Overview of the MID instrument

Ulrike Boesenberg
MID

Schenefeld, 2022-01-24

MID
Materials Imaging and Dynamics

mid-info@xfel.eu

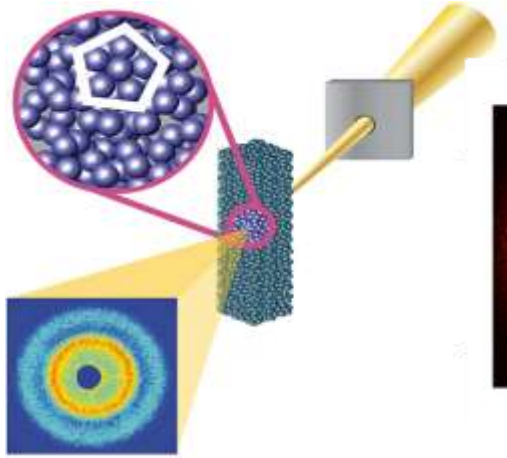
Torben Anderson
Gabriele Ansaldi
Alexander Bartmann
Ulrike Boesenberg
Felix Brausse
Bertram Friedrich
Jörg Hallmann
Karina Kazarian
Wei Lu
Anders Madsen
Johannes Möller
Maria Peter
Ilia Petrov***
Angel Rodriguez Fernandez
Andreas Schmidt**
Markus Scholz*
Roman Shayduk
Konstantin Sukharnikov**
Wenxin Wang****
Mohamed Youssef
Alexey Zozulya

* now at FLASH
** MID and HED
*** MID and X-ray Optics Group
****MID and DESY-FS-PETRA

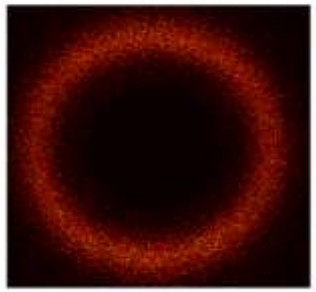
The MID instrument: it all started in 2009…

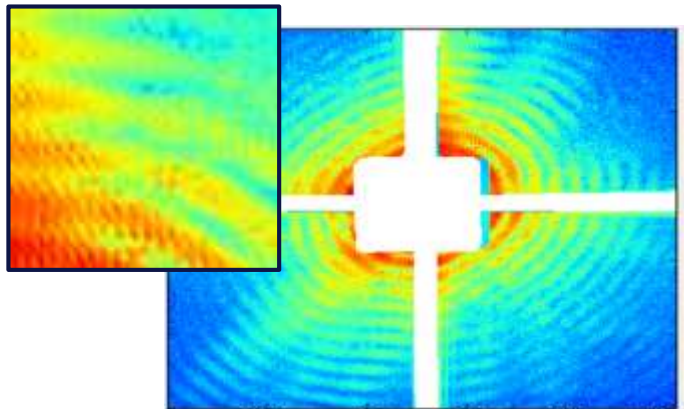
The Materials Imaging and Dynamics (MID) station aims at the investigation of nanosized **structure** and nanoscale **dynamics** using **coherent hard X-rays**. Applications to a **wide range of materials** from hard to soft condensed matter and biological structures are envisaged

(1st MID workshop, Oct 2009 @ ESRF, Grenoble)



XCCA

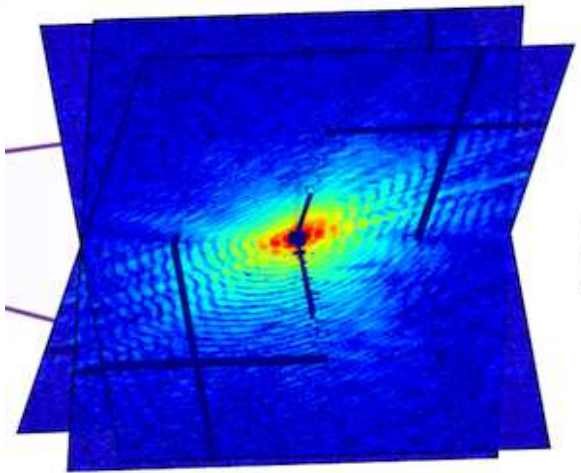




Holography

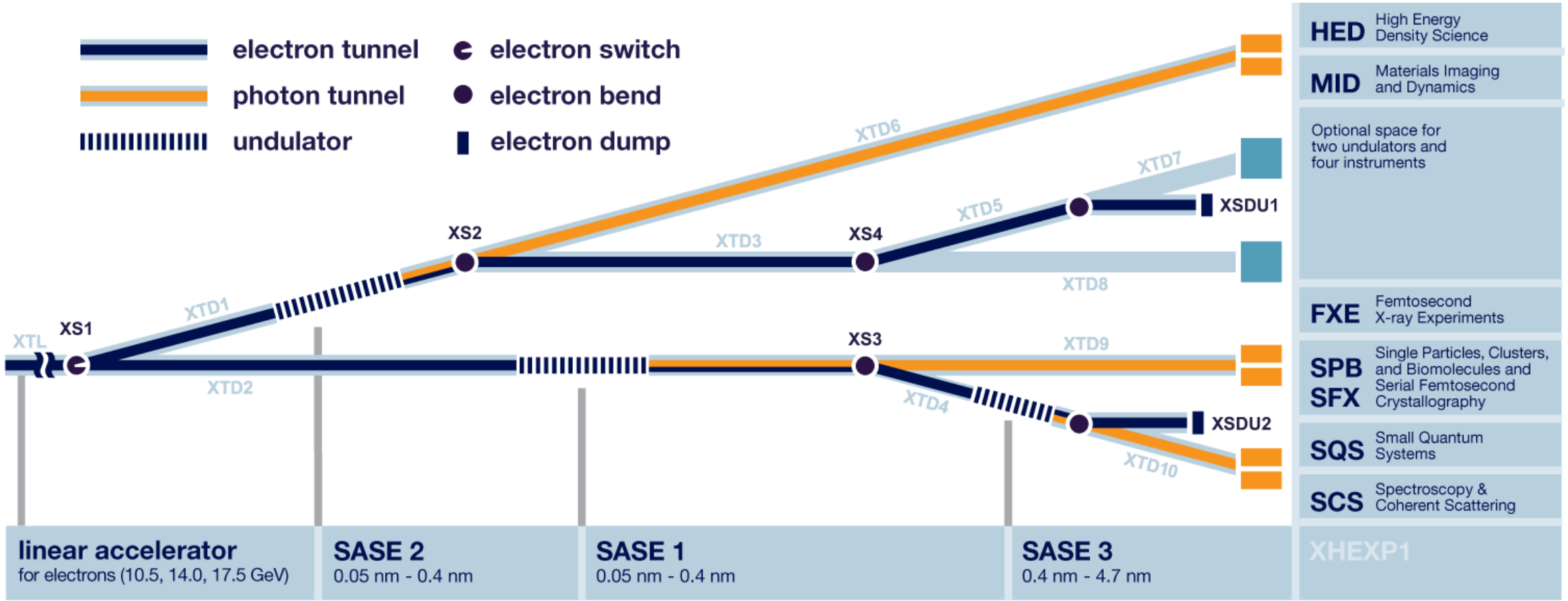
CDI

XPCS

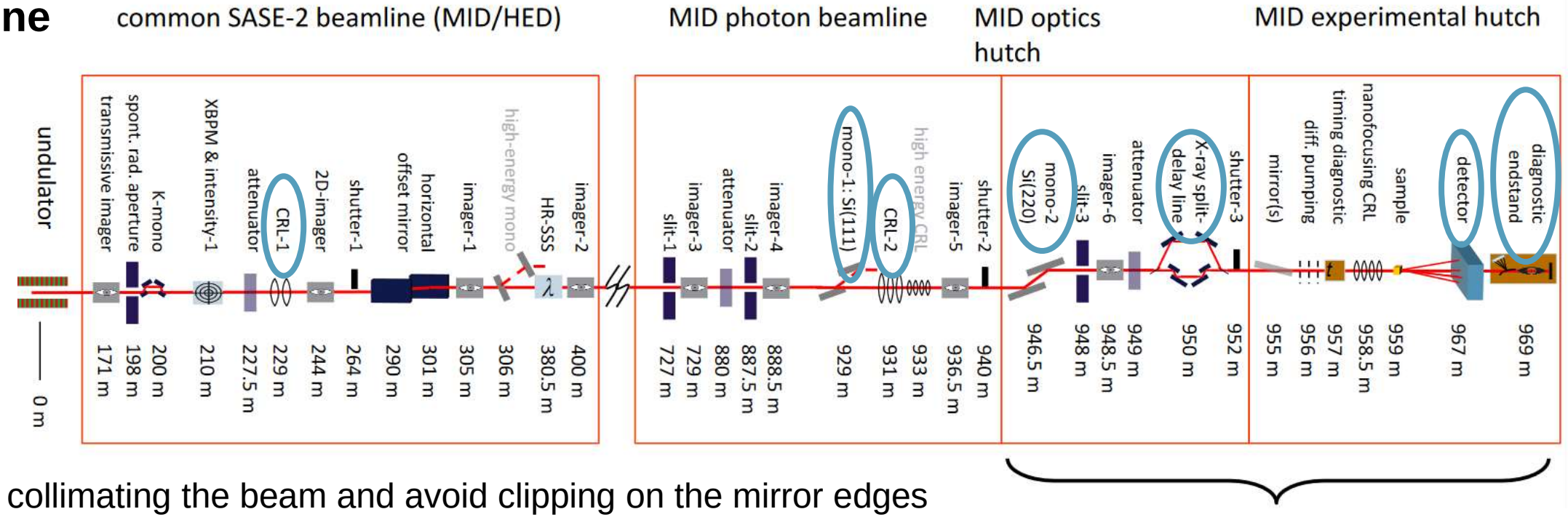


in combination with:
- External pump
- Spectroscopy
- Nano-focusing
- Split-delay techniques

Beamline layout and experiment stations



MID – outline



- CRL 1 for collimating the beam and avoid clipping on the mirror edges
- CRL 2 medium focussing scheme at the sample position – all arms are enabled now
- Attenuators, slits and imagers along the tunnel and in the optics hutch
- Monochromators
  - Si 111 – 5-25keV, commissioned and available
  - Si 220 – under commissioning (Optics hutch)

