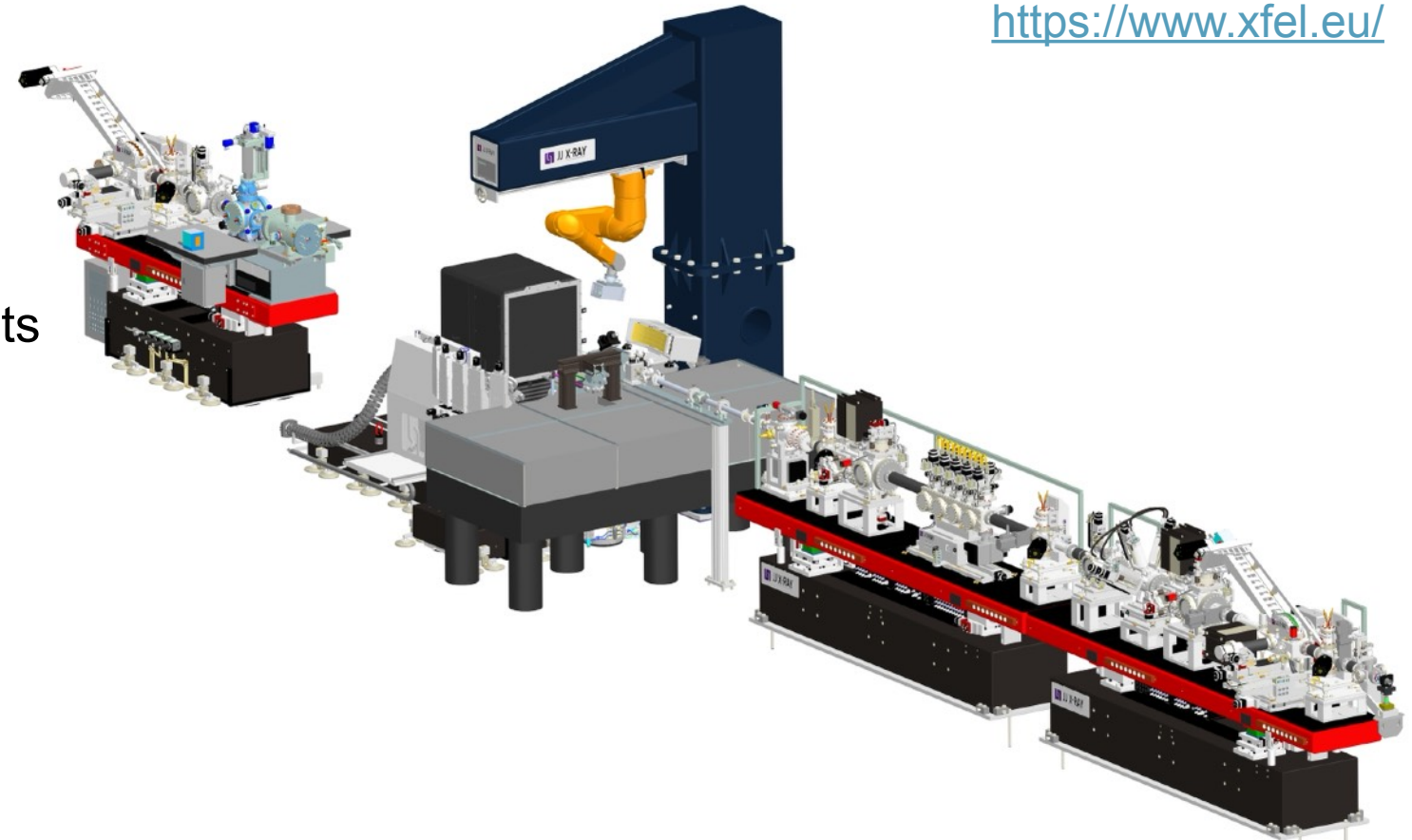


# Run 12 @ FXE Town Hall Update

Chris Milne on behalf of FXE

European XFEL  
FXE – Femtosecond X-ray Experiments



<https://www.xfel.eu/>

**EuXFEL Town Hall**  
10.10.2023

# FXE: Femtosecond Hard X-ray Experiments

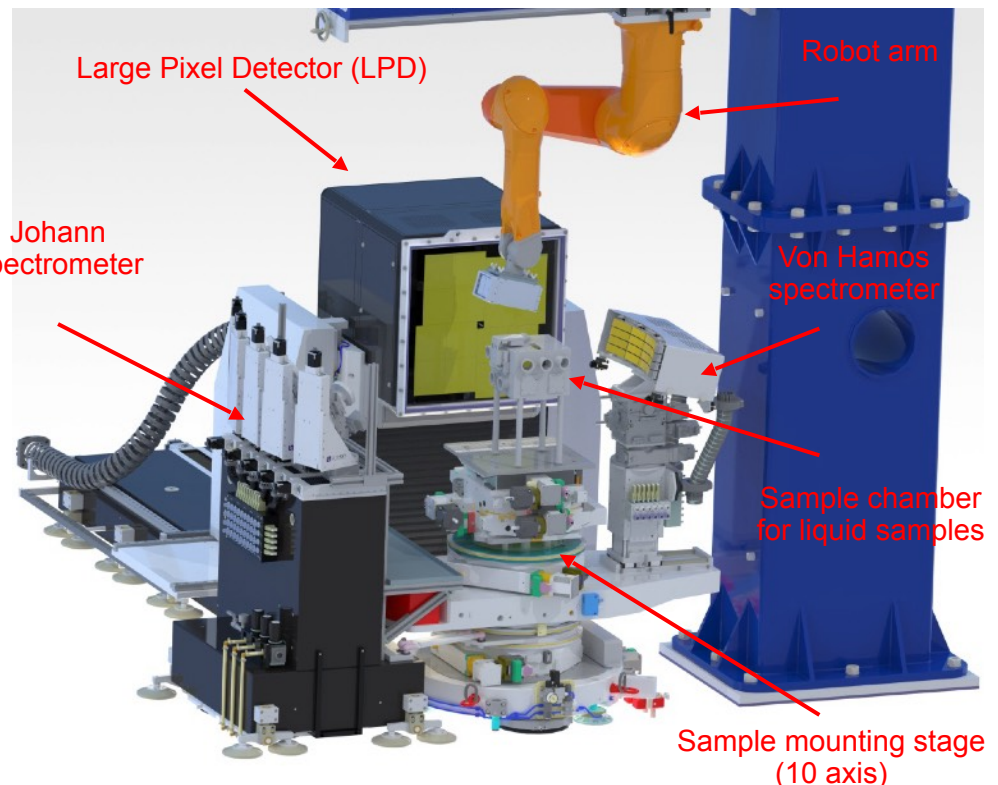
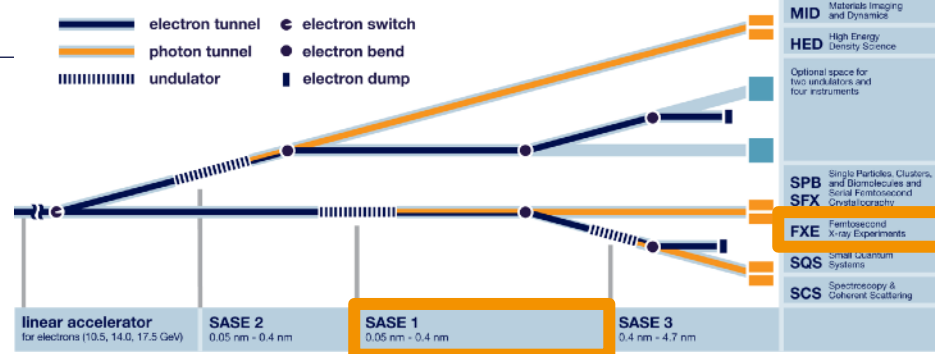
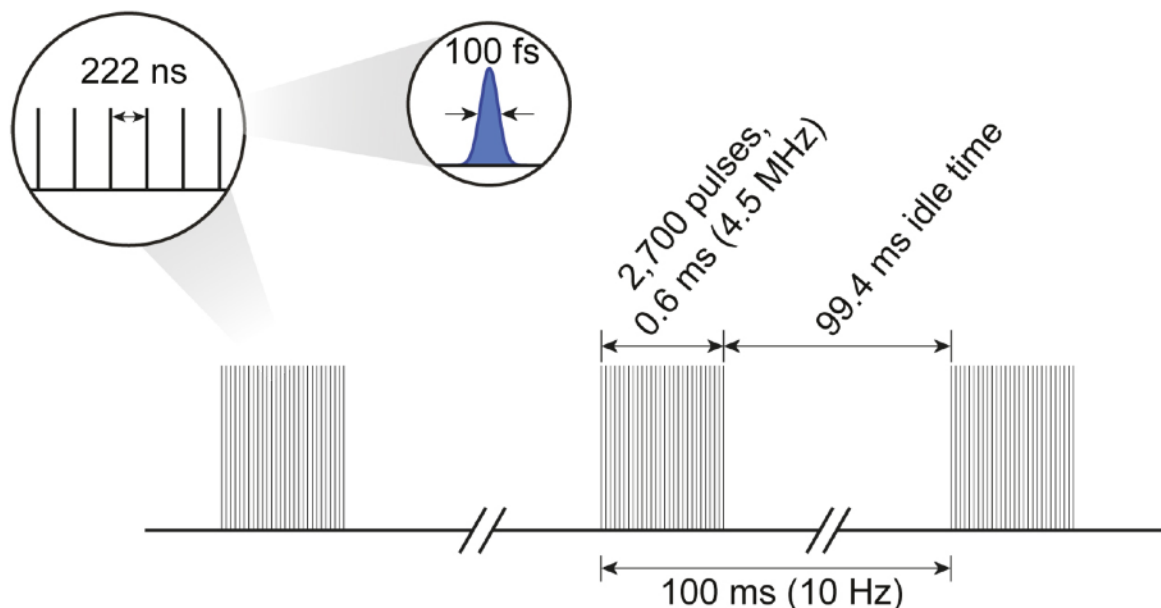
A Suite of **Simultaneous** X-ray Tools & Laser Excitation Sources

