

Small Quantum Systems (SQS)

M. Meyer
SQS scientific instrument

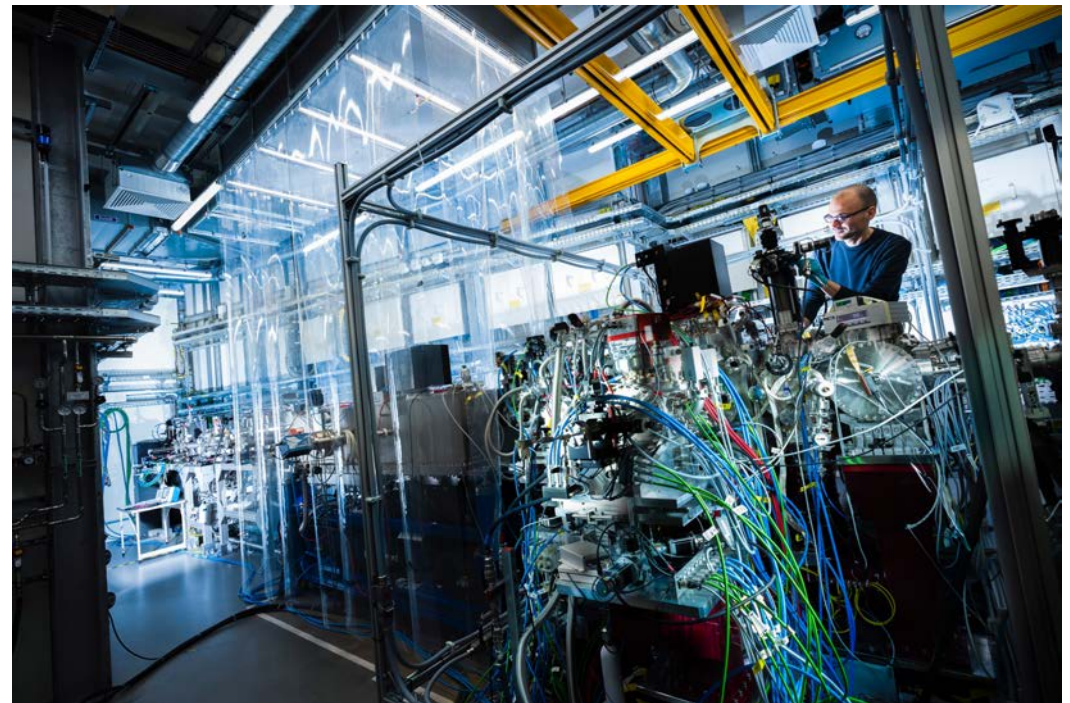
Townhall meeting, November 25, 2020



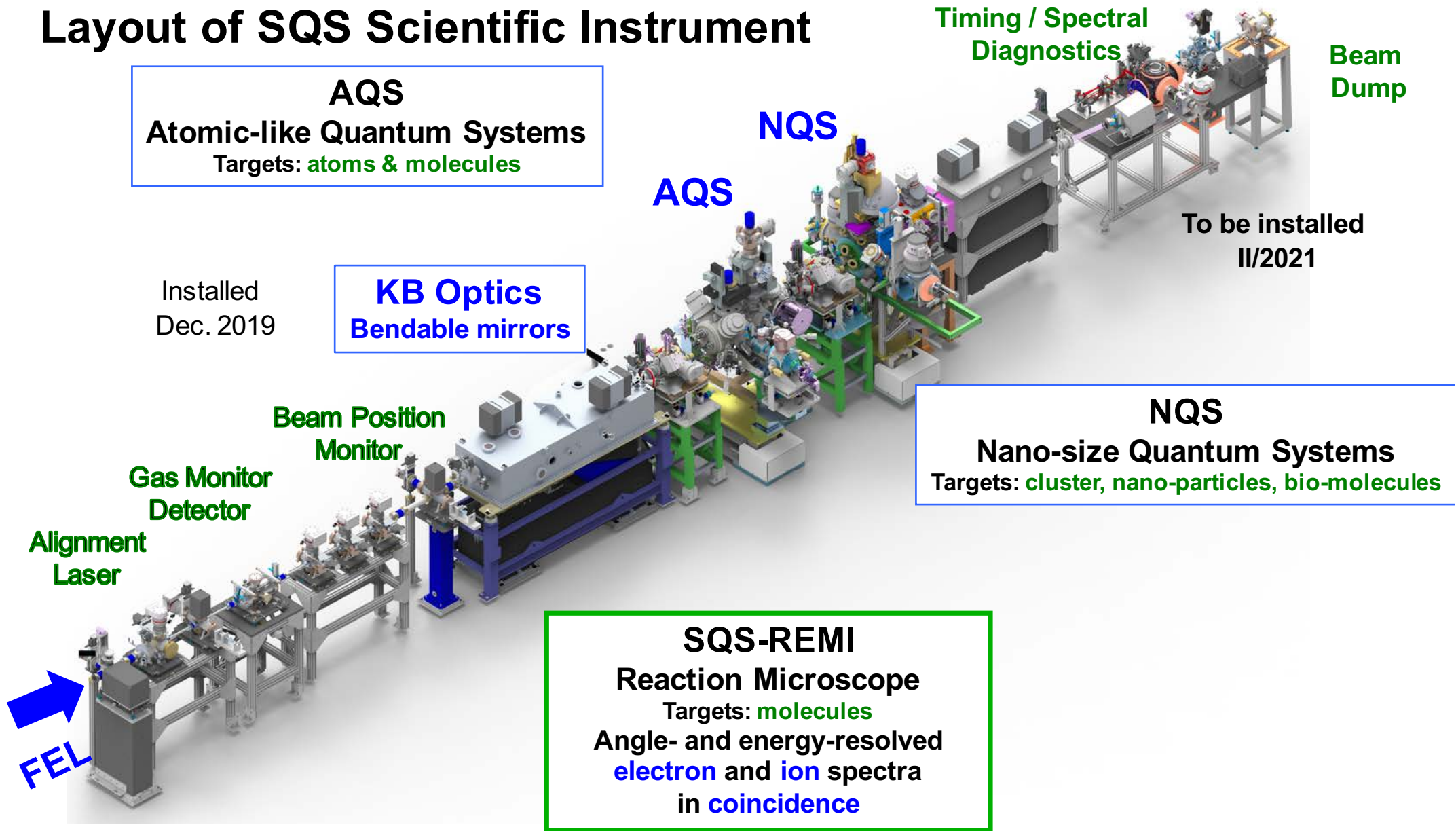
Gas Phase Samples

Soft X-Rays (500 – 3000 eV)

- Study of non-linear phenomena
- Time-resolved investigations
- Coherent Diffraction Imaging



Layout of SQS Scientific Instrument



AQS
Atomic-like Quantum Systems
Targets: atoms & molecules

Installed
Dec. 2019

KB Optics
Bendable mirrors

AQS

NQS

Timing / Spectral
Diagnostics

Beam
Dump

To be installed
II/2021

NQS
Nano-size Quantum Systems
Targets: cluster, nano-particles, bio-molecules

SQS-REMI
Reaction Microscope
Targets: molecules
Angle- and energy-resolved
electron and ion spectra
in coincidence