Beam parameters

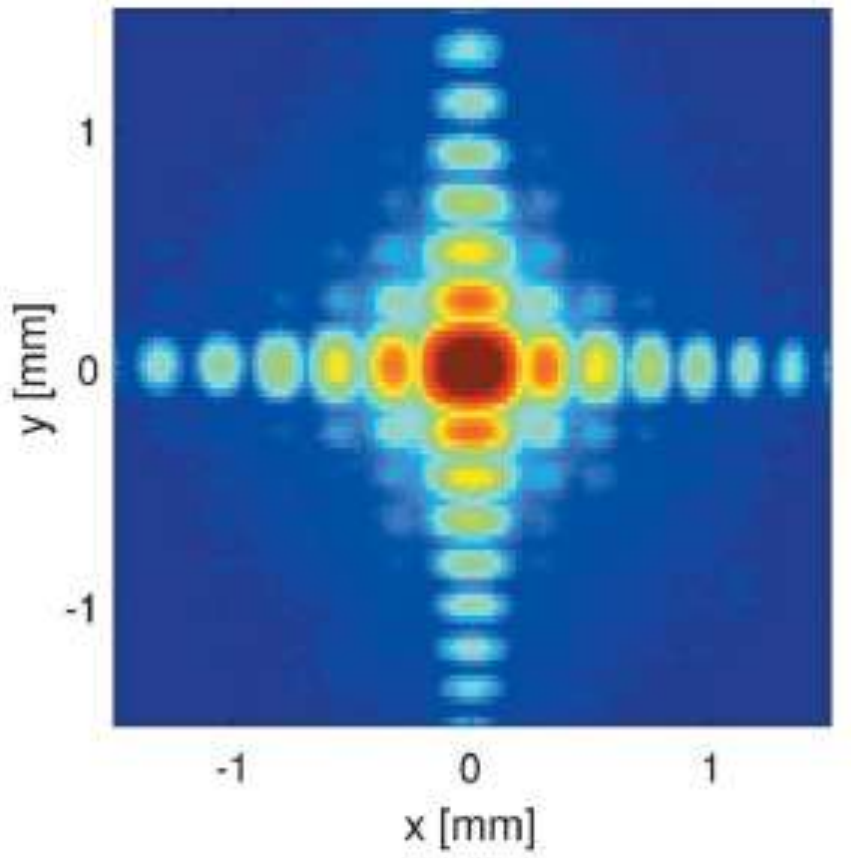
Talk by C. Lechner

- Standard 6-18keV SASE beam
  - Very first tests in SA2 (HED) up to 30keV
- Up to 3mJ per pulse
- 0-400 pulses per train
  - First tests with >1000 pulses per train
- Standard rep rate 2.2MHz
  - but also 4.5MHz and less (1.1, 0.55… MHz)
  - custom bunch pattern also possible
- Hard X-ray self seeding currently up to 13keV
- User experiment with shorter pulses -> talk by F. Trost
- Talk on special machine modes by C. Lechner

MID: Materials Imaging and Dynamics Instrument

Key experimental techniques used at MID

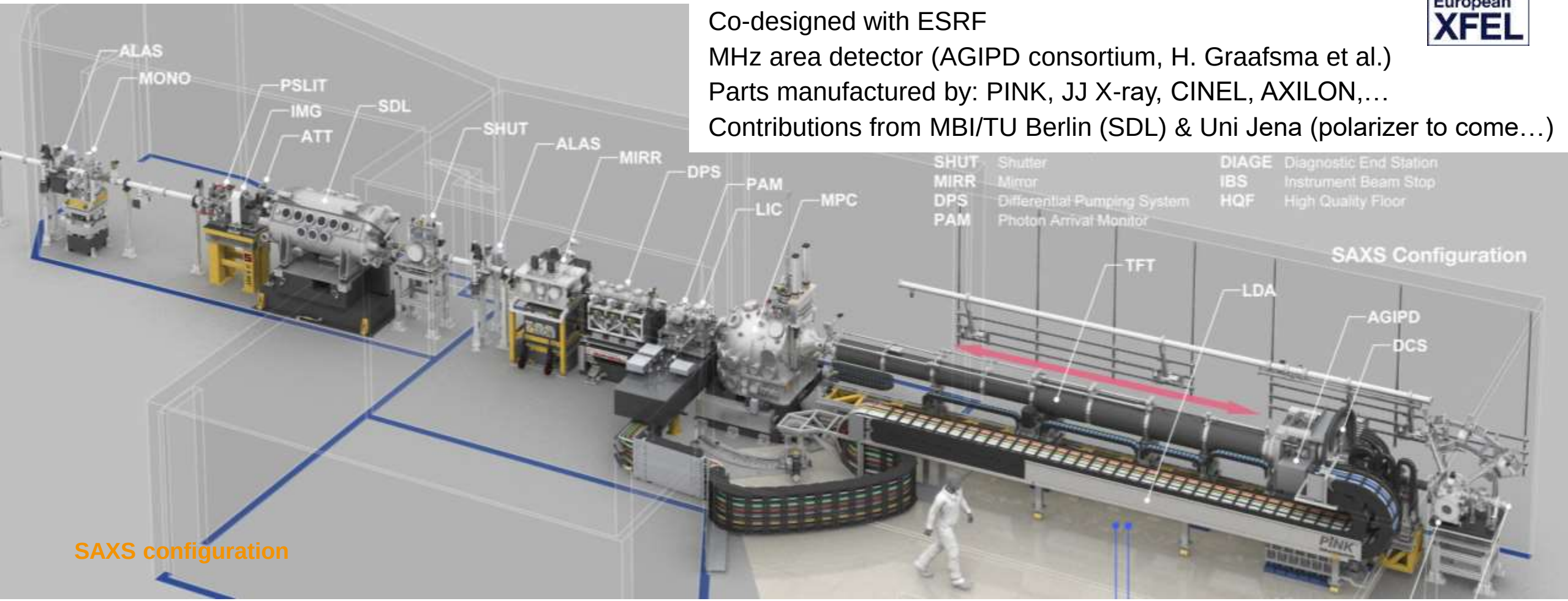
- MHz dynamics/XPCS
  - Small angle scattering geometry (SAXS)
  - Wide angle scattering geometry (WAXS)
  - At a selected Bragg peak in i.e. combination with a pump (optical/electrical/magnetic)
- Imaging
  - Holography
  - Ptychography
  - CDI
- SAXS/WAXS
  - XRD – powder pattern, water ring, etc.
  - Special *in-situ/operando* setups
  - Pump-probe experiments



Making use of the coherence, repetition rate, time resolution and high intensity of the X-rays at EuXFEL

Materials Imaging and Dynamics (MID) experiment

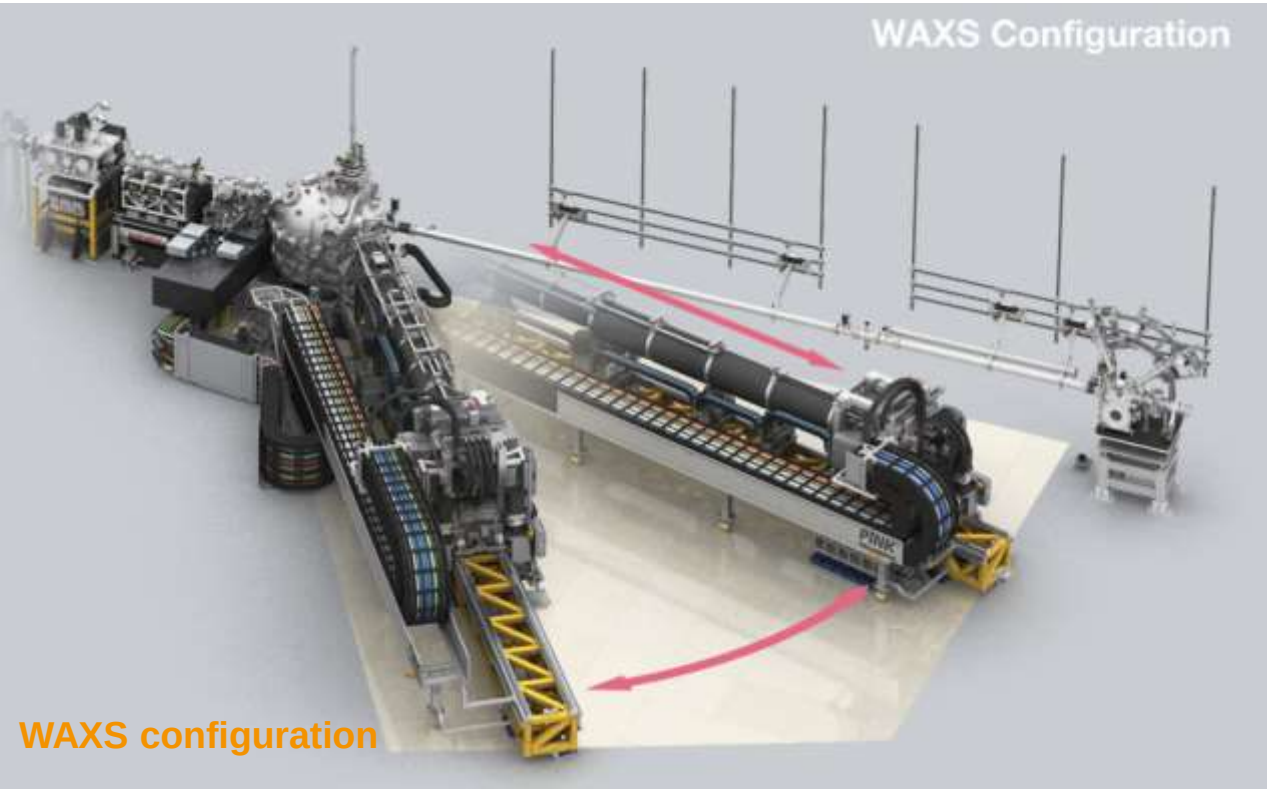
Co-designed with ESRF
MHz area detector (AGIPD consortium, H. Graafsma et al.)
Parts manufactured by: PINK, JJ X-ray, CINEL, AXILON,…
Contributions from MBI/TU Berlin (SDL) & Uni Jena (polarizer to come…)



SAXS configuration

*Madsen et al. JSR **28**, 637-649 (2021)*

MID overview



Materials Imaging and Dynamics (MID) instrument

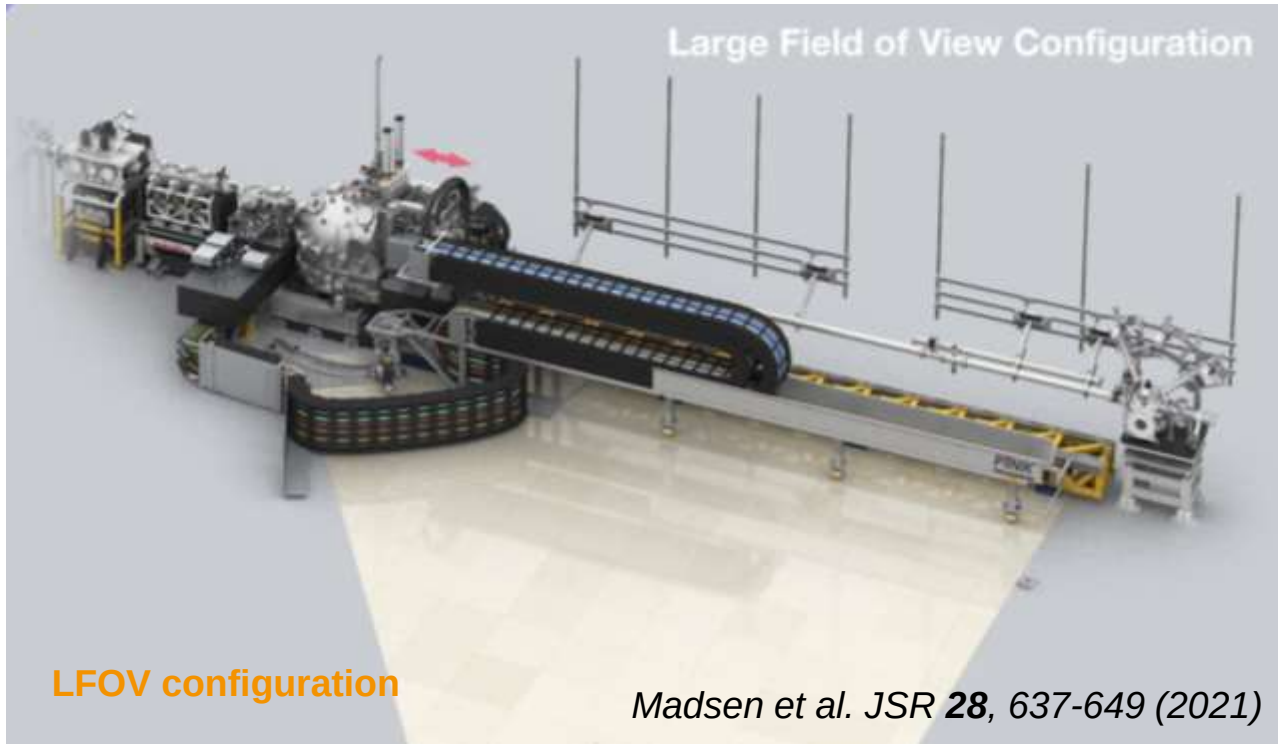
MHz area detector, 10^6 pix of 200 μm size (AGIPD)