**Single-shot** dispersive resonant and non-resonant **XES**: von Hamos

**Wide(Small)-angle X-ray Scattering** and **X-ray Diffraction**: Large Pixel Detector (LPD) and Jungfrau

**X-ray absorption spectroscopy** (5-20 keV): **scanning** (Si(111) 4-bounce mono) and **single-shot** (Spectrum analyzer)

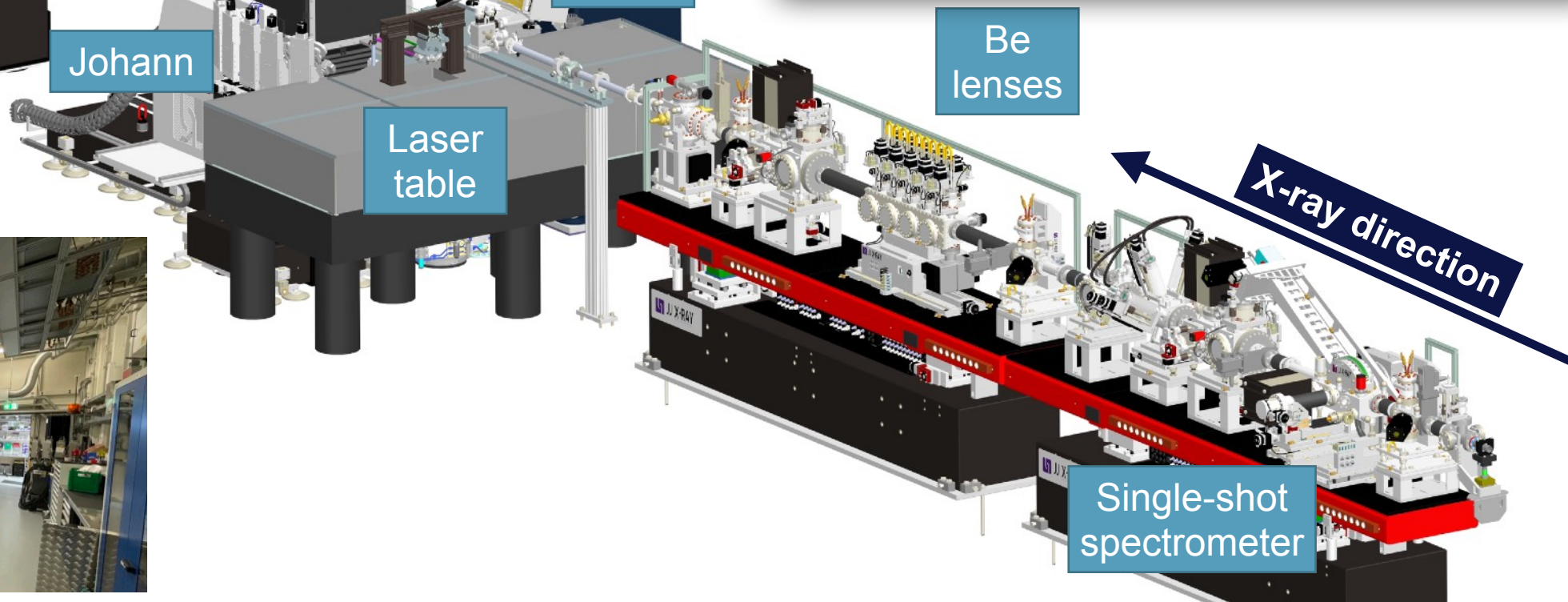
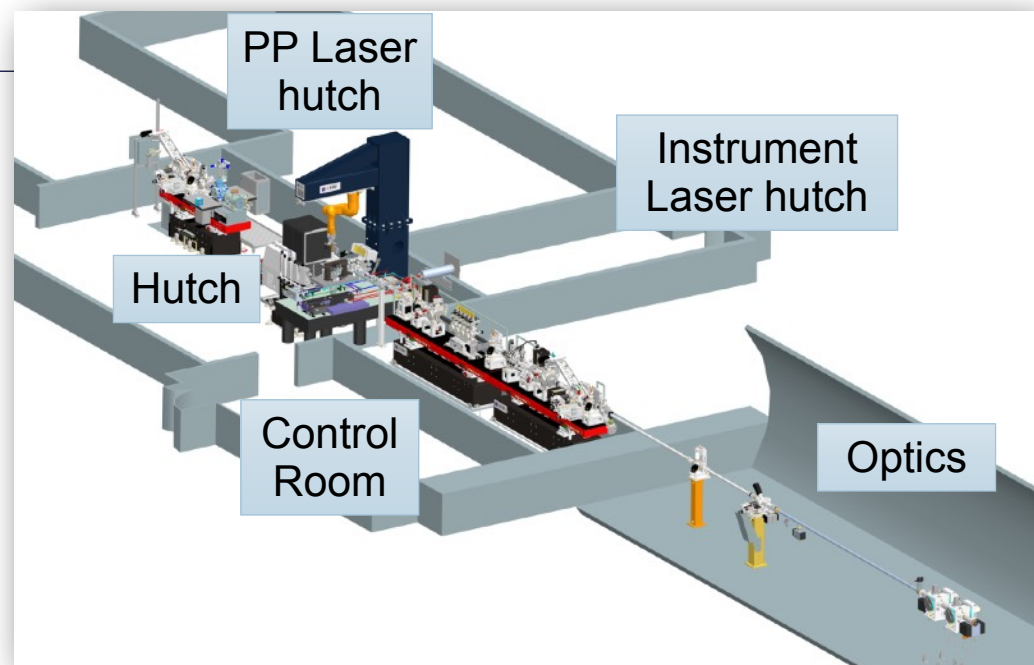
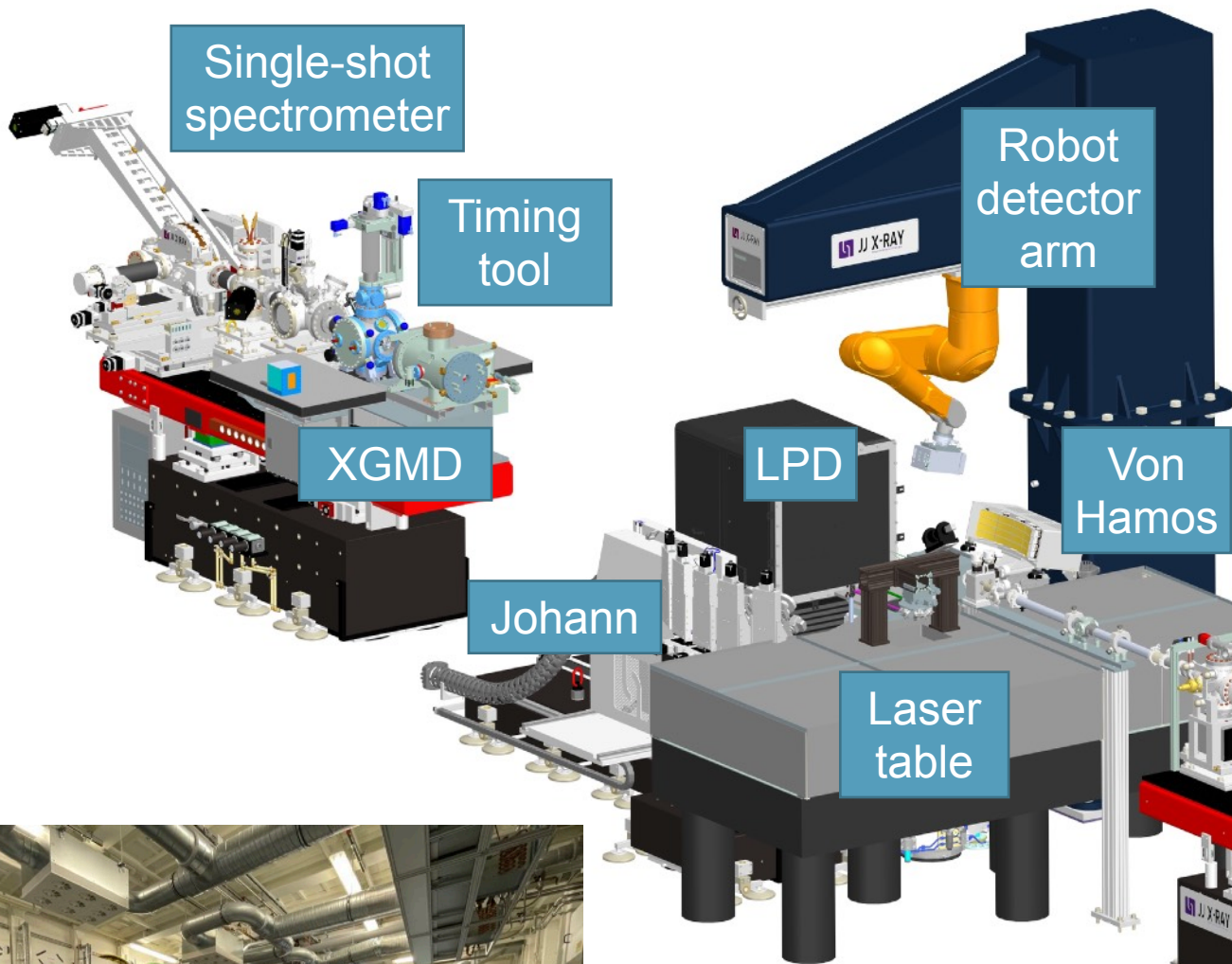
**Scanning** resonant and non-resonant **XES** (RXES): Johann spectrometer