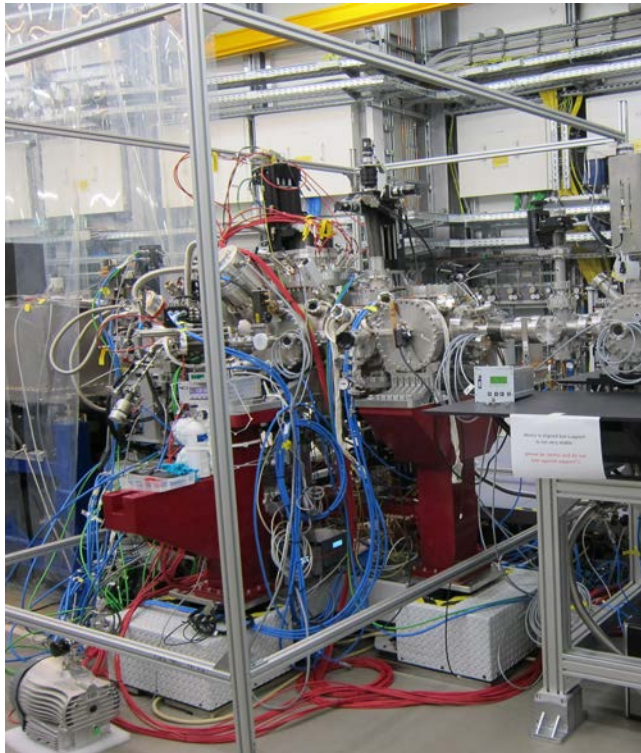
SASE3 Soft X-Ray radiation parameters

Photon Beam Parameter	Unit	Operation 2021 RUN7
Electron energy	GeV	11.5, 14, 16.5
Photon energy	eV	500 – 1500 (@ 11.5 GeV) 660 – 2500 (@ 14 GeV) 920 – 3000 (@ 16.5 GeV) fully tunable !!
Spectral Bandwidth	%	~1% in SASE mode or monochromatized (resolution: 3000 @ 870 eV)
Pulse duration (calc.)	fs	25 (FWHM)
Pulse energy	mJ	up to 8 (depending on photon energy)
Number of pulses		up to 400 per train (@ 2.2 MHz)
Polarization		linear (horizontal)
Focus size	μm	1 – 2 (@ F1) 2 – 3 (@ F2)

AQS experimental chamber

Targets: atoms & molecules

Detection: electrons, ions



Sample delivery:

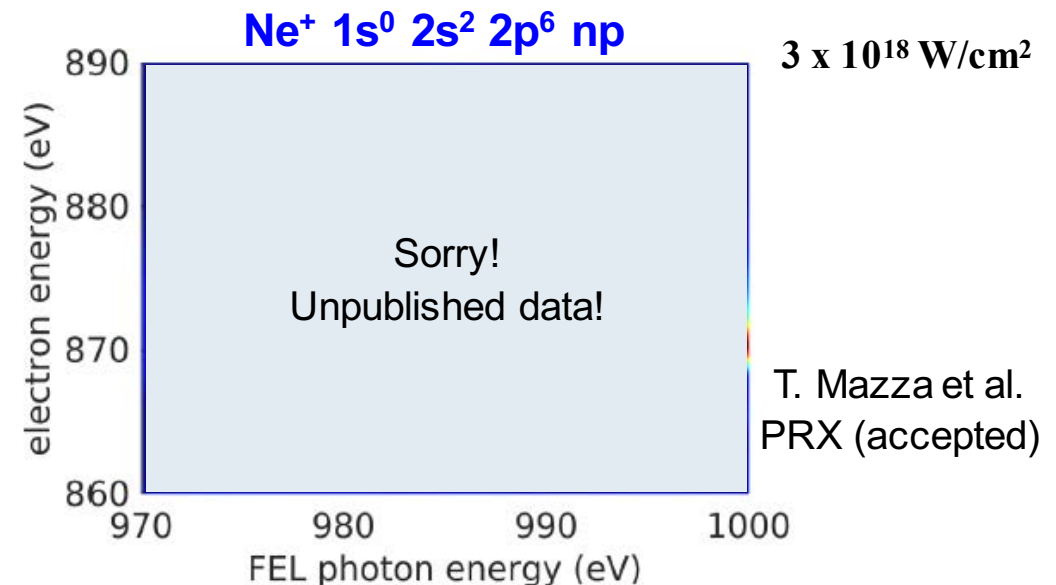
- Supersonic molecular beam
- Effusive gas jet (capillary)

European XFEL

AQS: Atomic-like Quantum Systems

- **6 eTOFs** High energy resolution
Non-dipole studies
- **ionTOF** High mass resolution
- **VMI** Angular distribution
e / ion – coincidences
- **MBES** High electron acceptance
e-e, e-ion coincidences

