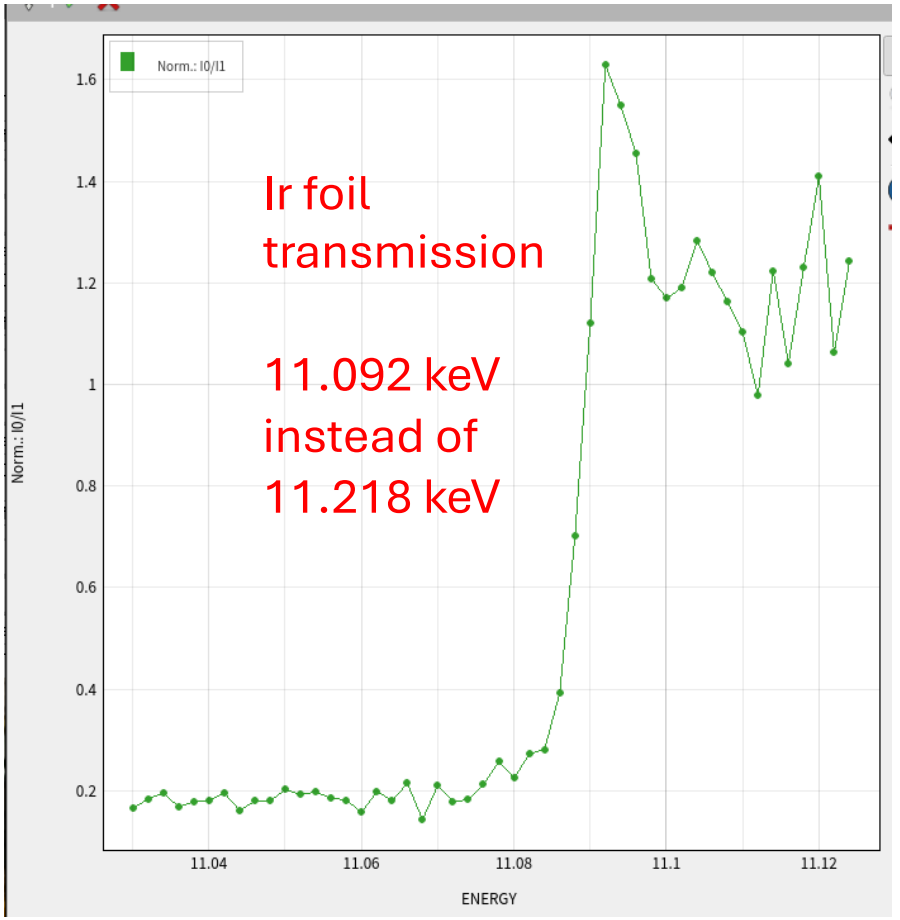
NAFO CRL focussing



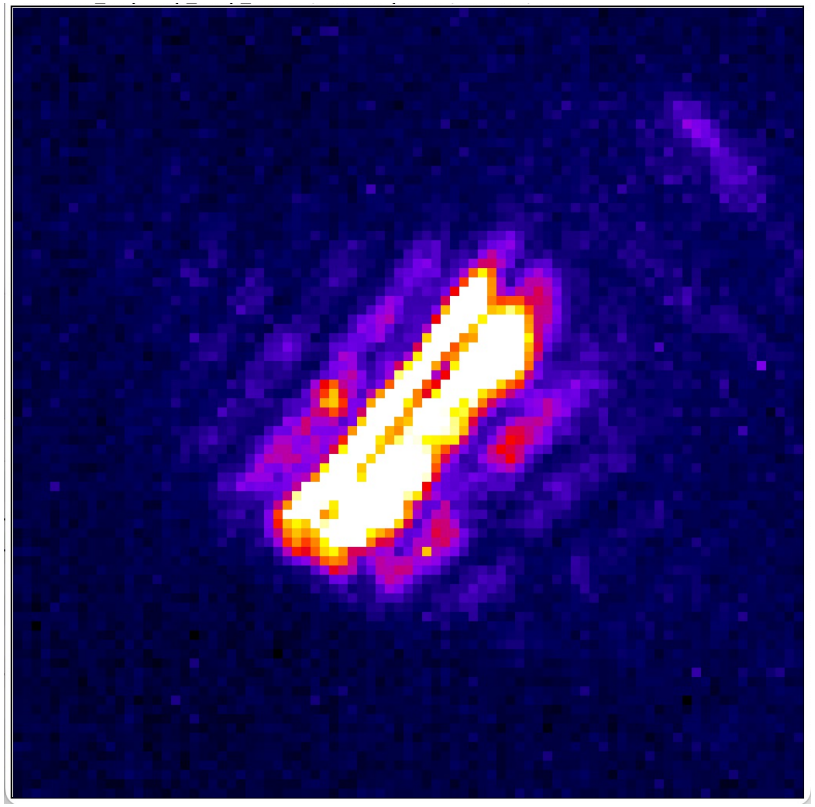


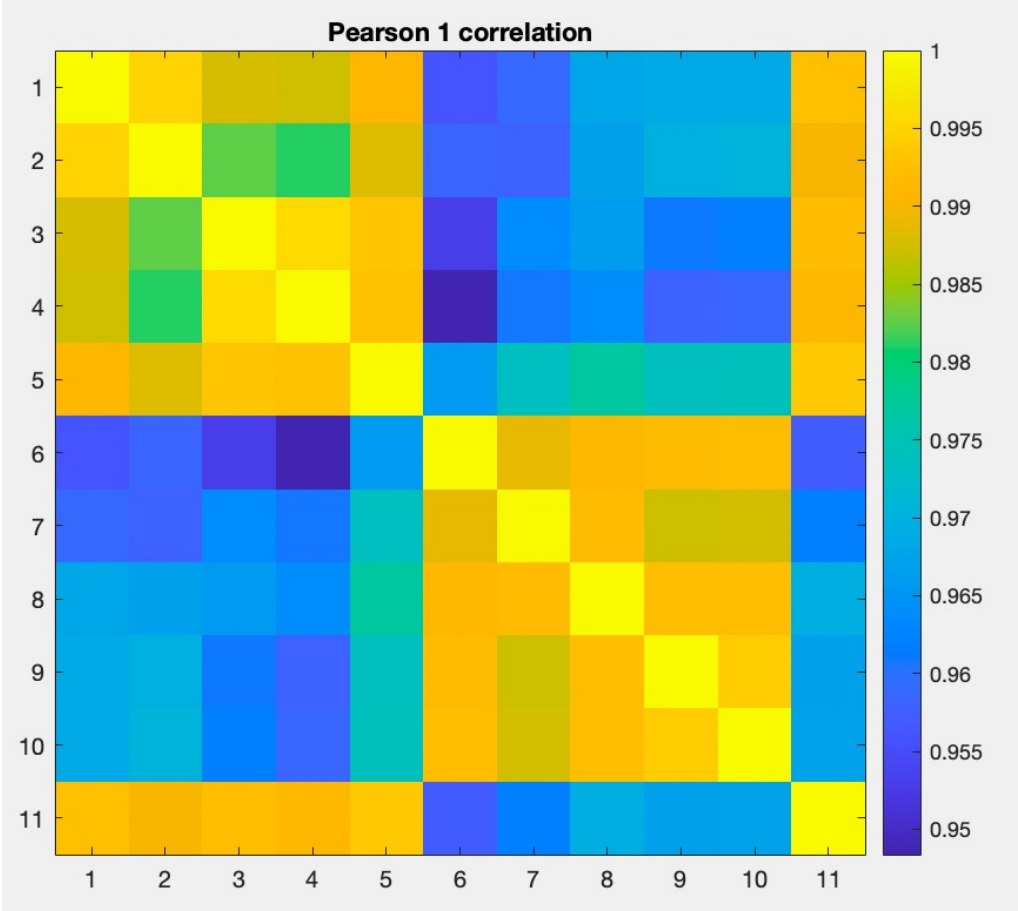
cryostream cooling

Single crystal sample of Sr_2IrO_4 at 100K



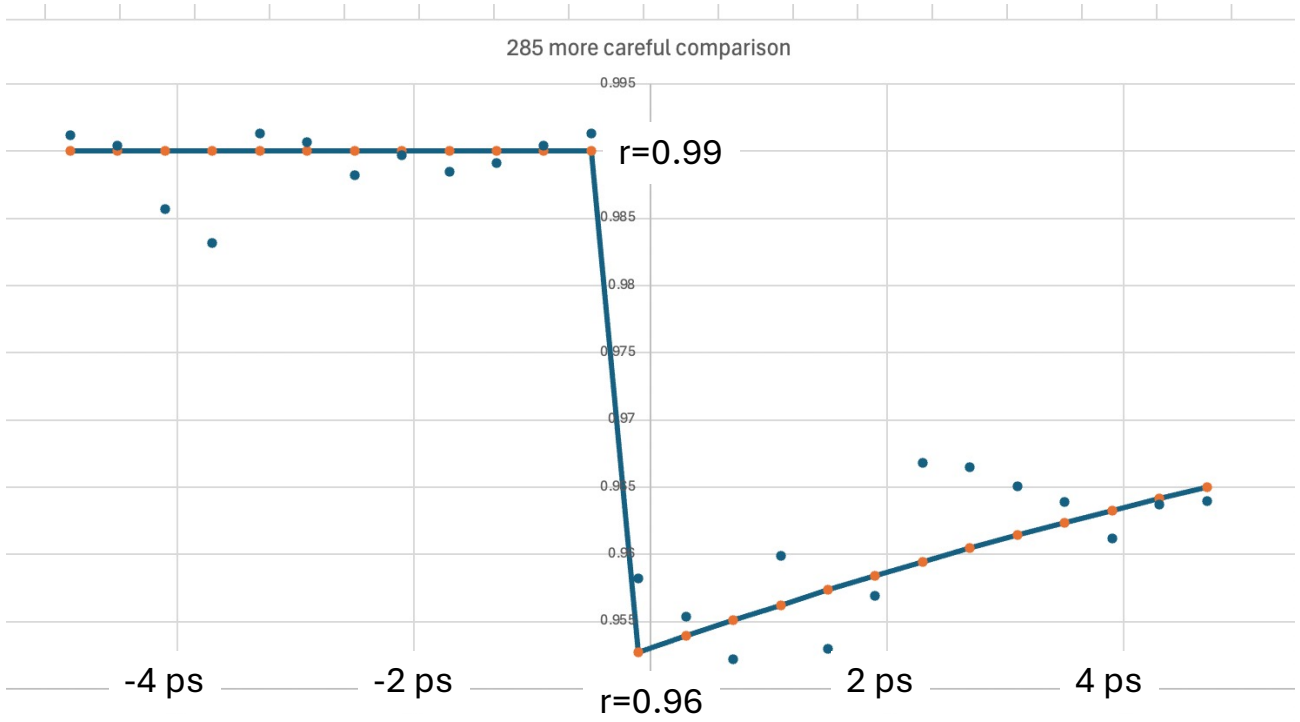
Coherent diffraction at 106 peak
T=100K E=11.215 keV





I. K. Robinson, Polish Acad Sci 2024

Run285 bin = 4 compare with P5 reconstruction 800 nm Laser at 50% = 15 mJ/cm^2



5.3	offset
0.037	amp
12 ps	decay
0.99	scale

I. K. Robinson, Polish Acad Sci 2024

Magnetic Coherent X-ray Diffraction

- Bragg Coherent Diffraction Imaging at E-XFEL
- Phase domain images of Sr_2IrO_4
- Antiferromagnetic (AFM) domains
- Domain counting rule
- Laser driven migration of AFM domains