“Scientific instrument Femtosecond X-ray Experiments (FXE): instrumentation and baseline experimental capabilities” A. Galler , et al., *J. Synch. Rad.*, 26, 1432 (2019)

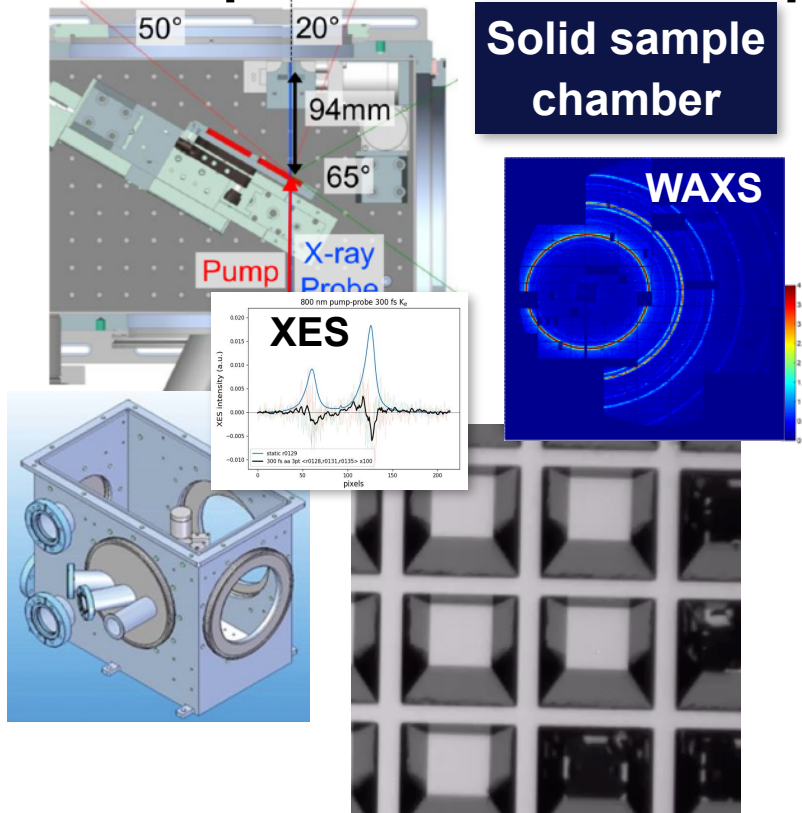
“Ultrafast X-ray Photochemistry at European XFEL: Capabilities of the Femtosecond X-ray Experiments (FXE) Instrument” D. Khakhulin, et al., *Appl. Sci.*, 10, 995 (2020)