Versatile setup, multi-purpose interaction chamber

Windowless (in-vacuum setup) or sample in air

Sample - detector distance 0.2 – 8 m

2θ up to ~50^o , 5 - 24 keV (7-18 keV tested so far)



*Madsen et al. JSR **28**, 637-649 (2021)*

Multi-Purpose Sample Chamber at MID

- Large volume chamber for window-less experiments
- in-air setup with single crystalline diamond window
- Heavy-load hexapod
- Hexapod for local optics (nano-focusing)
- Feedthroughs and ports for electronics/motors
- In-line microscope
- Clean-up slits
- Sample environments… magnet, cryostat, extra optics, furnace, user equipment etc.

*Madsen et al. JSR **28**, 637-649 (2021)*

AGIPD Detector

Talk by J. Möller

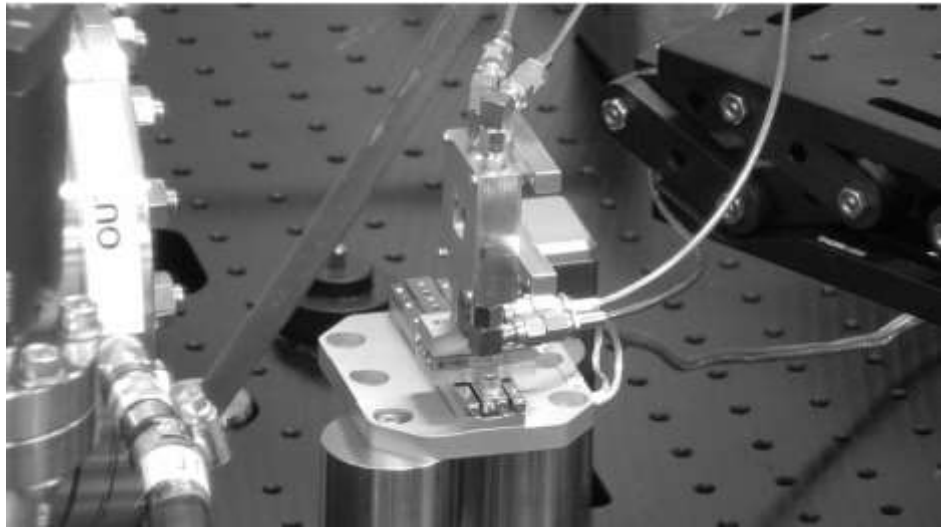
AGIPD detector on support

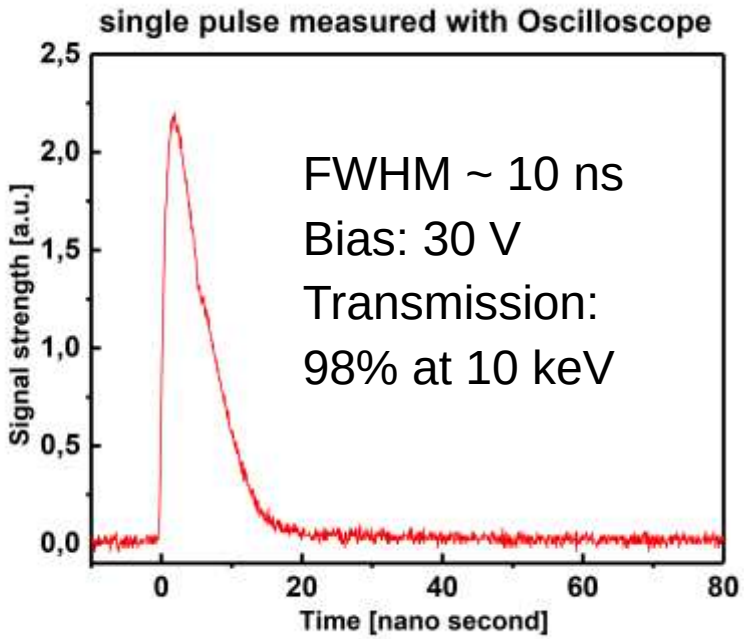
- AGIPD: 1MPixel, approx. 20 x20 cm^2 area
- pixel size 200x200um^2
- Four quadrants with central hole (flexible size)
- Capable of 4.5MHz
- 352 storage cells (352 images/train)
- Single photon sensitive
  - Special high CDS mode for very low intensities
- Up to 10^4 photons/pixel with 3 gain stages
  - 3rd gain stage (low gain) not yet fully separated from medium gain stage

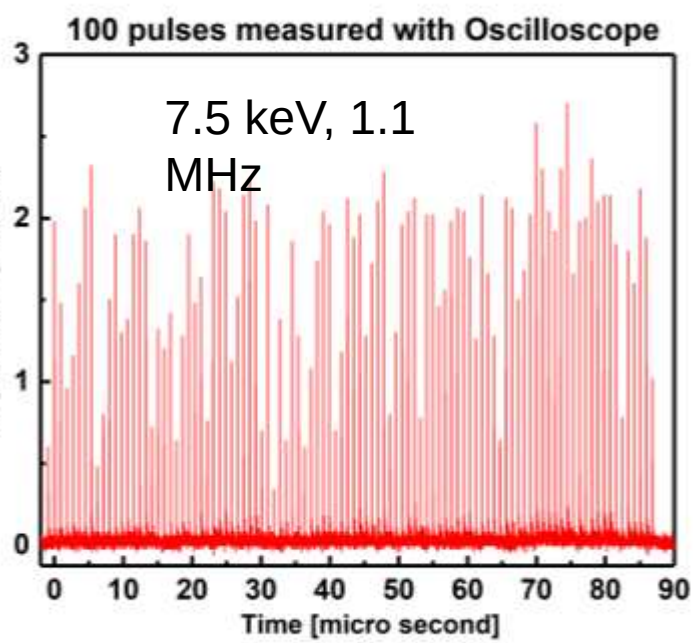
*Allahgholi et al. JSR **26**, 74-82 (2019)*

Other detectors

- ePix and Jungfrau detectors: 0.5MPix detectors (2 modules), 50 and 75um pixel size, 10Hz and future 16 storage cells (Jungfrau).
- Gotthard: 50um pixel strip detector. First generation 0.5MHz capable, next generation up to 4.5MHz (used in spectrometer) -> Gotthard-II is capable of 4.5MHz and is expected in 2022
- Diamond solid state ion chambers: 4.5MHz pulse resolved intensity monitors and future position sensitive monitors.







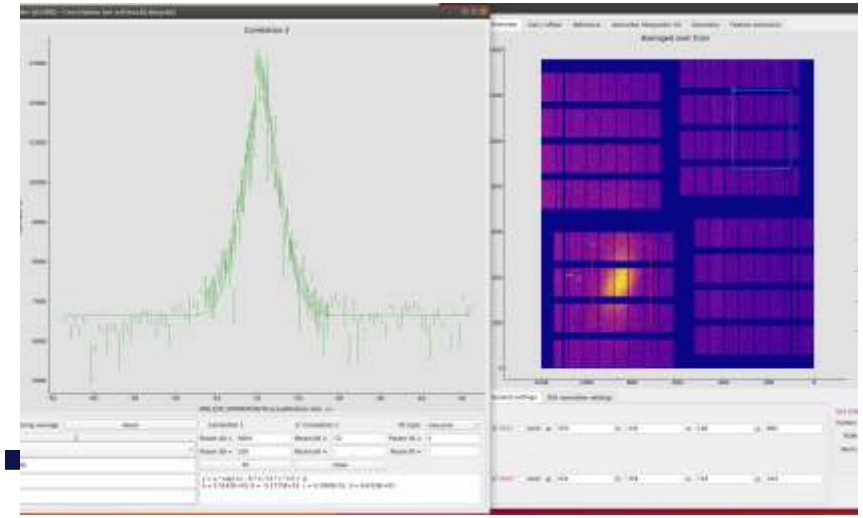
W. Freund (XPD)

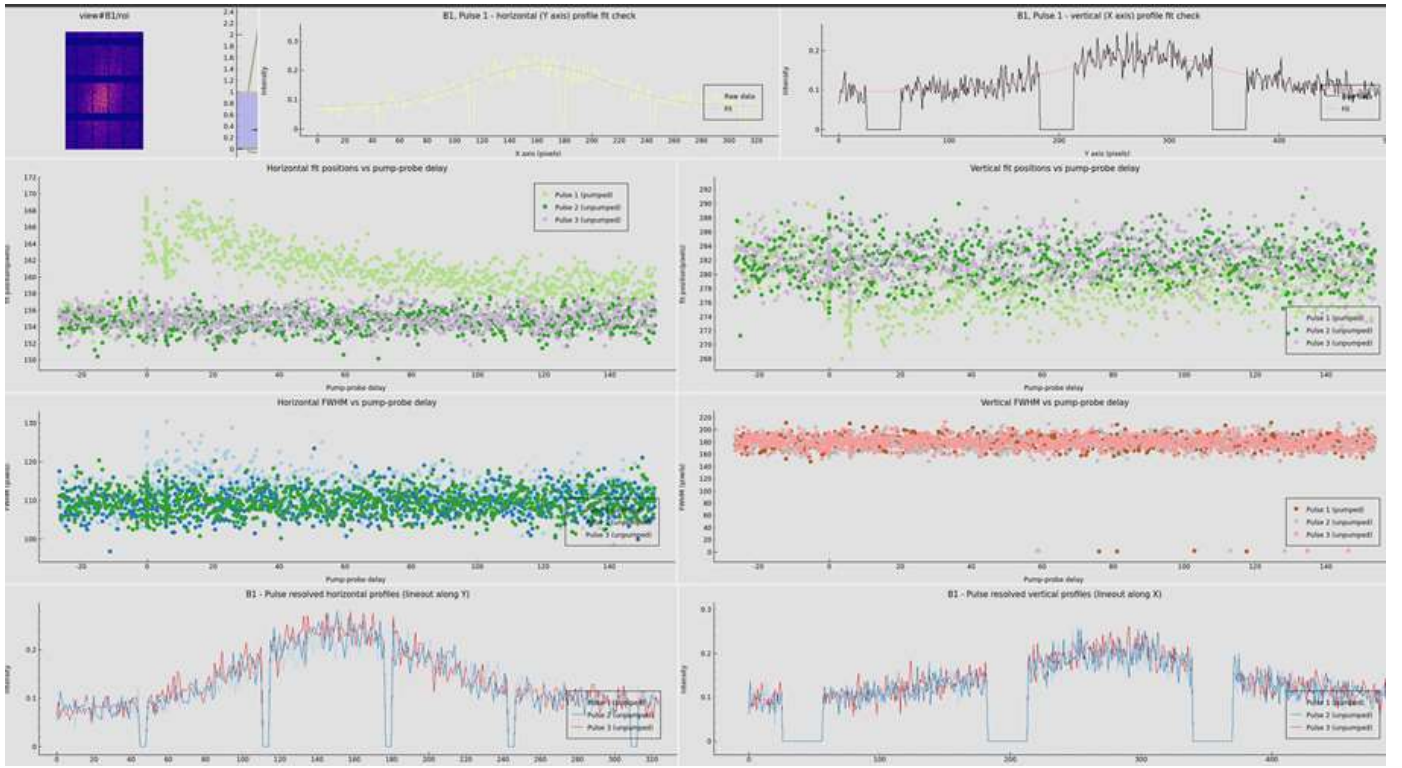
T. Roth et al., JSR. ***25****, 177 (2018)*