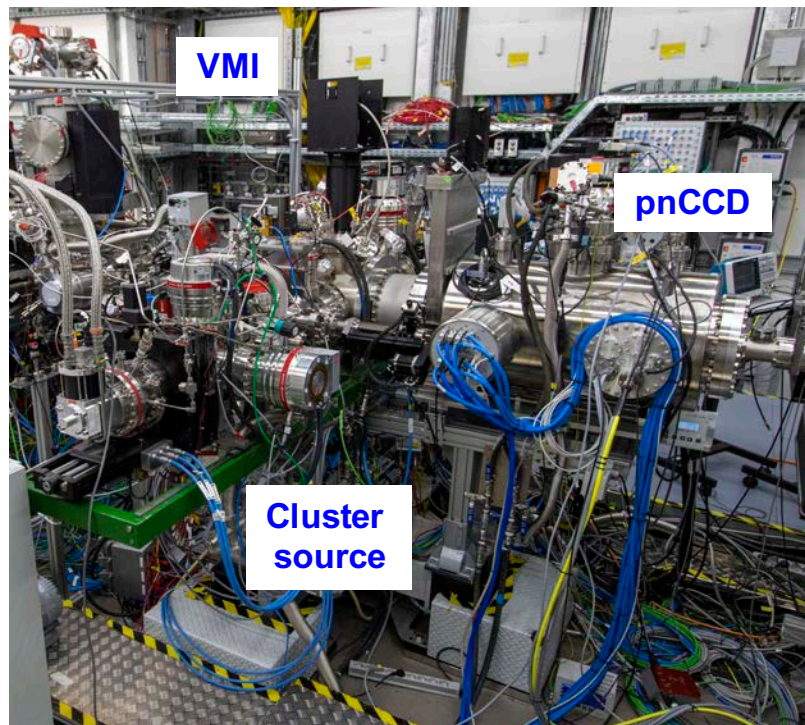
Example: Double Core Hole Resonances in Neon



NQS experimental chamber

Targets: Cluster, Nano-particles, bio-molecules

Detection: electrons, ions, photons



Sample delivery:

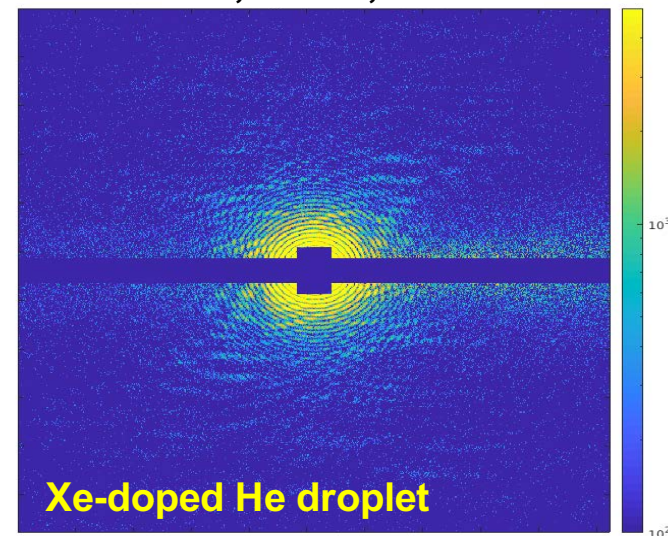
- Rare gas cluster / He-droplet source
- Aerosol source
- COMO set-up (J. Küpper / CFEL)

NQS: Nano-size Quantum Systems

- ionTOF Fragmentation products
- VMI Angular distribution
- Large area pixel detectors
 - Coherent diffraction imaging
 - pnCCD
 - DSSC