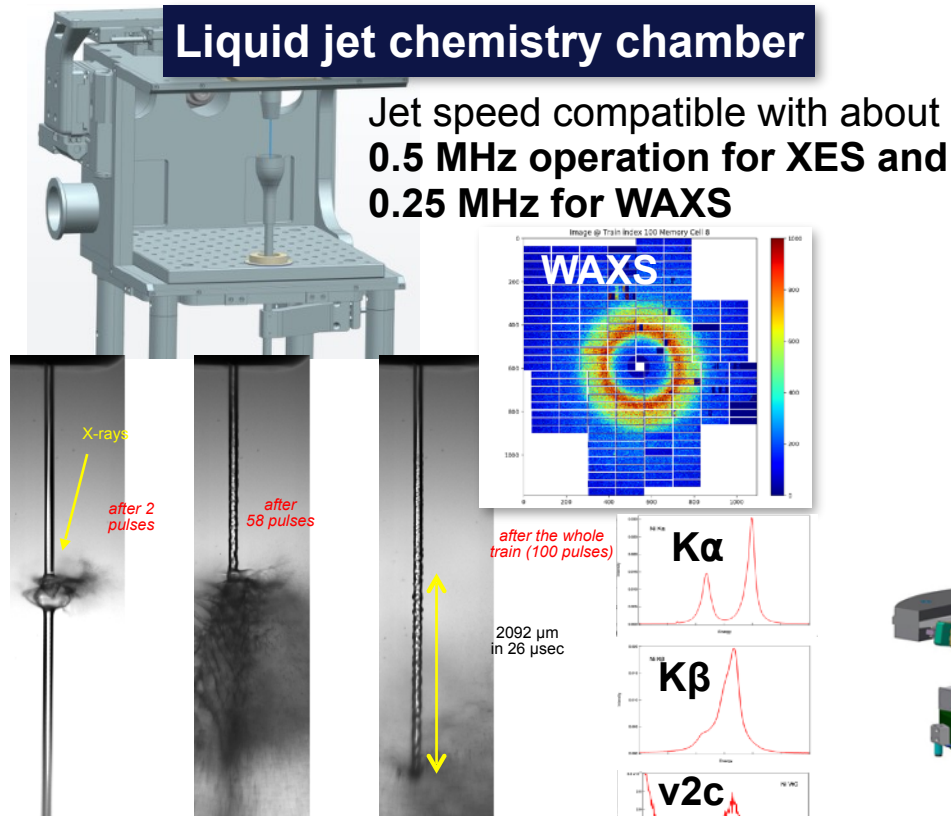


# Sample environment: Liquid & Solid state experiments

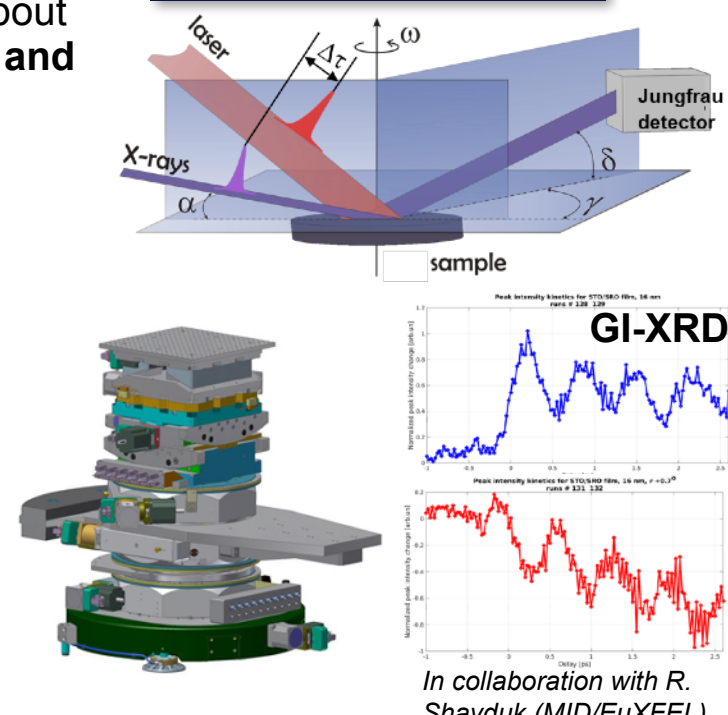
## Solid sample chamber



## Liquid jet chemistry chamber



## Single-crystal grazing-incidence diffraction



- Vacuum environment (1e-5 mbar)
  - X-ray probe in transmission geometry
  - Up to 15k samples accessible per filling/evacuation
  - Parallel X-ray emission and scattering compatible
  - Diffraction up to 8.8 Å<sup>-1</sup> at 16.5 keV and  $2\theta_{max}=63^\circ$
- courtesy of P. Zalden ([peter.zalden@xfel.eu](mailto:peter.zalden@xfel.eu))

- He environment
  - Open on 3 sides (XES, XAS, WAXS compatible)
  - Parallel UV-Vis flow loop to monitor sample
  - Jet diameter 25-200 μm
  - Bragg angle range 67-83°
  - WAXS maximum Q up to 10 Å<sup>-1</sup>
- courtesy of F. Lima ([frederico.lima@xfel.eu](mailto:frederico.lima@xfel.eu))

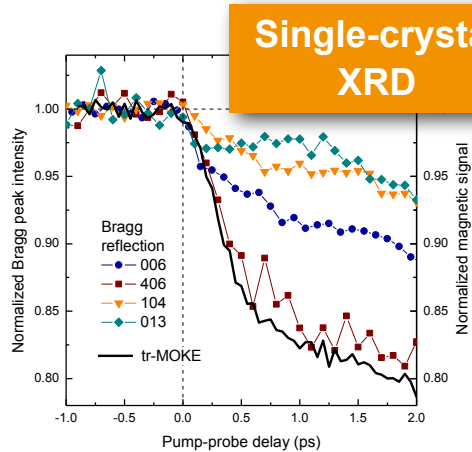
- Vertical and horizontal geometry
  - Grazing and symmetric Bragg diffraction
  - Flexible tracking of Bragg peak with detector on Robot arm
  - Cooling and heating of samples supported
  - Compatible with von Hamos XES for vertical sample geometry
- courtesy of D. Khakhulin ([dmitry.khakhulin@xfel.eu](mailto:dmitry.khakhulin@xfel.eu))



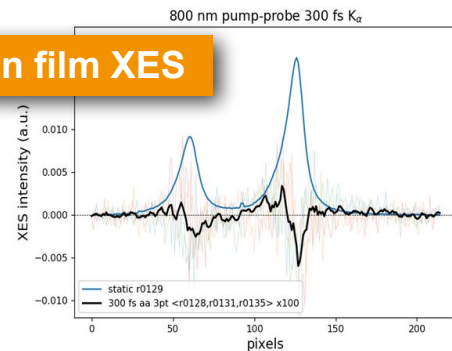
# Scientific Scope of FFE: Measuring ultrafast dynamics with hard X-rays

## Ultrafast solid-state dynamics

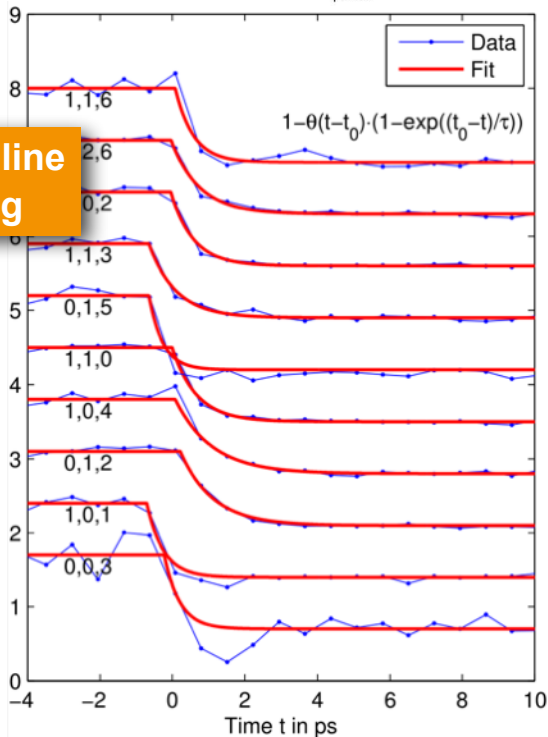
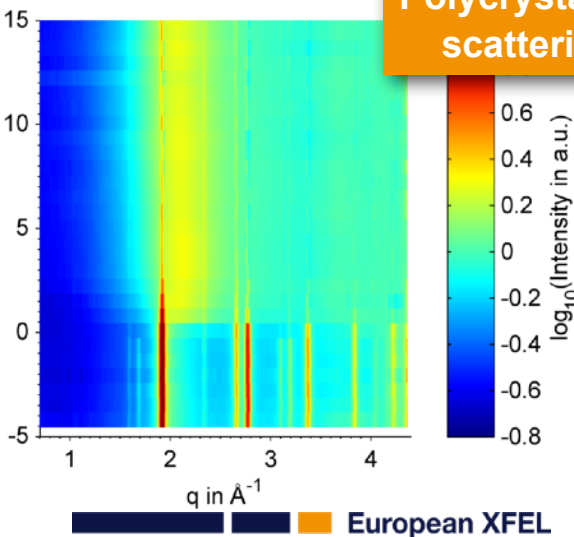
Single-crystal XRD



