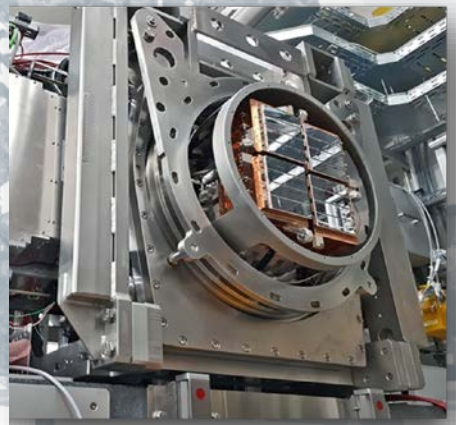
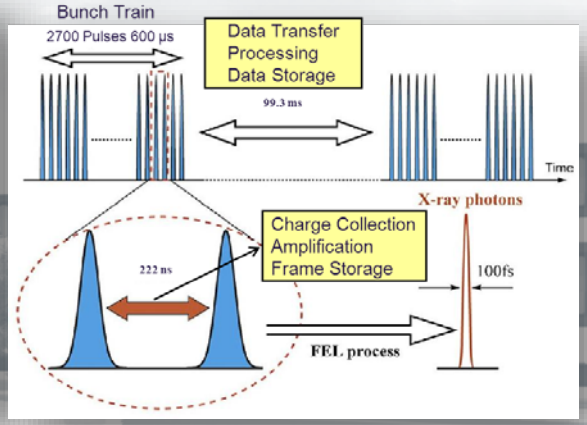
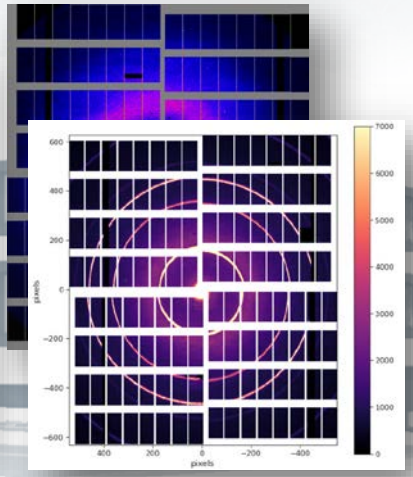
1 Mpix Adaptive Gain Integrating Pixel Detector (AGIPD) at European XFEL

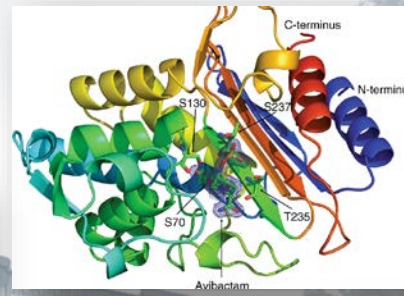
Experience with the detectors installed at SPB/SFX and MID Instruments

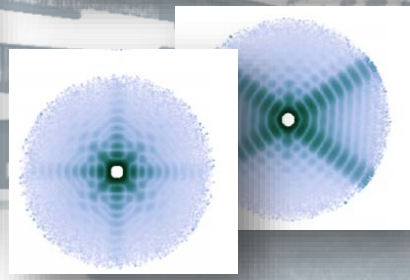
Jola Sztuk-Dambietz











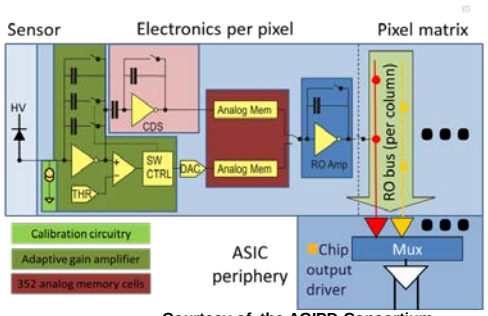
International Forum on Detectors for Photon Science
Virtual Thursdays 2021

1Mpix AGIPD detector system(s) at Europen XFEL

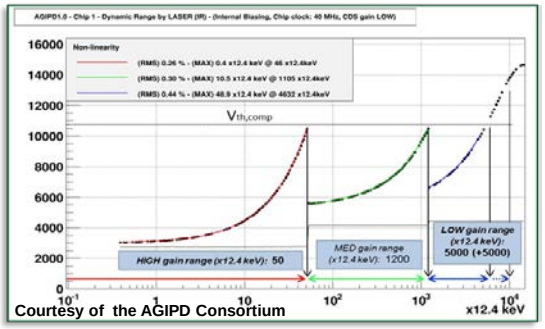
- **Detectors developed for XFEL.EU by AGIPD Consortium (DESY, PSI, Uni Bonn, Uni Hamburg)**