Example: Imaging of He droplets

5K, 20 bar, 500nm

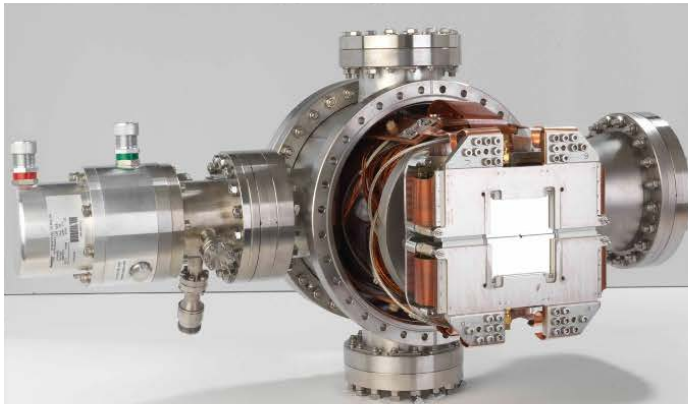


R. Tanyag,
D. Rupp et al.
(TU/MBI Berlin)

Single Particle Imaging at SQS

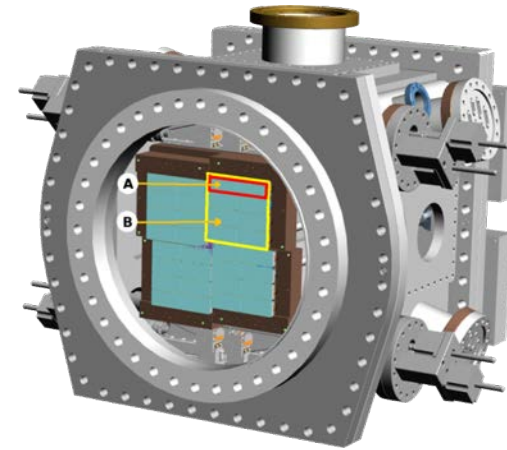
pnCCD detector

“Low Speed” Imagers for 10 Hz Applications



DSSC

High-repetition rate 1 Mpixel detector



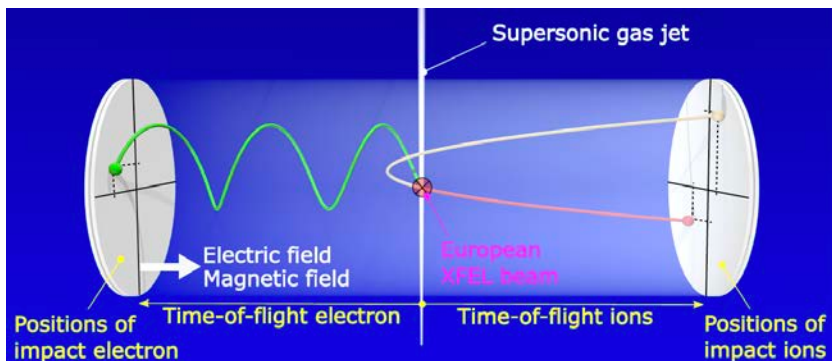
Parameter	pnCCD	Mini-SDD
Energy range	0.03 – 25 keV	0.5 – 6 keV
Detector size	78 x 78 mm ²	210 x 210 mm ²
Number of pixels	1024 x 1024	1024 x 1024
Sensor pixel size	~ 75 x 75 μm ²	~ 236 x 236 μm ²
Dynamic range	>6000 ph @ 1 keV	256 ph @ 1 keV
Frame rate	Up to 150 Hz	0.9 – 4.5 MHz
Read-out of frames	1 @ 10Hz	800 @ 10Hz
Vacuum conditions	< 10 ⁻⁸ mbar	10 ⁻⁷ mbar



SQS-REMI experimental chamber

Targets: molecules
Detection: electrons, ions

User contribution
 U. Frankfurt (R. Dörner et al.)



European XFEL

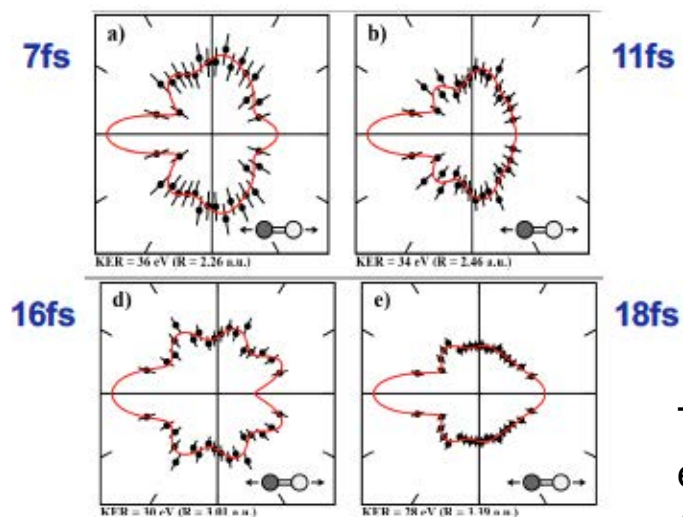
SQS-REMI Reaction Microscope

COLTRIMS set-up
 (Cold Target Recoil Ion Momentum Spectroscopy)