Online analysis and preview

Talk by J. Möller
Talk by J. Wrigley, Tue

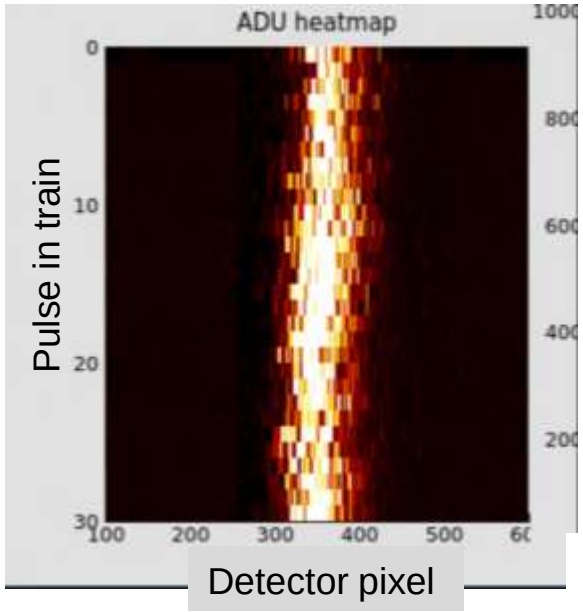
- Custumized for the experiments i.e. macros– contact us well in advance
- Improvements on our scanning tool (normalization, synchronization, motors etc.)
- Improvements on online preview
  - pulse/train resolved online analysis of Bragg peaks
  - Intensity, center of mass, profile…
  - Normalization, correlations
  - Speckles (in-progress)
  - pump-probe

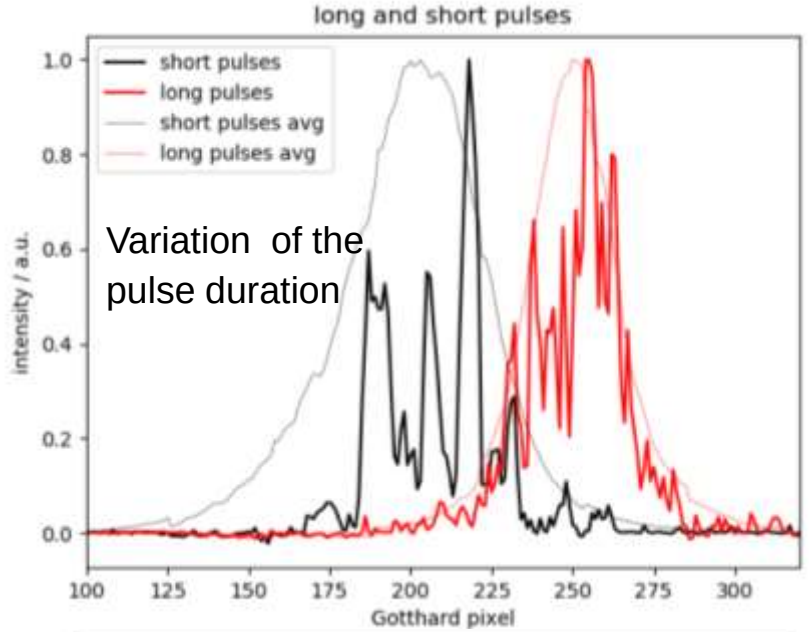


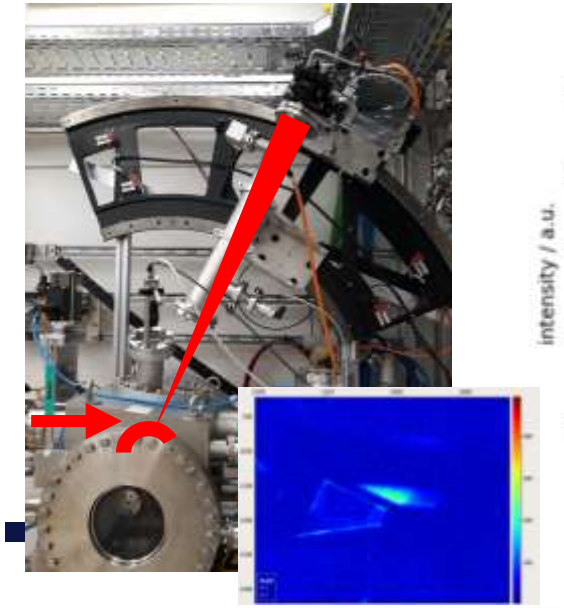


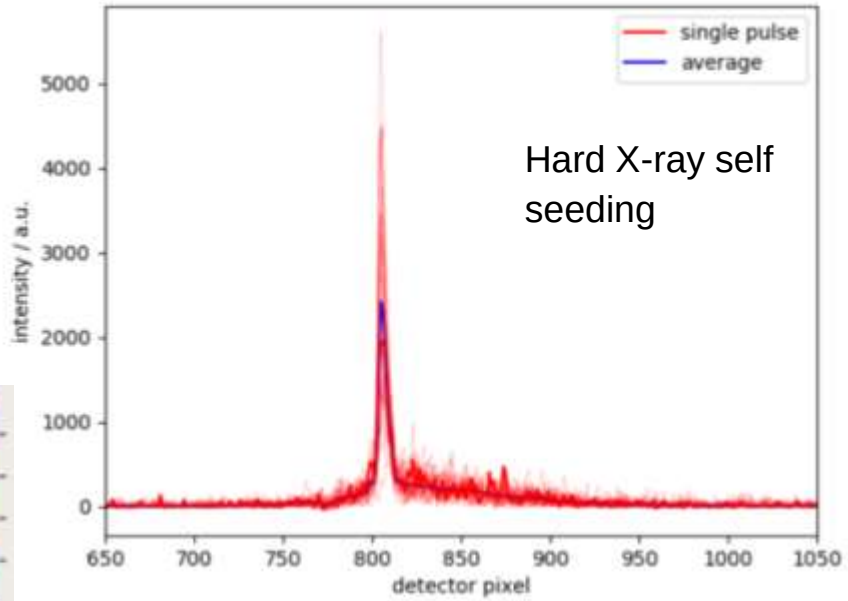
Spectrometer in the DES

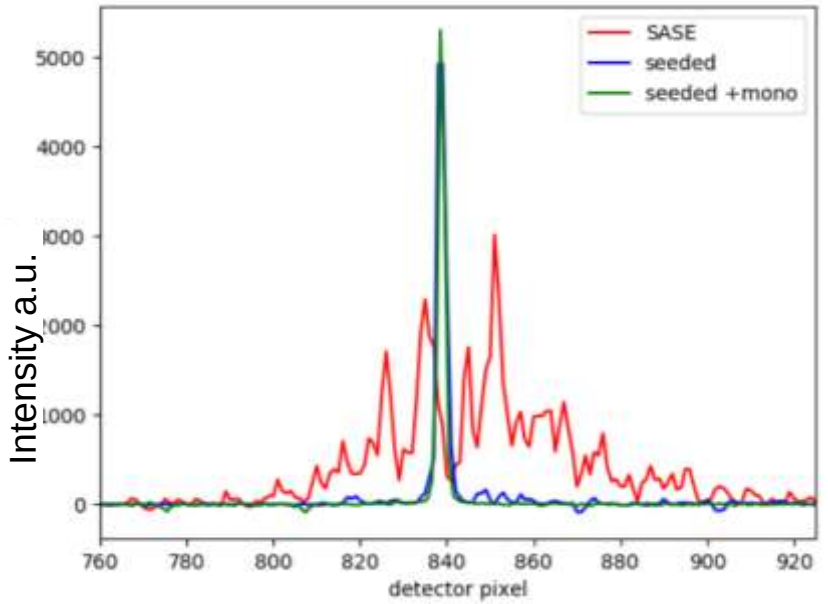
- The bend-diamond spectrometer is a very useful tool for beam characterization
  - 220 reflection, 20um thick, bending radius ~0.1m
  - Hard X-ray self seeding
  - Energy chirp over the train
  - Pulse duration
  - Energy calibration









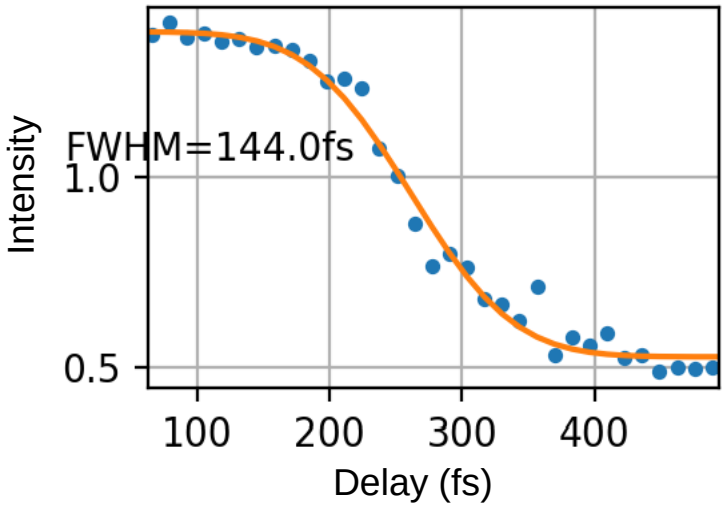


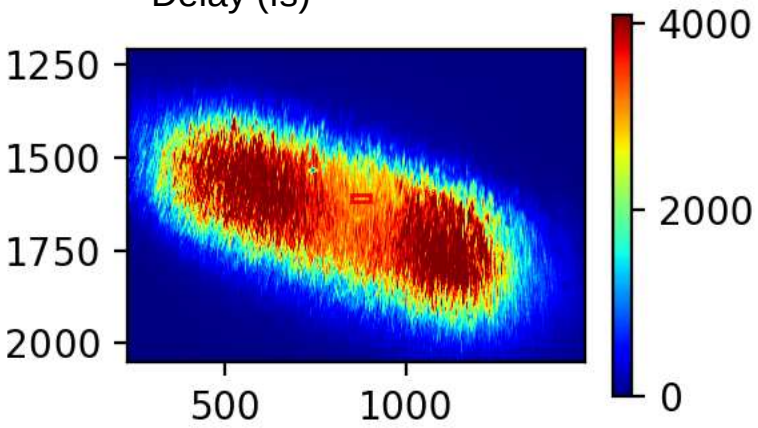
*Madsen et al. JSR **28**, 637-649 (2021)*
*Boesenberg et al. Opt. Express **25**:2852-2862 (2017)*