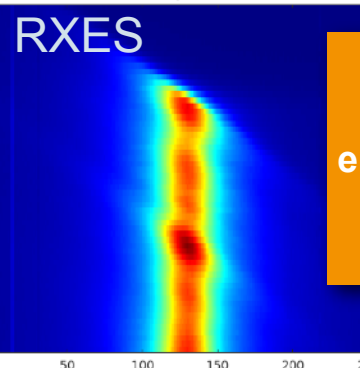
Thin film XES



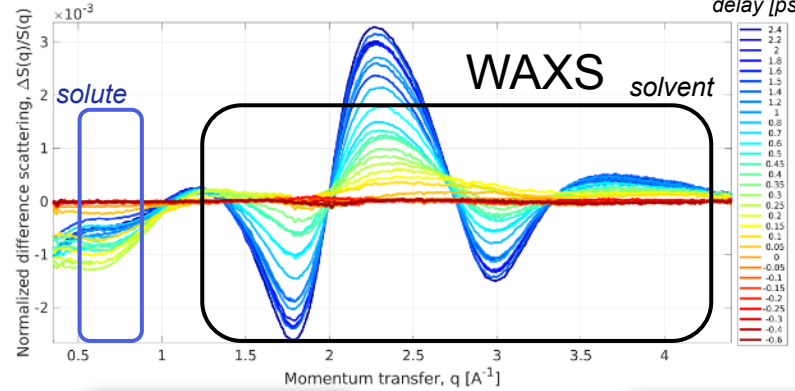
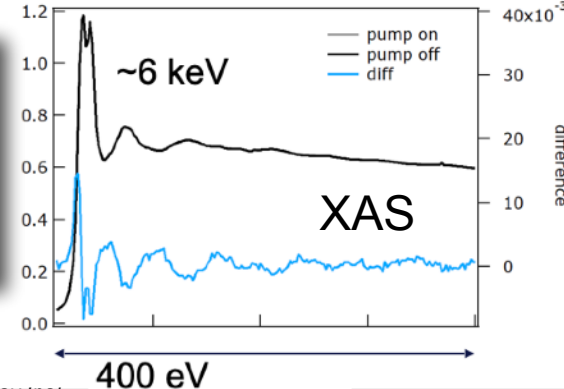
Polycrystalline scattering



## Ultrafast (bio)chemical dynamics

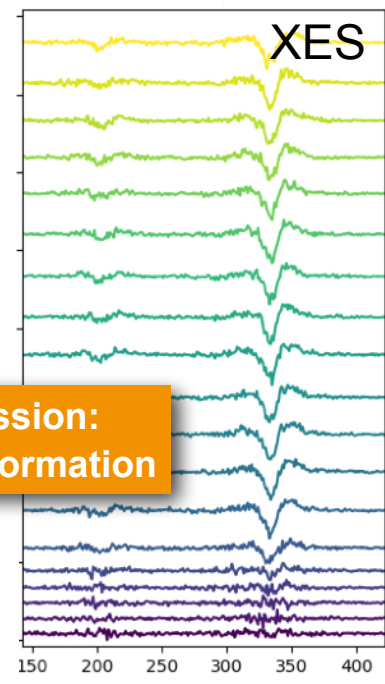
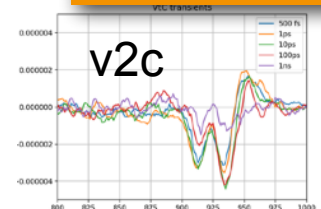


X-ray absorption: electronic and structural information



Scattering: structural information

X-ray emission: electronic information



# FXE Group Members

## Engineering team



Martin Knoll

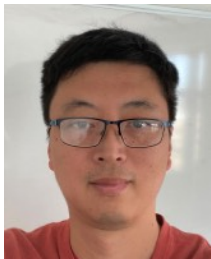


Paul Frankenberger



Siti Heder

## Postdocs



Han Xu



Doriana Vinci



Hao Wang



Diana Bregenholt  
Jakobsen

## Leading Scientist



Chris Milne

## PhD students



Sharmistha Paul Dutta

## Joint PhD students

- Tobias Eklund (Mainz)
- Nodoka Hara (Camerino)
- Nupur Khatu (Venice)
- Juan Hidalgo (IMDEA)

## Scientists



Dmitry Khakhulin



Frederico Alves Lima



Mykola Biednov



Yohei Uemura



Peter Zalden



Yifeng Jiang



Fernando Ardana Lamas



Xinchao Huang

## Detector Scientist



Hazem Yousef

## Administrative Support



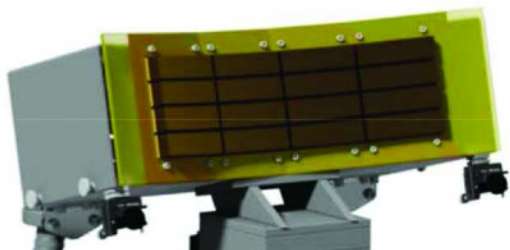
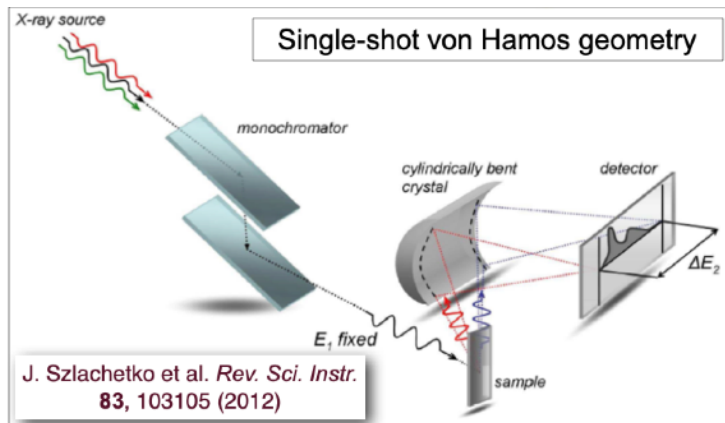
Maria Peter