- Electron & Ion Momentum Imaging
- Coincidence Spectroscopy
- Coulomb Explosion Imaging

Example:
 Photoelectron diffraction imaging of O₂ break-up
 Kastirke et al., Phys. Rev. X 10, 021052 (2020)

electron – ion (O⁺/O³⁺) coincidences



T. Jahnke
 et al.
 (U. Frankfurt)

Time-resolved experiments

X-Ray - Optical Pump-Probe

Pump-Probe Laser (M. Lederer et al.)

< 20 fs, 800 nm, 0.2 mJ at 1.1MHz

< 20fs, 800 nm, 1 mJ at 188 kHz

SHG: 400 nm, 0.1 mJ, 30-50 fs

THG: 266 nm 0.06 mJ, <100 fs

Fiber Laser (SQS: P. Grychtol / D. Rivas)

< 300 fs, 1030 nm, 2 mJ at 112.5 kHz rep. rate

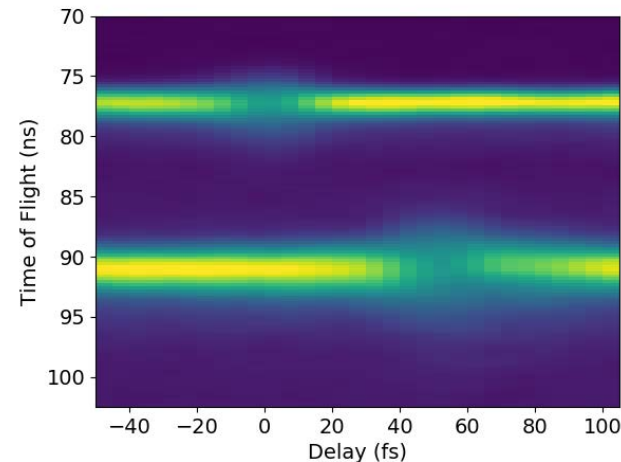
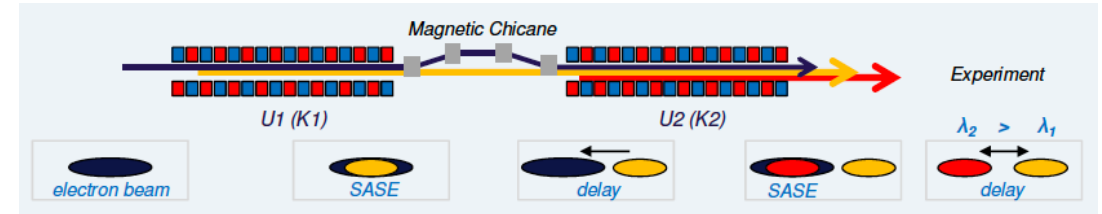
< 40 fs, 1030 nm, 1.35 mJ at 112.5 kHz rep. rate

Pulse Arrival Time Monitor

Synchronization < 20 fs

European XFEL

2-Color Pump Probe (2CPP) X-ray – X-ray Pump-Probe Magnetic chicane in SASE3 undulator



Electron spectra

C1s photolines

660eV and 698 eV

Delay 50 fs

(D. Rivas et al.)

Photon energy range: 500 – 1500 eV (→ 3000 eV)

Pulse energy: up to 300 - 500 μJ

Pulse duration: < 30 fs

Temporal delay: up to 1 ps

Operation in close collaboration
with S. Serkez & G. Geloni

RUN 7: July – November 2021

<https://www.xfel.eu/facility/instruments/sqs>

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REMI: Rebecca.Boll@xfel.eu

Laser: Patrik.Grychtol@xfel.eu and Daniel.Rivas@xfel.eu

**X-ray beam
transport:** Tommaso.Mazza@xfel.eu

or simply sqs@xfel.eu