Pump-probe experiments at MID

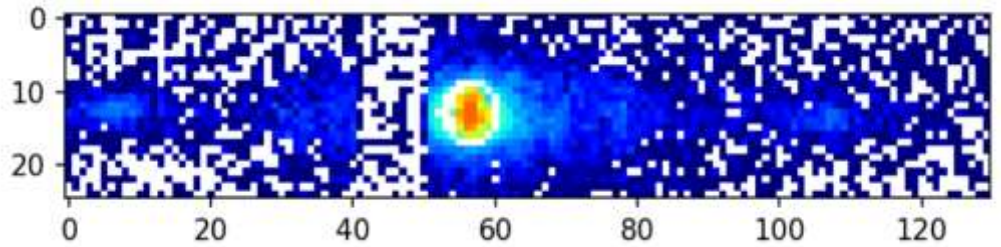
Talk by R. Shayduk
Talk by T. Salditt
Talk by A. Stierle in plenary session on Wed.

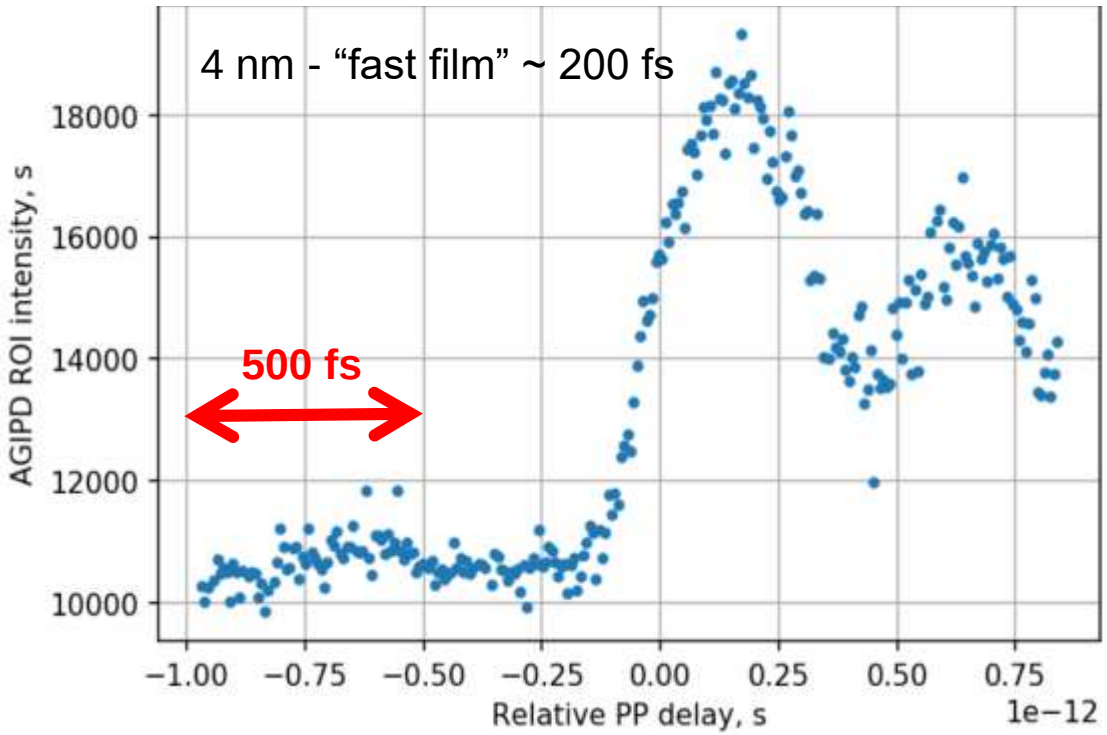
X-ray Pump – Optical probe on YAG





800 nm pump – X-ray probe
SrRuO3/SrTiO3 thin film





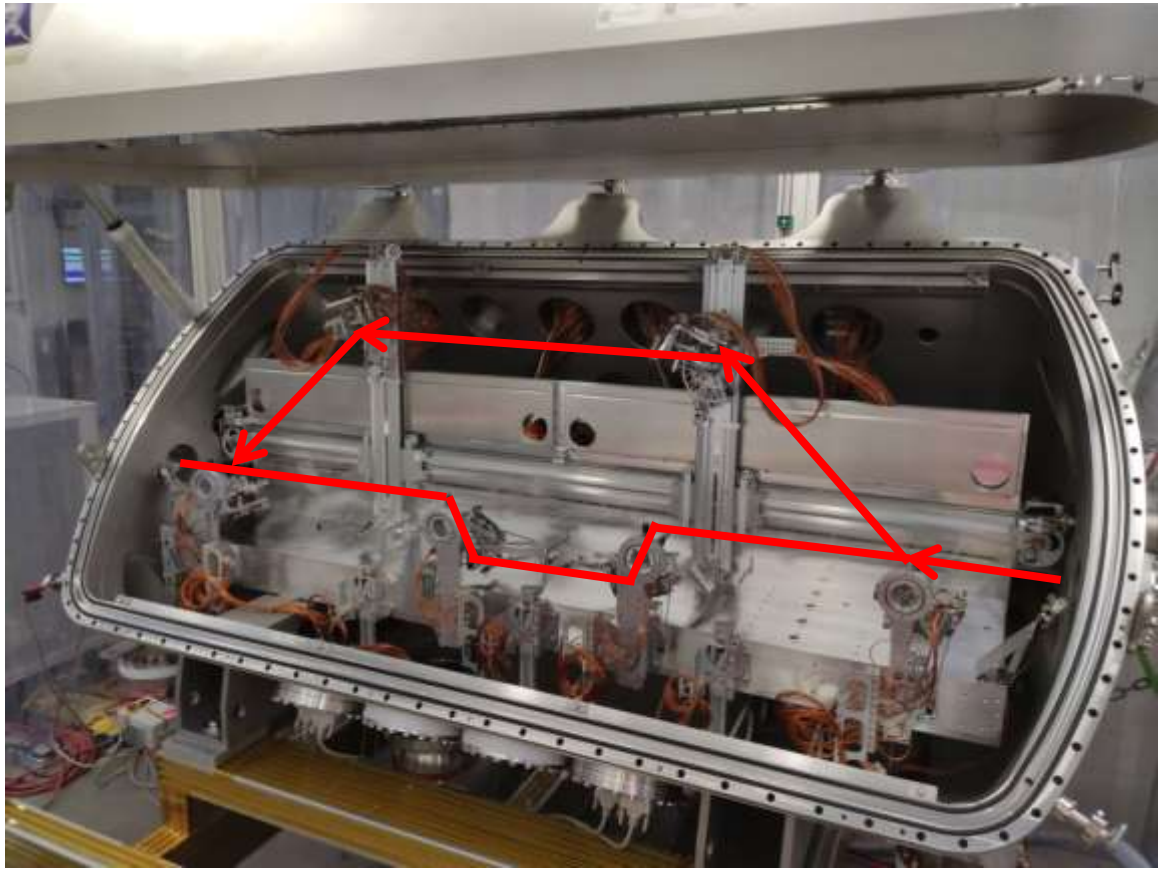
fs laser parameters: 800 nm, ~15 fs, ~150 fs jitter (or less), ~0.6 mJ/pulse
nanosecond laser also available.

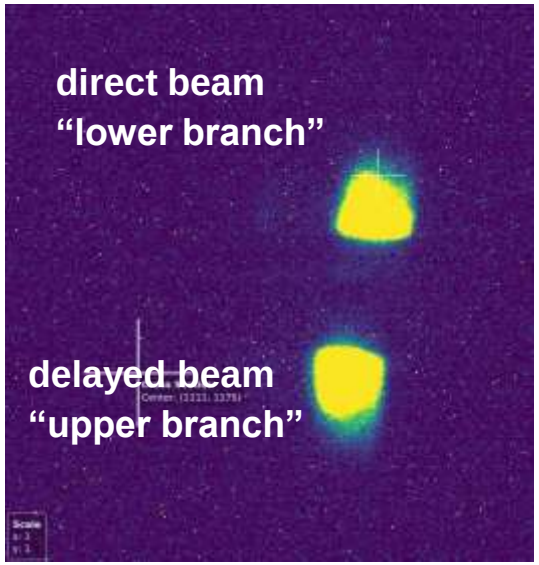
Shayduk, Hallmann et al. submitted for publication (2021)

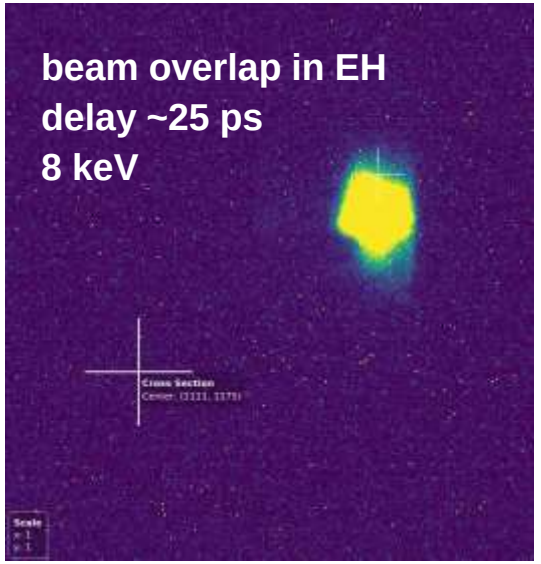
Split – and – delay – line (SDL)

