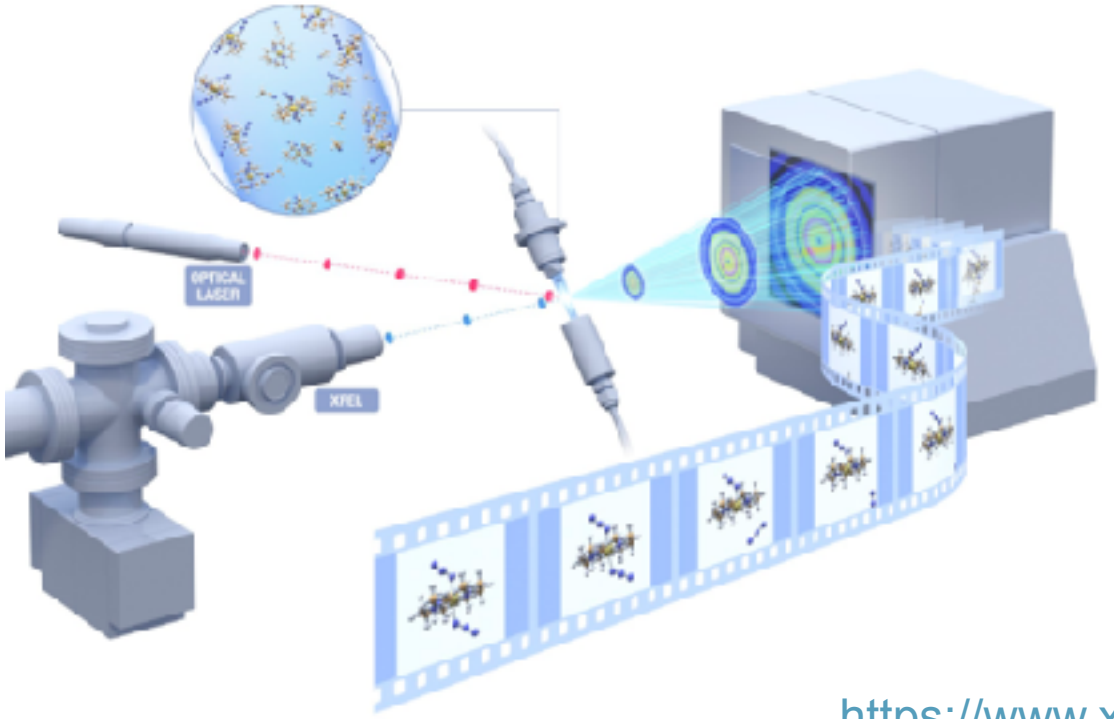
Run 8 @ Femtosecond X-ray Experiments

Chris Milne on behalf of FXE

European XFEL
FXE – Femtosecond X-ray Experiments



European XFEL Town Hall
3.11.2021

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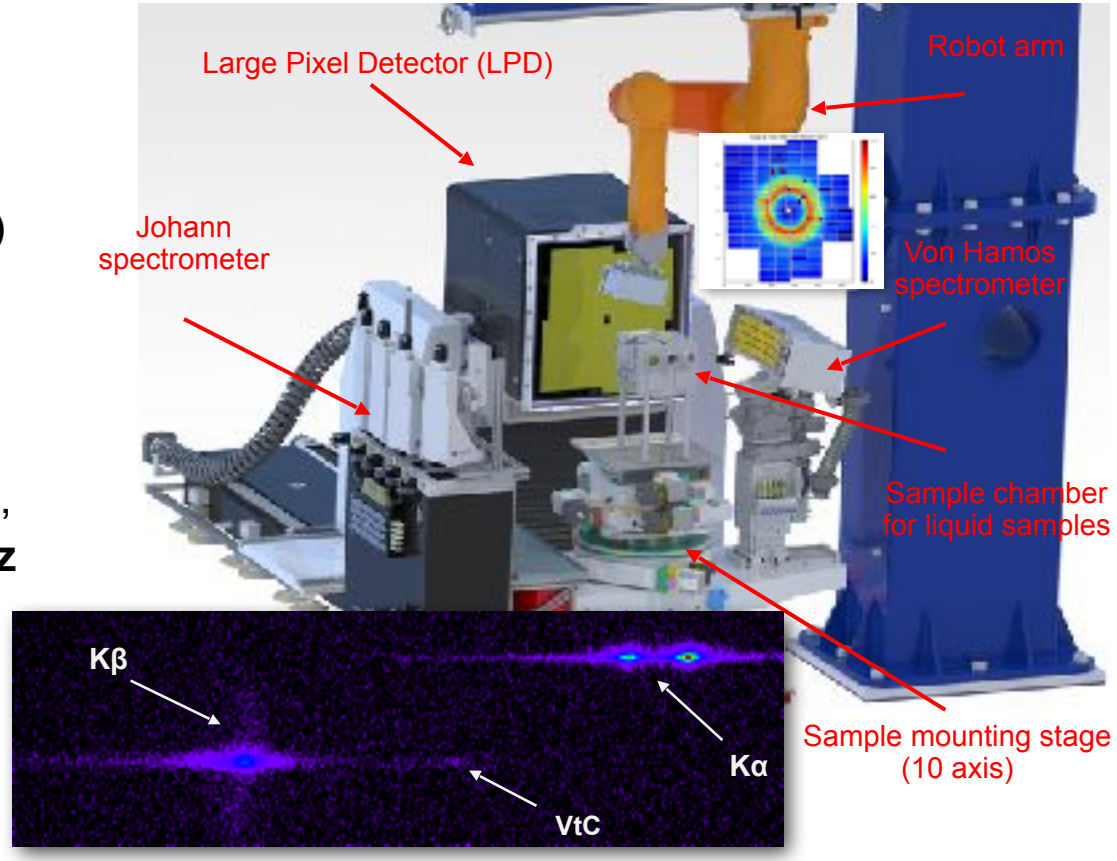
FXE: Femtosecond Hard X-ray Experiments

A Suite of **Simultaneous** X-ray Tools combined with flexible Laser Excitation Sources

- **Single-shot** dispersive resonant and non-resonant **XES**: von Hamos
- **Wide**(Small)-**angle X-ray Scattering**: Large Pixel Detector (LPD) and Jungfrau
- Huber sample motion, goniometer for **single-crystal X-ray diffraction** with Jungfrau detector motion using the robot arm
- Tuneable laser excitation covering 1030, 515 nm (1 ps), 800, 400, 266 nm (15 or 50 fs) and an **OPA** (50 fs, 240 nm to 3 um) with **THz** in development ($LiNbO_3$, 0.2-0.3 THz)