# FXE Update

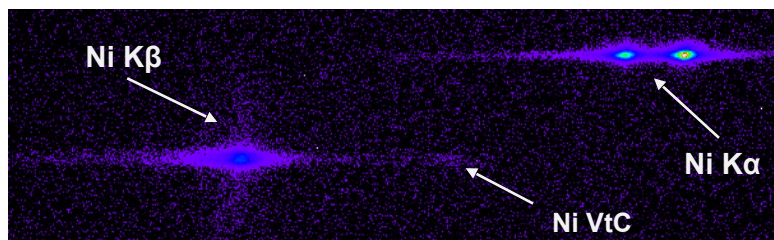
# X-ray Spectrometers

## von Hámos



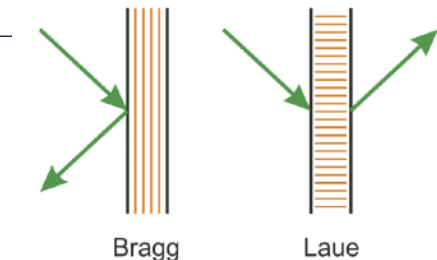
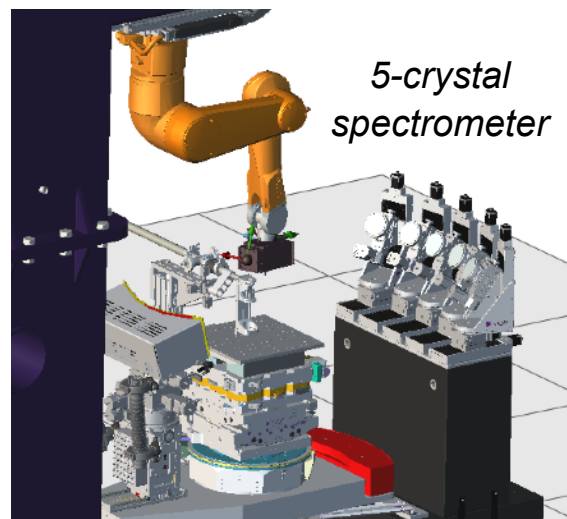
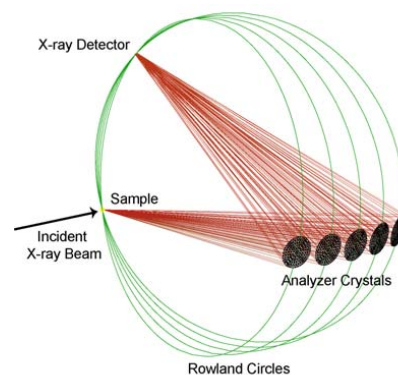
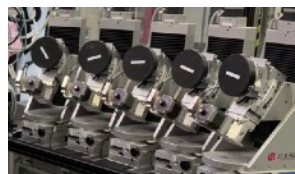
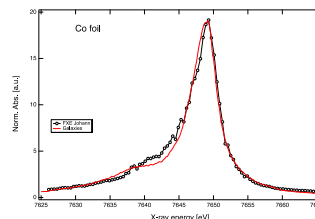
16-crystal spectrometer

- Dispersive
- Single-shot
- Requires 2D detector
- Bragg

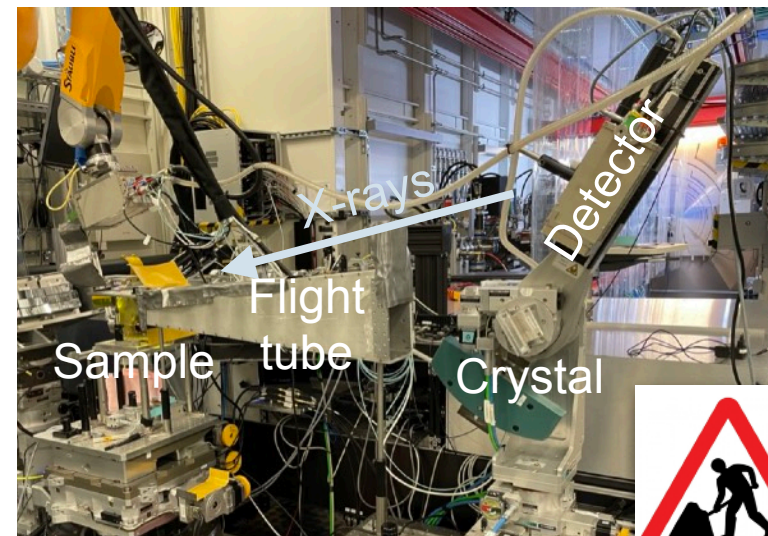


## Johann

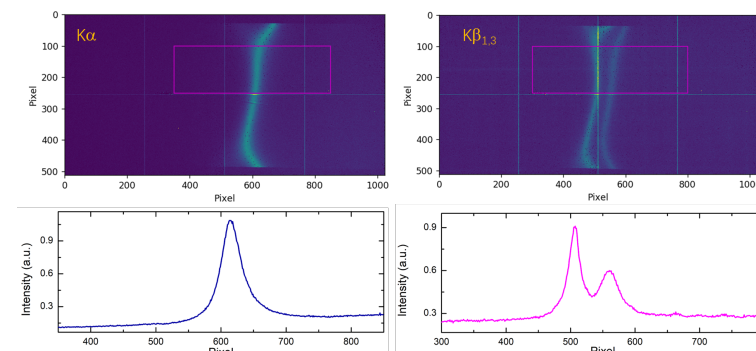
- Scanning
- Can use 0D or 2D detector
- Bragg



## DuMond

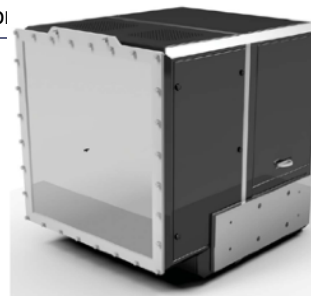


- Scanning
- Requires 2D detector
- Laue
- >15 keV





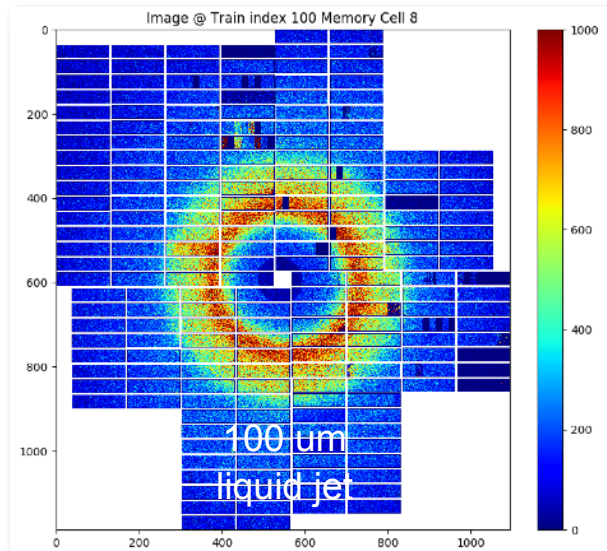
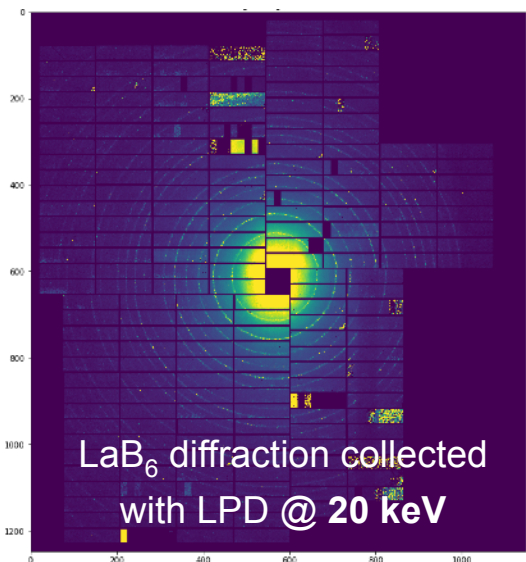
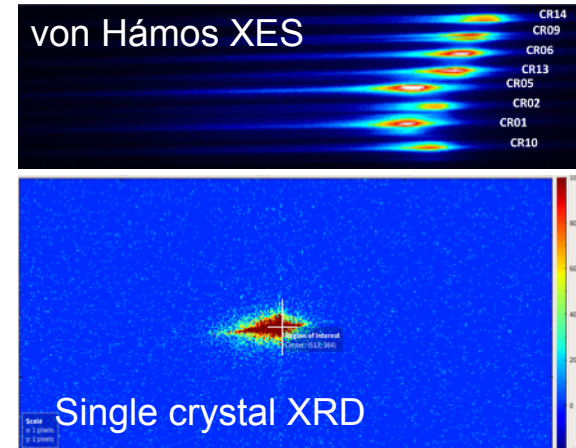
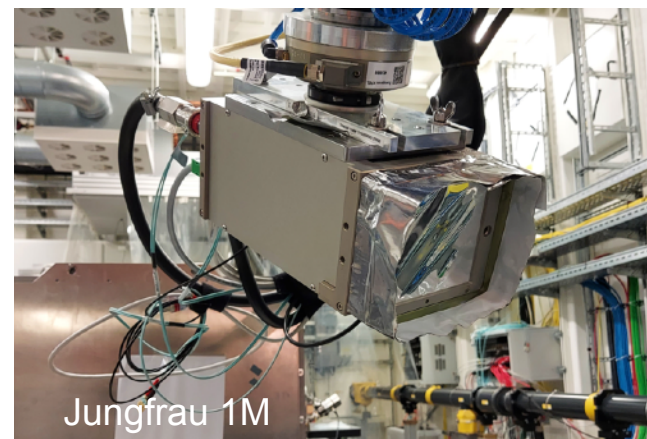
# 2D X-ray detectors @ FXE