Talk by W. Lu

- First user experiment with the SDL will take place in March 2022







Design values:
delay: -10 ps – 800 ps
5-10 keV

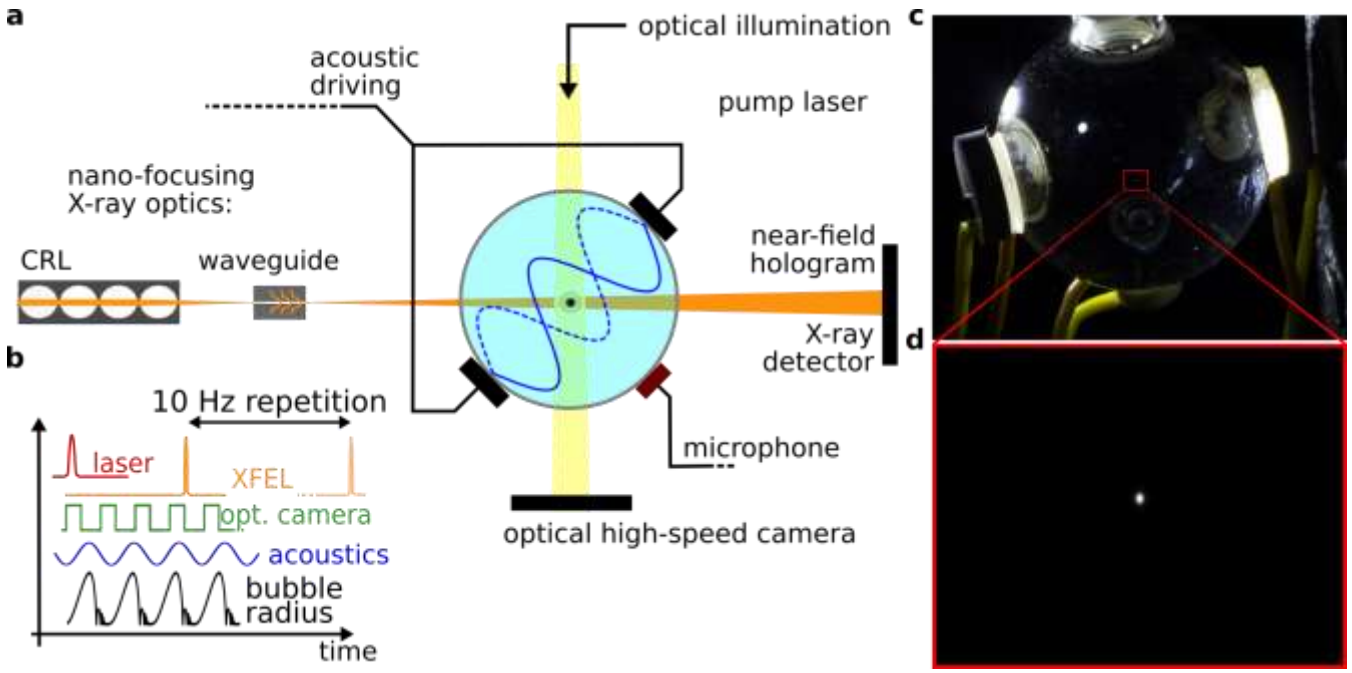
S. Eisebitt (MBI)
W. Lu, B. Friedrich et al. (MID)

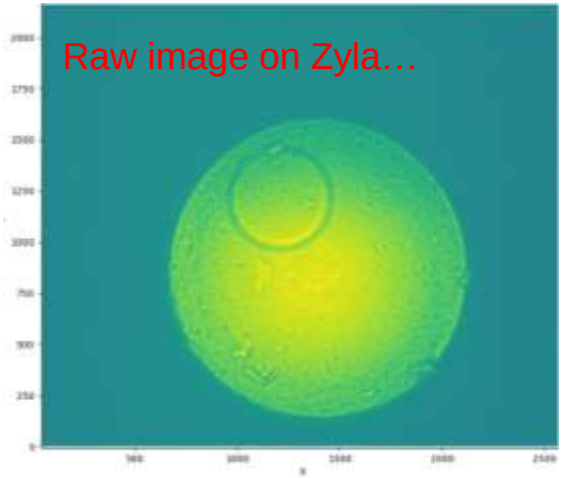
W. Lu et al. Rev. Sci. Instrum. ***89*** *(6):063121 (2018)*

Funding via BMBF Verbundforschung under contracts 05K13KT4 and 05K16BC1 is gratefully acknowledged.

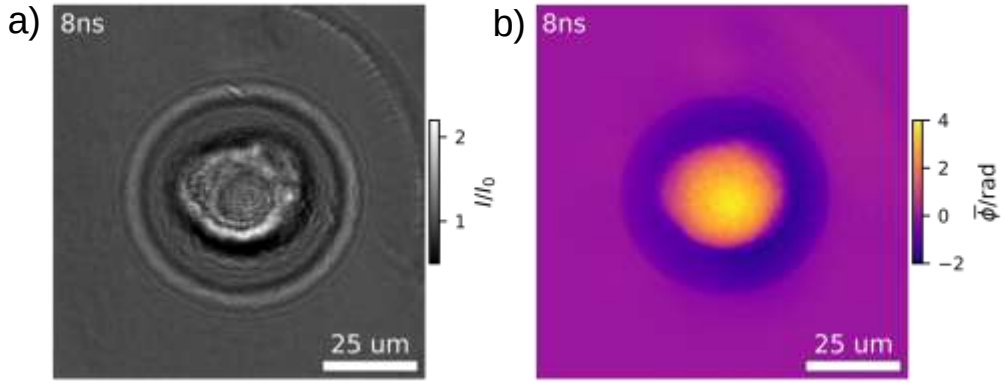
Measurements of cavities (bubbles) in a water jet and stationary (trapped)

- 18 keV pink beam – in-air setup
- Nano-focusing optics
- Inducing the cavitation with the 800nm optical pump laser (fs)
- Holography setup with 10Hz Zyla camera at 9m in the defocused beam





Talk by T. Salditt



a) flatfield corrected hologram and b) AP phase reconstruction (preceding experiment with ns laser)…

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

DESY.

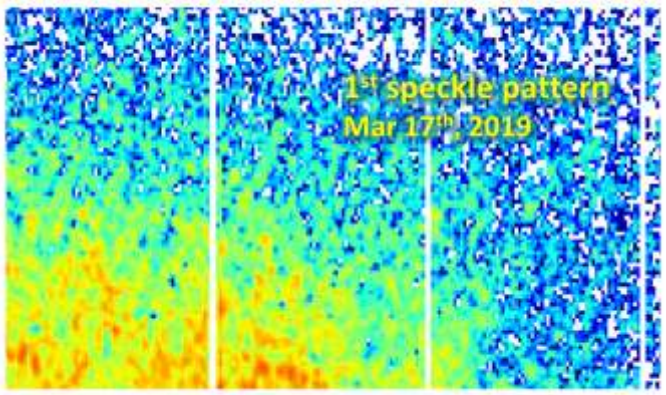
M.Vassholz *et al., Nat.Com.* ***12(1)***:3468(2021)
J.Hagemann, JSR ***28***:52-63 (2021)
M. Osterhoff, JSR ***28***:987-994 (2021)

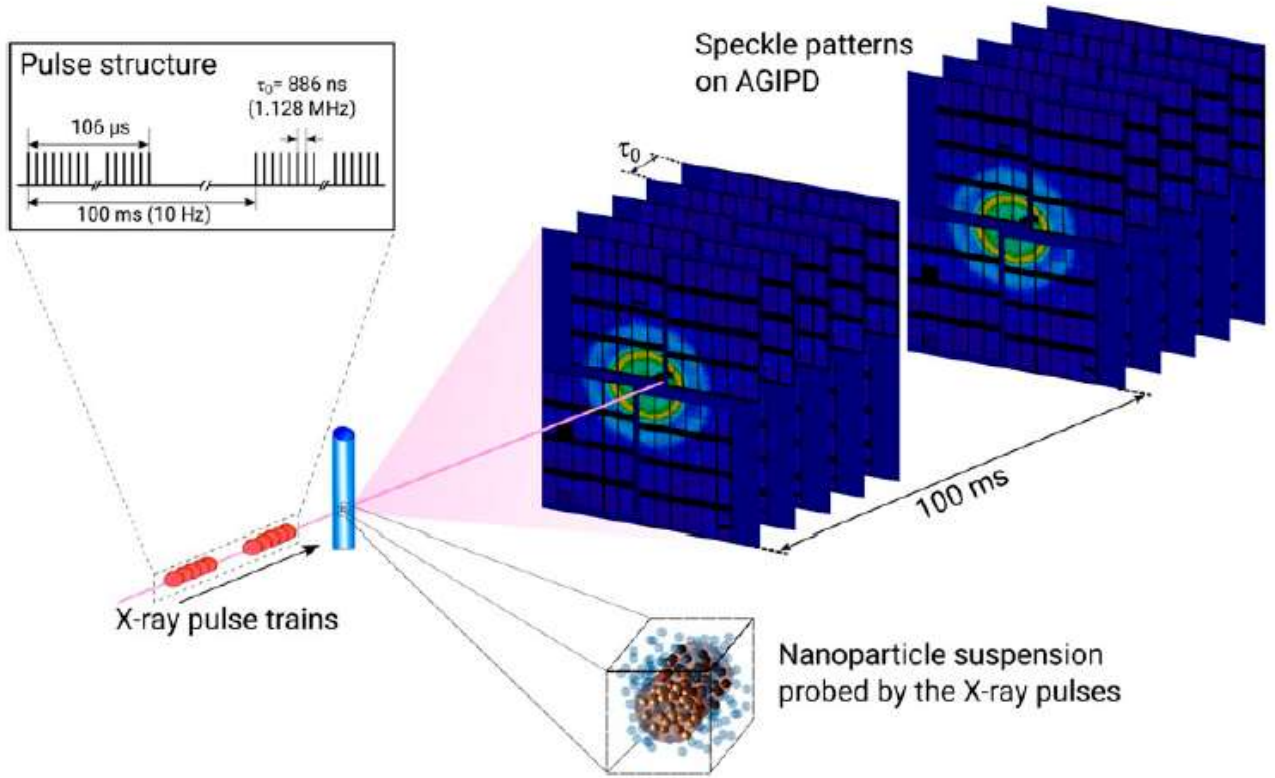
H. Hoeppe, T. Salditt et al.

MHz X-Ray Photon Correlation Spectroscopy

Talk by F. Dallari
Talk by M. Reiser

- To look at dynamics in a system
- Record a time series of speckle patterns
- Calculate a time correlation
- Fast dynamics are accessible with the high repetition rate of the EuXFEL
- Typically use for particles in solution, glasses, etc.