- **X-ray absorption spectroscopy** (5-20 keV): **scanning** (Si(111) 4-bounce mono) and **single-shot** (Spectrum analyzer)
- **Scanning** resonant and non-resonant **XES** (RXES): Johann spectrometer



"Scientific instrument Femtosecond X-ray Experiments (FXE): instrumentation and baseline experimental capabilities" A. Galler , et al., *J. Synch. Rad., 26, 1432 (2019)*
"Ultrafast X-ray Photochemistry at European XFEL: Capabilities of the Femtosecond X-ray Experiments (FXE) Instrument" D. Khakhulin, et al., *Appl. Sci., 10, 995 (2020)*

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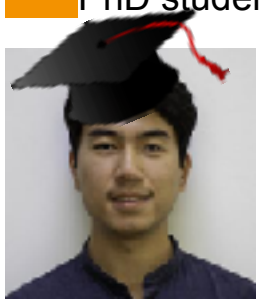

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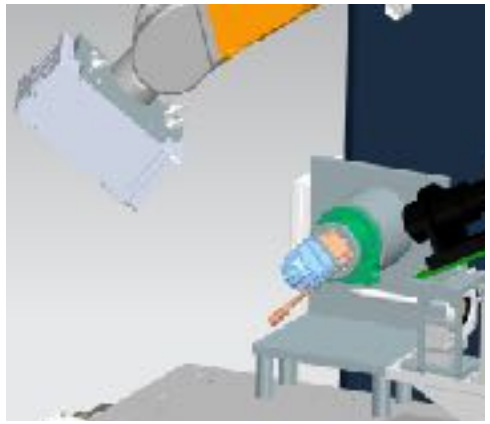
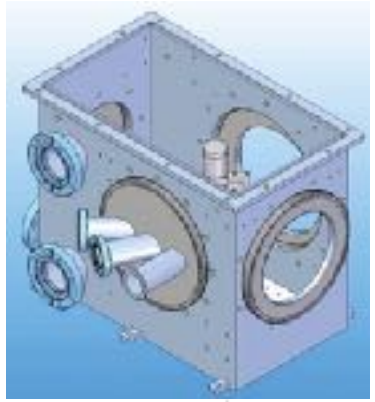
Standard sample environment and geometries: Chemistry & Solid state experiments