## Large Pixel Detector

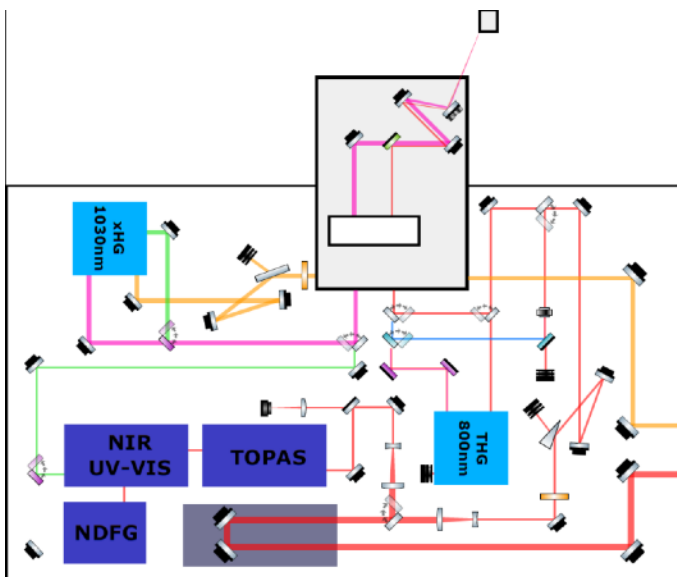
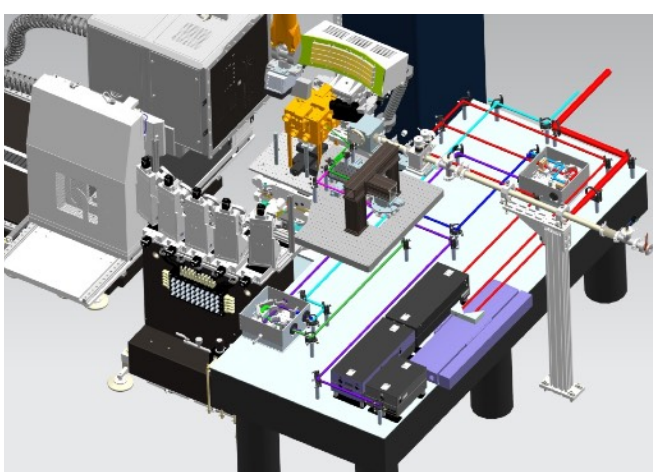
## Jungfrau

- LPD built by the Rutherford Appleton Laboratory for the European XFEL
- 1 Megapixel** – 500µm pixels
- 4.5 MHz frame rate**
- High dynamic range**, 1 to  $1 \times 10^5$  photons per pixel per pulse. Using **parallel gain stages** (1x, 10x, 100x)
- High energy sensitivity** – 500µm thick Si sensor
- 512 (510) frame memory depth** continuously stores all three gains, overwriting whenever a veto is received

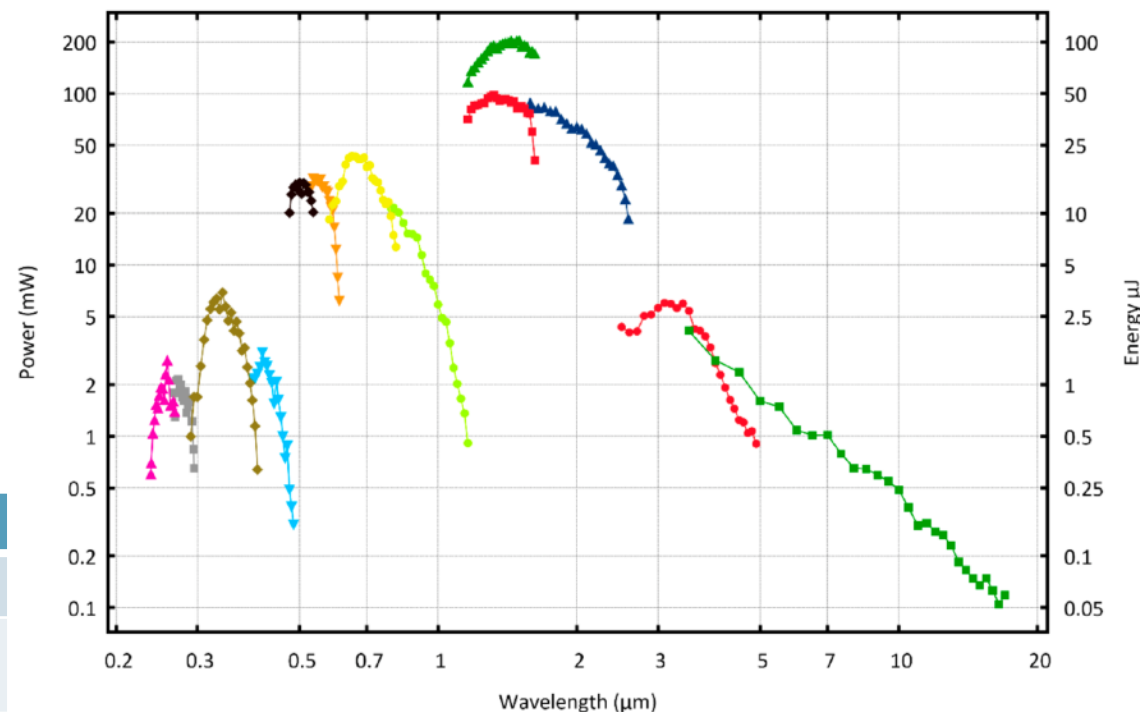


- Jungfrau built by the **Paul Scherrer Institute**
- 500 kpixel** per module (FXE has a 500k and 1M)
- 10 Hz** operation or **16-cell burst mode** (160 Hz)
- High dynamic range**, 1 to  $1 \times 10^5$  photons per pixel per pulse. Using **gain switching**
- Low noise:** < 2 keV single-photon sensitivity
- 75 µm pixels**

# Optical excitation schemes and conditions



- DF1-SIG
- DF2-SIG
- ▲ IDL
- ▼ SF-IDL
- ◆ SF-SIG
- SH-IDL
- SH-SF-IDL
- ▲ SH-SF-SIG
- ▼ SH-SH-IDL
- ◆ SH-SH-SIG
- SH-SIG
- SIG
- ▲ SIG+IDL