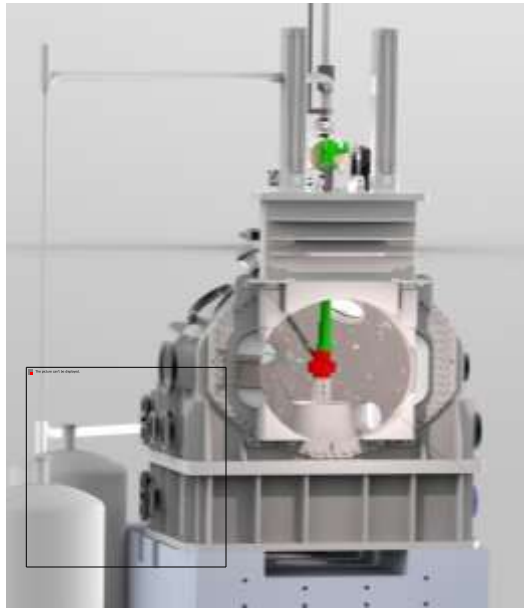




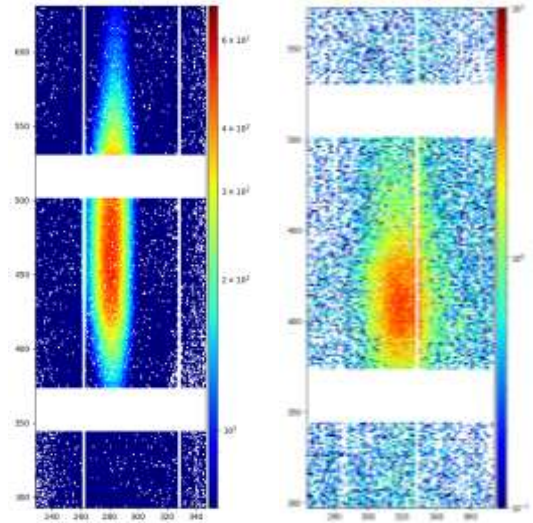
*Lehmkühler et al. PNAS **117**:24110-24116(2020)*

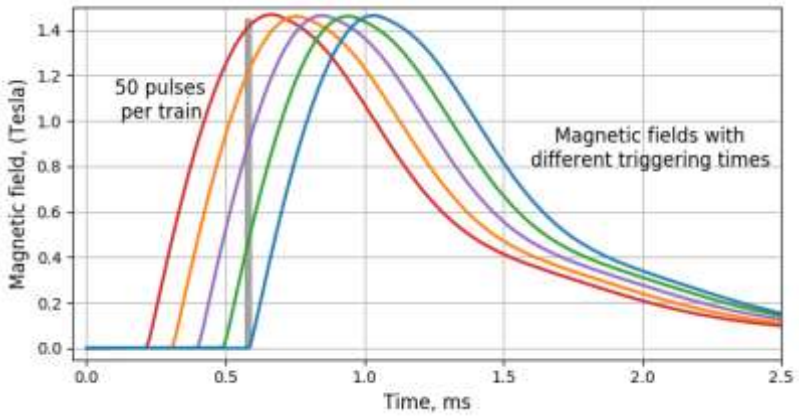
Cryostat and pulsed magnetic field setup (PUMA)

Talk by K. Kazarian



T_{min} ~ 5K
B_{max} ~ 12T, soon 15T



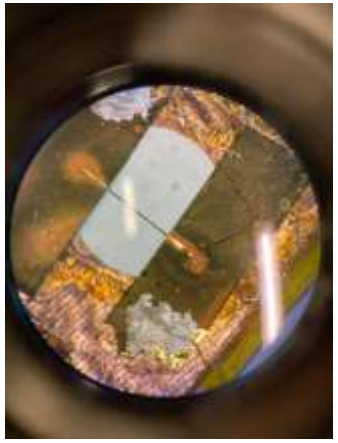


Reflections on AGIPD
a) Cr(002) reflection, b) CDW
(002-2δ), where δ=1/27 lattice constant

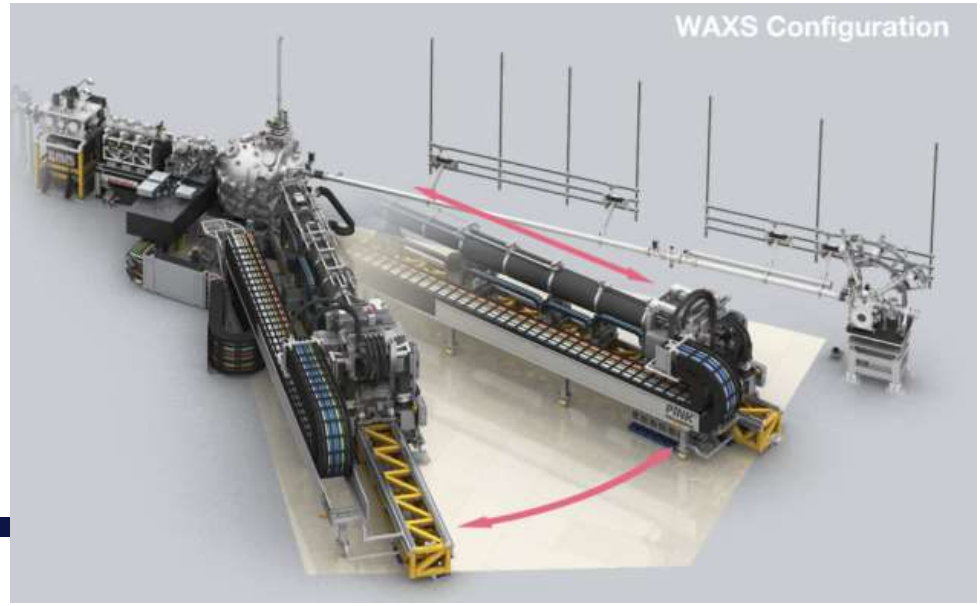
PUMA developed with J. Moore (sample env group)

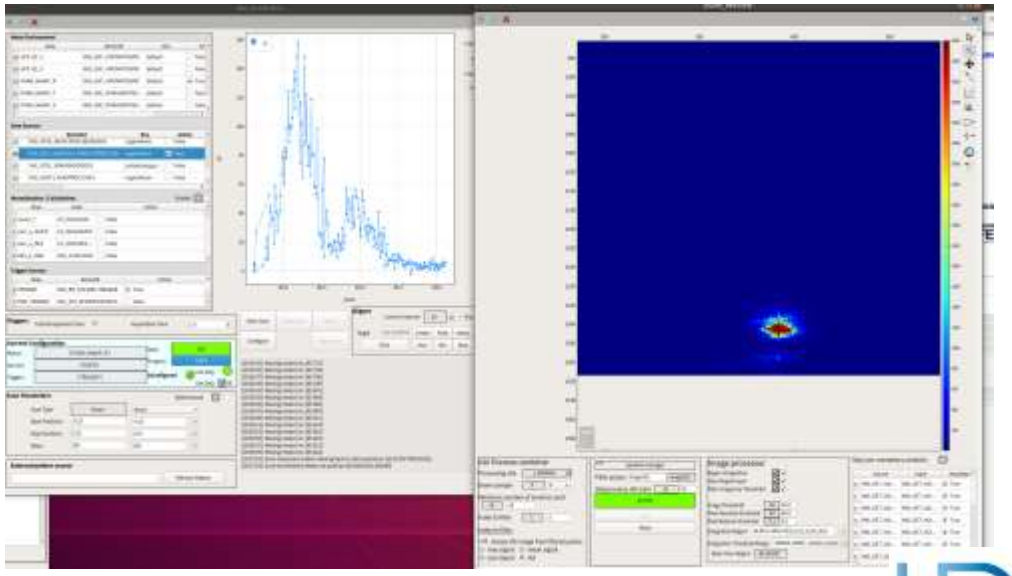
Cryostat plus electrical sample stimulation – Charge Density Waves

Talk by D. LeBolloc'h



- First user-experiment with HXRSS @ 9keV ~ 200uJ/pulse
- Observing changes in the diffraction-peaks (Bragg, satellite, CDW) with electrical current stimulation and time
- WAXS configuration with AGIPD ~8m
- Solid sample (20um $NbSe_3$ wire), up-to 60 pulses/train at 2.25MHz
- careful evaluation of the beam damage threshold