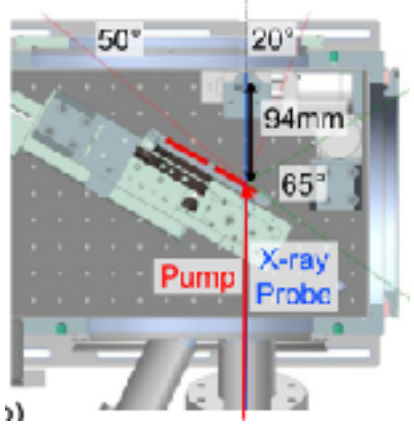
*Fixed target **10 Hz diffraction** experiment (single pulse per train)*



- Vertical and horizontal geometry
- Grazing and symmetric Bragg diffraction
- Flexible tracking of Bragg peak with detector on Robot arm
- Cooling and heating of samples supported
- Compatible with von Hamos XES for vertical sample geometry

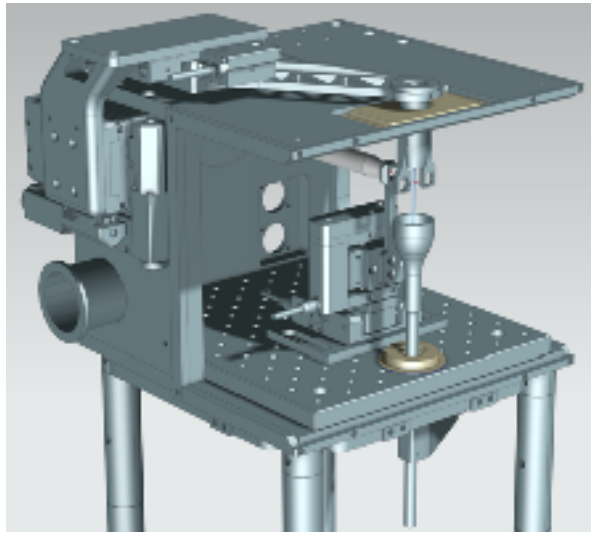
*Destructive **single-shot diffraction** experiment (<10 Hz)*

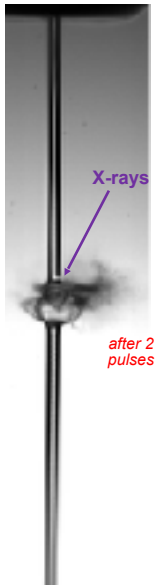




- Vacuum environment (1e-5 mbar)
- X-ray probe in transmission geometry
- Parallel X-ray emission and scattering compatible
- Diffraction up to 8.8 $Å^{-1}$ at 16.5 keV and $2\theta_{max}=63°$

*Jet speed compatible with about **0.5 MHz operation***



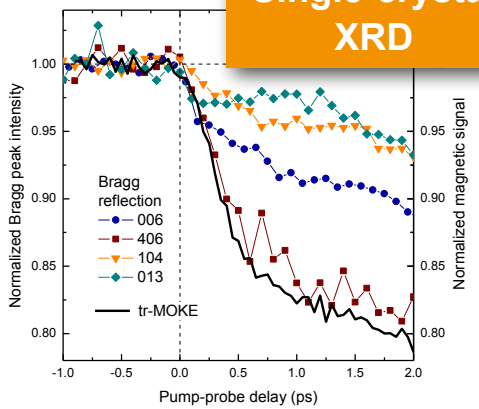


- He environment
- Open on 3 sides (XES, XAS, WAXS compatible)
- Parallel UV-Vis flow loop to monitor sample
- Jet diameter 25-200 µm
- XES Bragg angle range 67-83°
- WAXS maximum Q up to 10 $Å^{-1}$

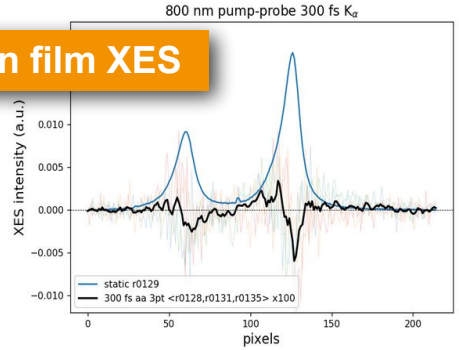
Scientific Scope of FXE: Measuring ultrafast dynamics with hard X-rays