Parameter	Pump-probe system 1	Pump-probe system 2
Fundamental wavelength	800 nm	1030 nm
Pulse rep. rate.	282 kHz (1.1, 4.5 MHz)	4.5 MHz
Pulse energy	800 μJ (200 μJ at 1.1 MHz)	1 mJ (40 mJ at 100 kHz)
Pulse duration (FWHM)	15 fs / 50 fs	800 fs
Frequency conversion	SHG, THG, OPA (50 fs)	SHG, THG, FHG
OPA wavelength range *	240 nm – 15000 nm *	N/A



**Topas OPA installed** and output commissioned, used successfully for in-house experiment 12.2022



**THz source** developed in laser lab, next step is to install in the X-ray hutch (LAS, SCS)



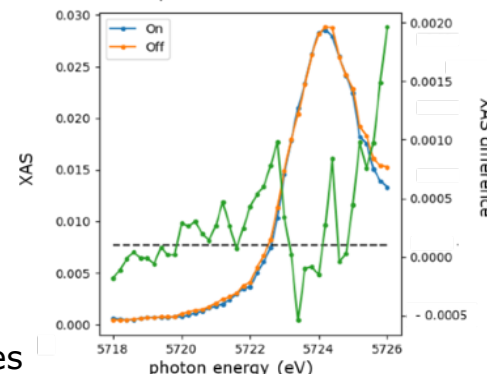
# (Resonant) X-ray absorption spectroscopy and scanning the mono

**EXPERIMENT 3435**  
**FXE: Structure and electronic properties of excited states in CeO<sub>2</sub>**

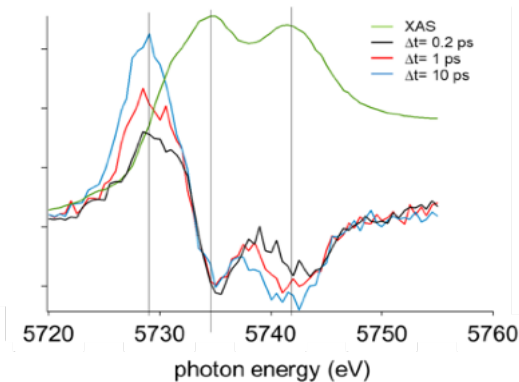


Main proposer: Paola Luches  
 Local contact: Yifeng Jiang

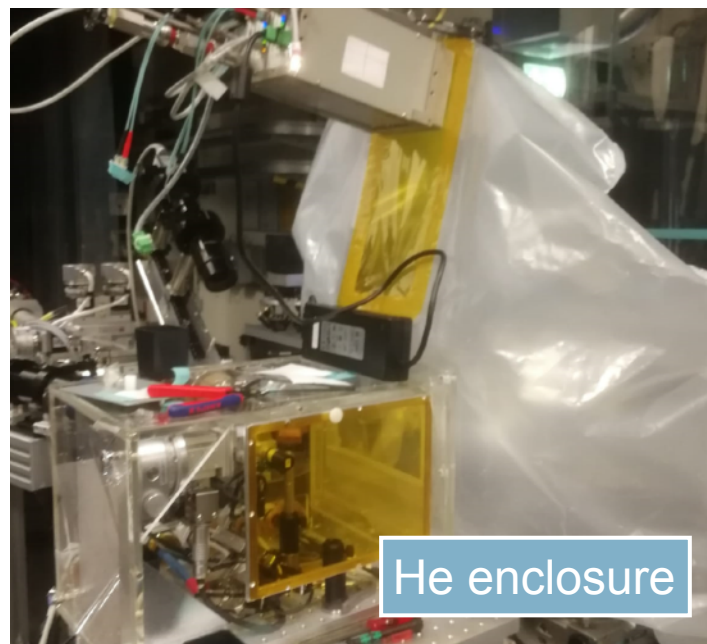
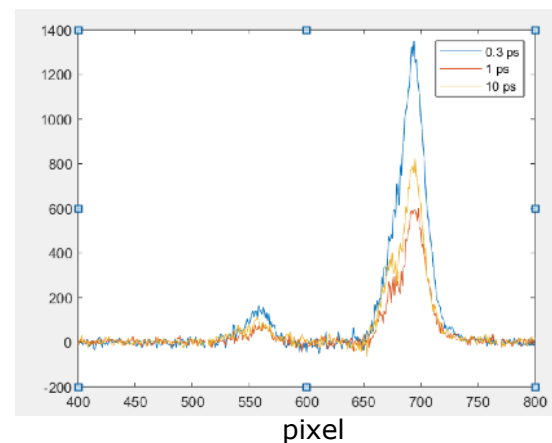
pump-probe HERFD-XAS at pre-edge  $\Delta t = 1$  ps



p-p XAS at different delay times

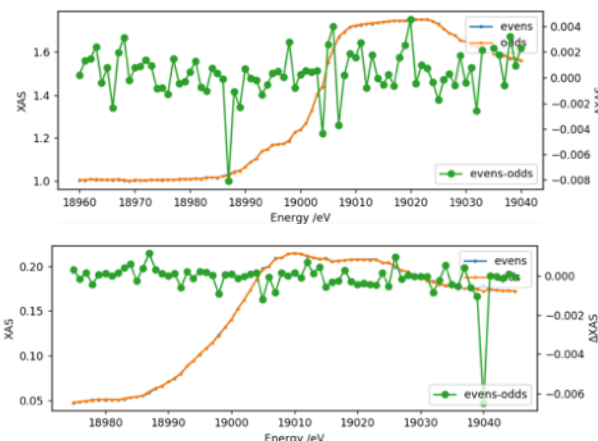


Ce L $\alpha$  RXES at different delay times



He enclosure

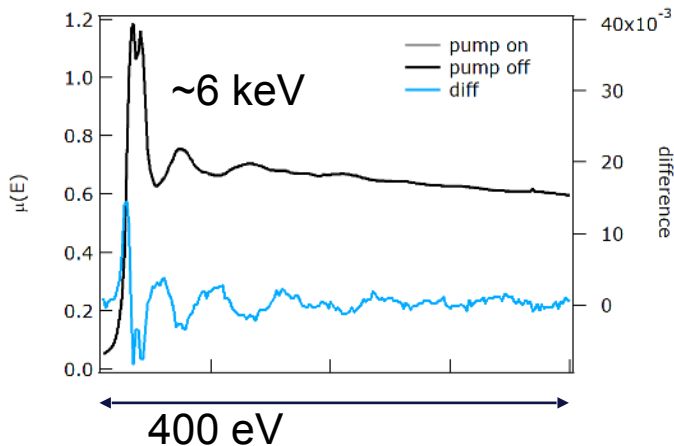
Mono and XAS capability at 19 keV (niobium K-edge)



Nb<sub>2</sub>O<sub>5</sub> thin film. ~10 mins.

NbO<sub>2</sub> thin film. ~10 mins.

- Thin film targets
- Ideal for low E<sub>ph</sub> spectroscopy (Ti, V, Cr K edges)
- tr-EXAFS possible
- Simultaneous diffraction
- 20 pulses/train (94 kHz)
- He enclosure works for low-background measurements



Peter

Yohei

Yifeng

- Scanning works well
- Setup needs to be checked carefully (I<sub>zero</sub> signal levels, mono throughput etc.)
- Reliable over the week (e.g. mono in/out)

## Call 12: Contact us with any questions or for more details



### Email:

[christopher.milne@xfel.eu](mailto:christopher.milne@xfel.eu)

OR

[fxe-support@xfel.eu](mailto:fxe-support@xfel.eu)

[https://www.xfel.eu/  
facility/instruments/fxe/](https://www.xfel.eu/facility/instruments/fxe/)

- 100 fs time resolution
- X-rays from 4.6-20 keV
- Pump laser from 240 nm to 2  $\mu$ m
- Liquids, solids, thin films, GDVN
- X-scattering, diffraction and spectroscopy (limited SFX)