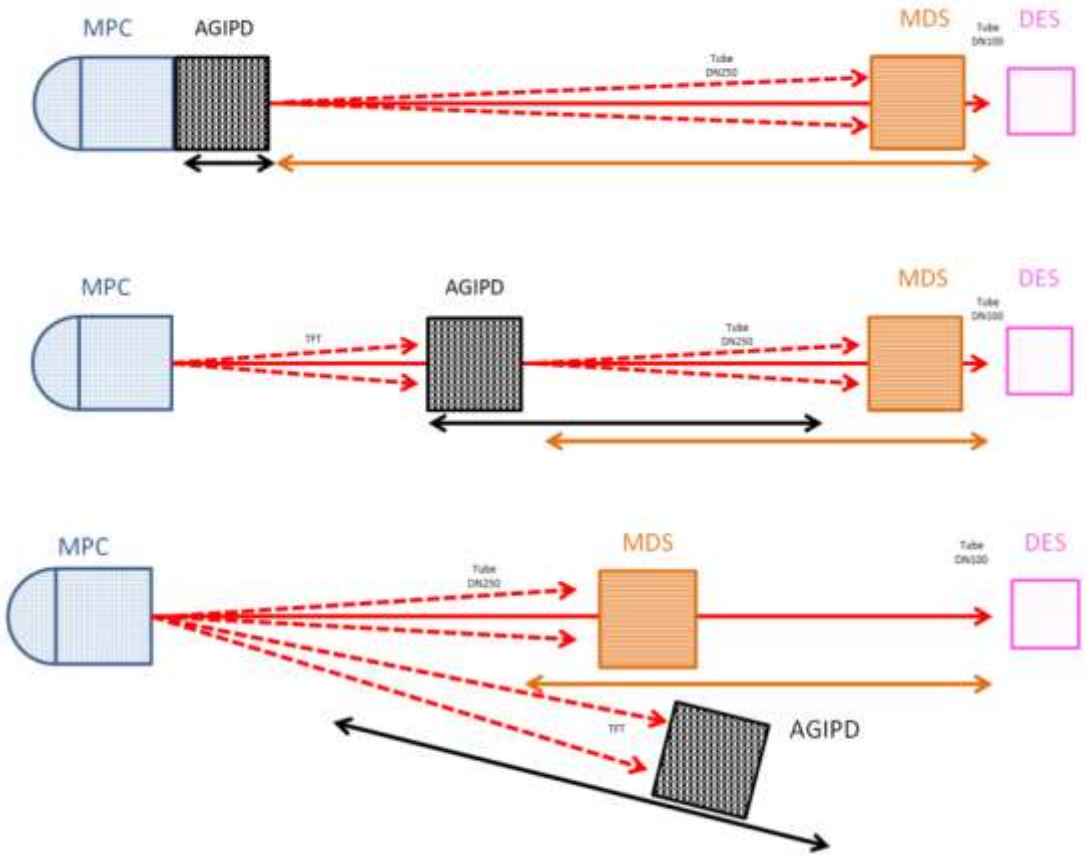


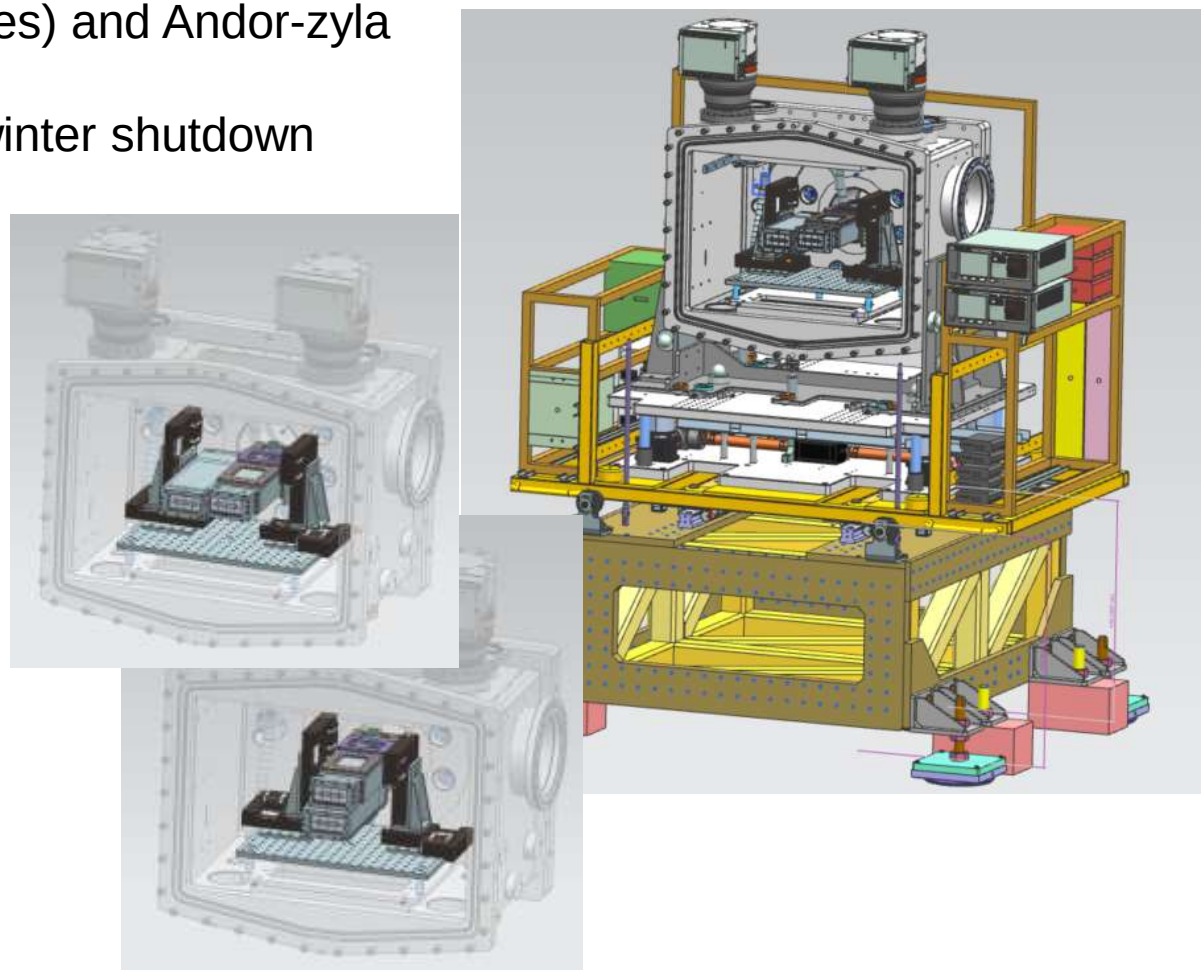


D. Le Bolloc'h et al.

MDS – Multiple Detector Stage for combined SAXS/WAXS

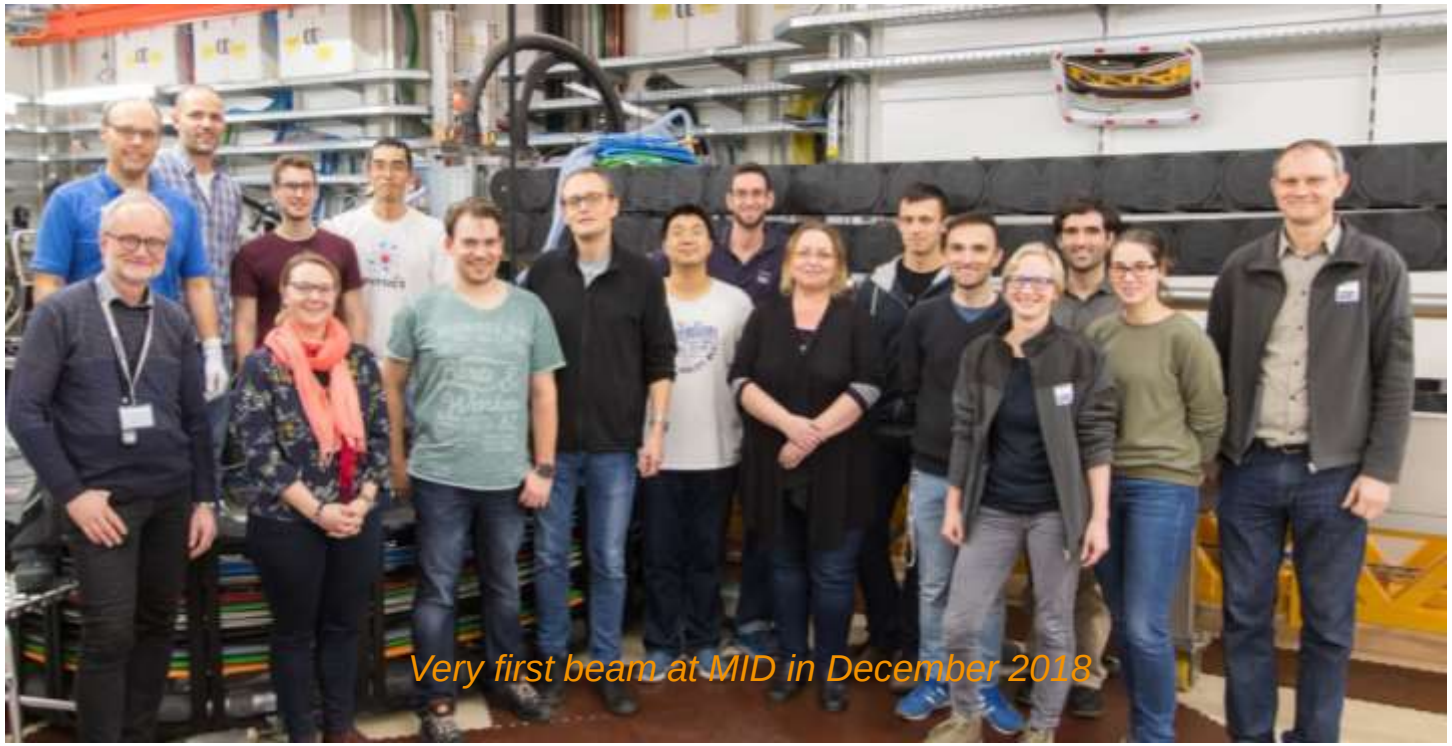
- Combination of the AGIPD with a second area detector in SAXS configuration in-air or in-vacuum
- Planned detectors ePix (2modules), Jungfrau (2modules) and Andor-zyla
- earliest installation in summer 2022, more likely next winter shutdown





Conclusions

- Possibilities at MID
  - Beam parameters
  - Focussing options
  - Detectors
  - Optical pump laser (fs)
  - Split-and delay line
- Ongoing work/improvements
  - Special operation modes
  - Online analysis and preview
  - MDS
- Some examples from the user experiments utilizing the MID instrument
  - Near-field holography imaging
  - Measuring lattice dynamics in WAXS configuration



Very first beam at MID in December 2018

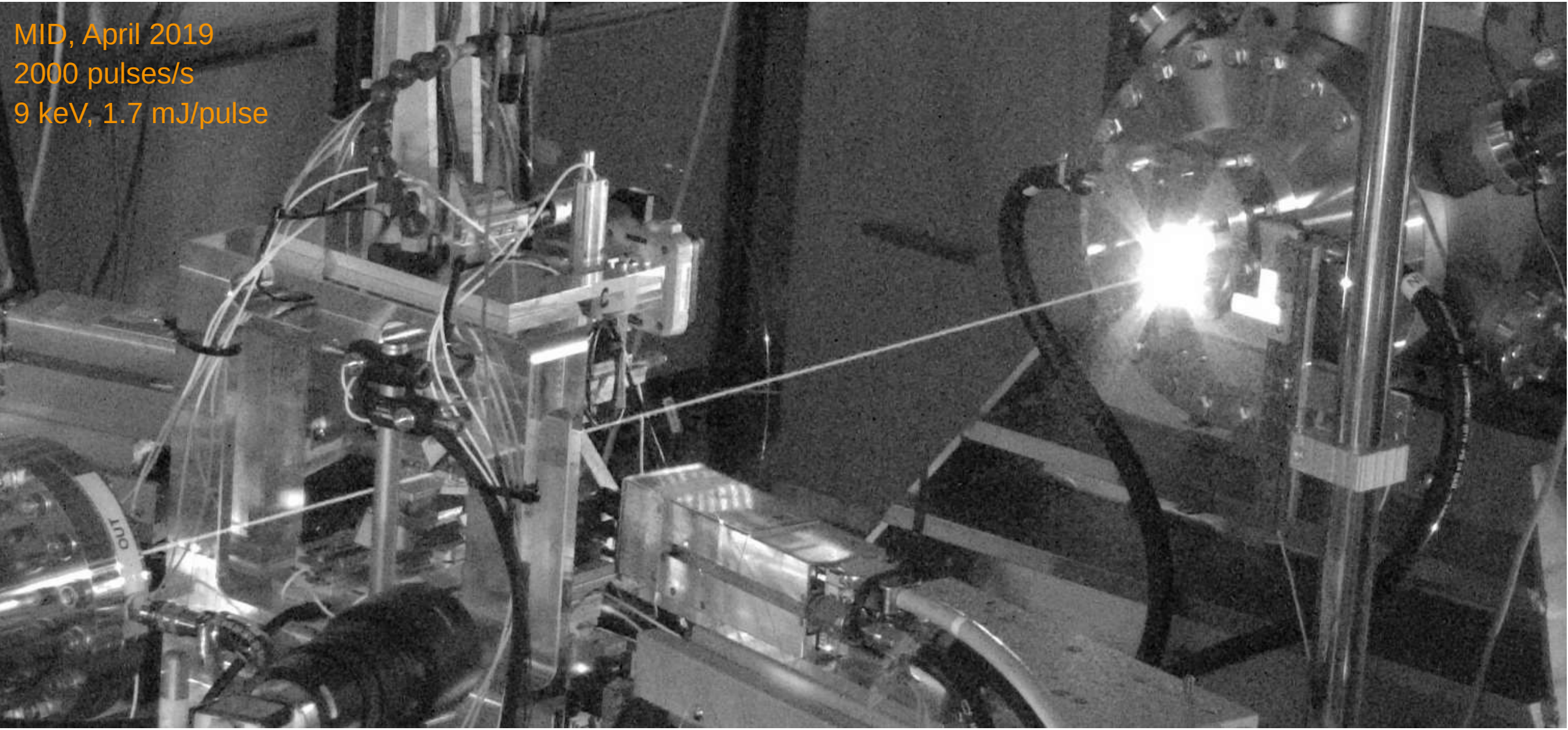
Acknowledgements

All involved expert groups and administration at European XFEL:
Detectors, DAQ & Controls, Sample Environment, Electronics & Electrical Engineering, IT, Network and Scientific software, X-ray Optics, Safety, Project coordination, Undulators, Instrument engineering, Optical lasers, Theory & Simulations, X-ray Diagnostics, User Office, Procurement, Finance & Controlling, TS, HR, PR, MB,…

Machine group and operators at DESY

User groups in 2021:

T. Salditt, H. Hoeppe *et al.*
A. Stierle, S. Chung *et al.*
H. Chapman, S. Bajt *et al.*
D. Le Bolloc'h *et al.*
F. Lehmkühler, F. Dallari, G. Gruebel *et al.*
F. Perakis, F. Zhang, M. Reiser, *et al.*
I. Robinson *et al.*
L. Müller, G. Gruebel *et al.*



Thank you for your attention!

European XFEL
mid-info@xfel.eu