Ultrafast solid-state dynamics

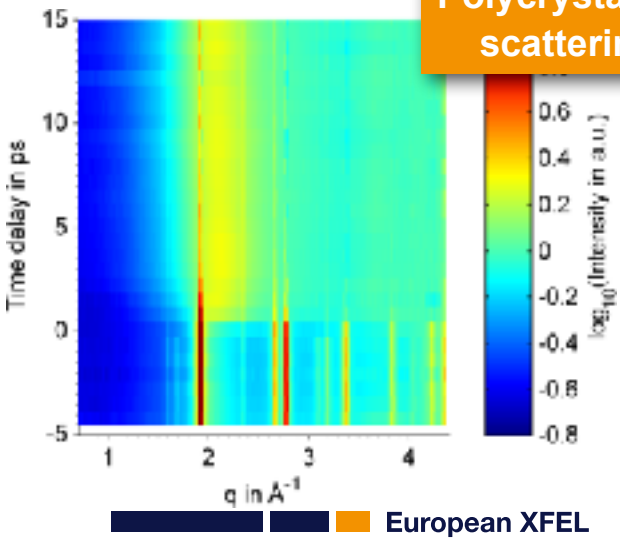
Single-crystal XRD

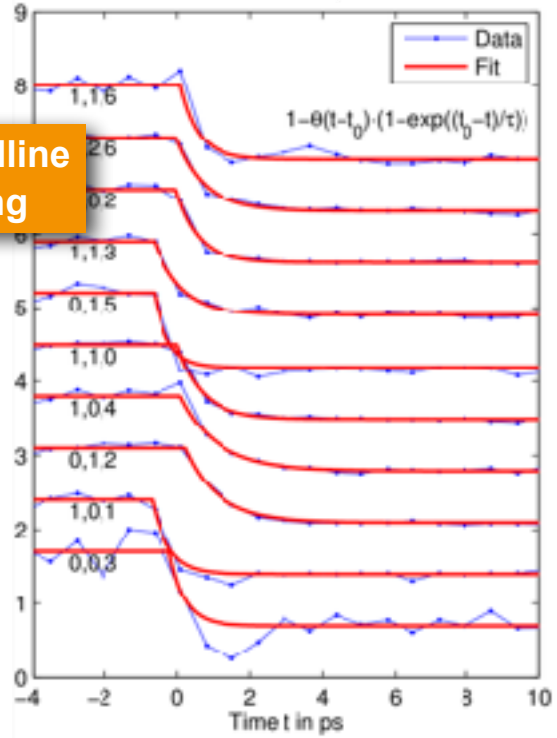


Thin film XES

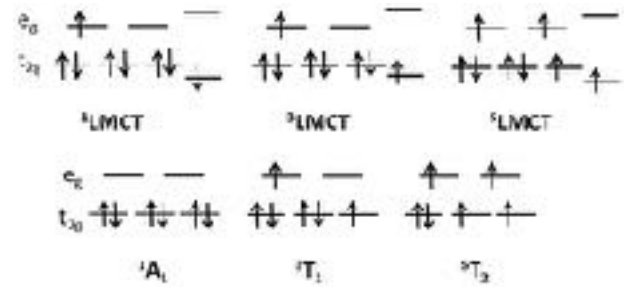


Polycrystalline scattering

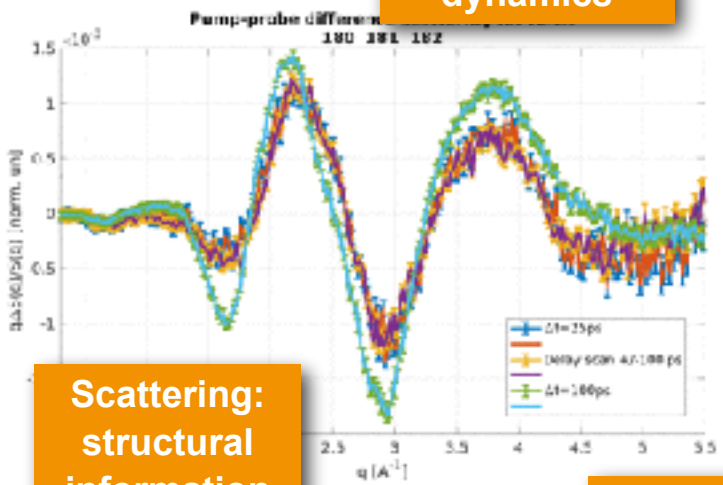


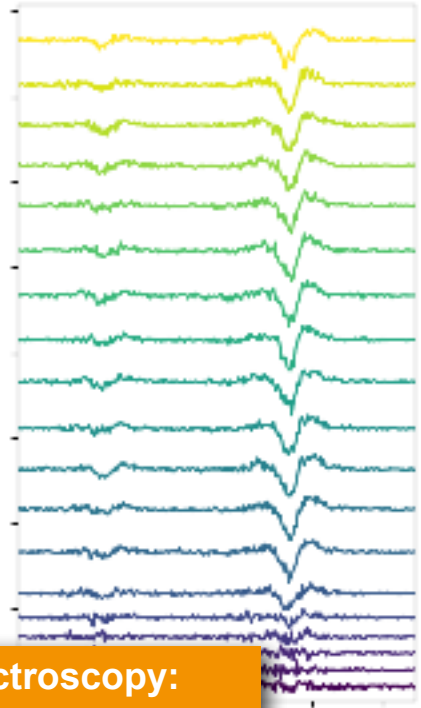


Ultrafast (bio)chemical dynamics



Excited-state electronic and structural dynamics





Scattering: structural information

Spectroscopy: electronic information

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Run 8: Liquid chemistry chamber standard setup

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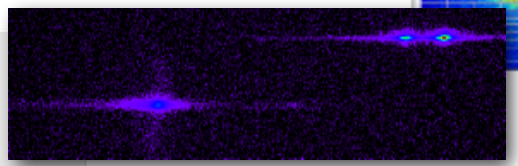

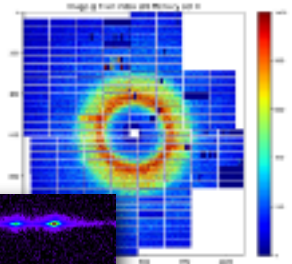

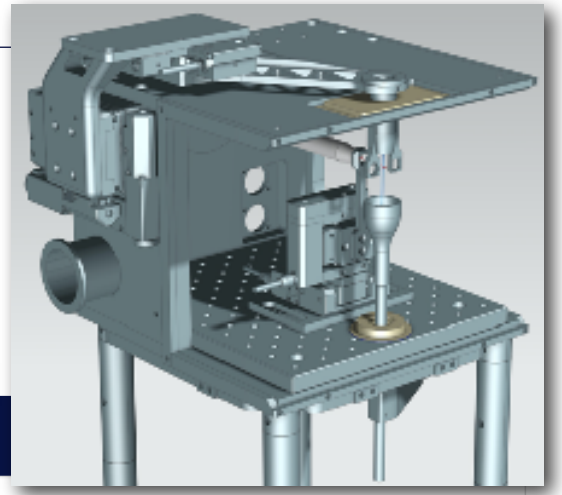

Pump laser parameters

Wavelength range	490 nm - 800 nm (TOPAS OPA) 800/400/267 nm (Harmonics)
Pulse duration	< 60 fs
Typical pulse energies @ 1.1 MHz repetition rate	> 10 uJ for TOPAS and xHG at 267 nm, 40 uJ and 120 uJ at 400 nm and 800 nm, correspondingly
Focus size	100 um
Polarisation	Linear vertical or horizontal

X-ray parameters

Incident X-ray energies	7, 9.3 or 12.5 keV
Repetition rate	100-500 kHz
Typical pulse energies	> 2 mJ
Focus size	10 um
Polarisation	Linear horizontal

Sample geometry details

Liquid jet diameter	100 um
Sample volume	>25 mL
Sample Pump	HPLC
Environment	He atmosphere
Sample-Scattering detector distance	> 10 cm
Parallel X-ray emission measurements	Cr Kα/Kβ/VtC Fe Kα/Kβ Co Kα/Kβ Fe Kα and Co Kα Ni Kα/Kβ/VtC Others possible, please contact FXE for details
Von Hamos Bragg angle range	Vertical 70 – 83°
Wide-angle scattering range	0.5 – 7 Å-1 (photon energy dependent)
Experimental geometry	Quasi-collinear with Incidence angle between the laser and X-ray beams: 15 degrees or 3 degrees, in horizontal plane.

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