AGIPD Pixel Design for Fast Imaging and High Dynamic Range

- Preamplifier with **adaptive gain** by insertion of additional feedback capacitors to lower sensitivity and increase dynamic range once a defined threshold is crossed
- Correlated Double Sampling (CDS) stage to remove reset noise and reduce low frequency noise
- Analogue memory, which can store 352 images
- Read out of stored signals are through the pixel buffer, column buffer and off-chip driver in between the bunch



Courtesy of the AGIPD Consortium

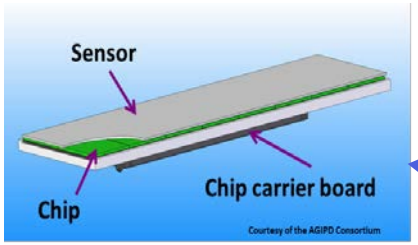


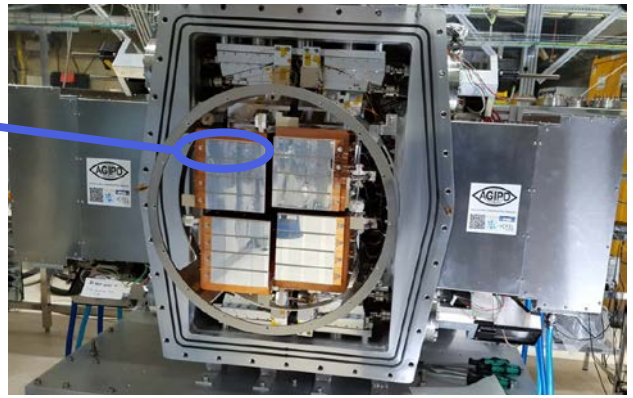
Courtesy of the AGIPD Consortium

Noise (HG)	**350 e r.m.s.**
Dynamic range	**Upto 10^4 10 keV ph/pix/pulse**

Hybrid detector - module

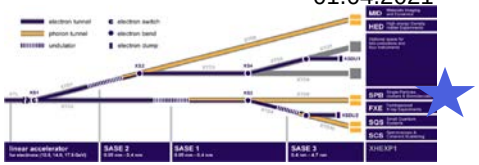
- Sensor:
  - Pixel size: **200x200 um**
  - **500 um** thick Si
  - 128 x 512 pixels
  - 2 x 8 read-out chips connected to sensor via bump-bonding
- Module size: **~26 x 105 mm²**





1M AGIPD system

- 16 modules are mounted on four independently movable quadrants
- Vacuum operation (P< 10^{-5} mbar)
- Electronics/Control: two independent detectors: ‘half 1’ and ‘half 2’
- Readout: 16 independent detectors



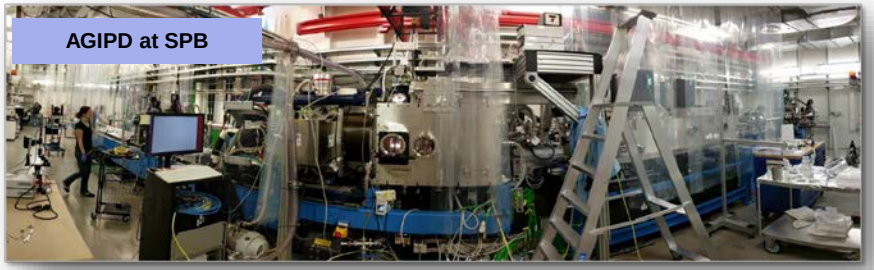
1Mpix AGIPD at SPB/SFX instrument

Single Particles, Clusters and Biomolecules and Serial Femtosecond Crystallography – SPB/SFX

- Hard X-ray beamline at SASE-I (design for 5-20keV), mostly operated at < 9.3 keV and 1.1 MHz
- Serial Crystallography and single particle imaging of biological samples and including time resolved experiments

1M AGIPD systems installed at SPB/SFX in Aug. 2017

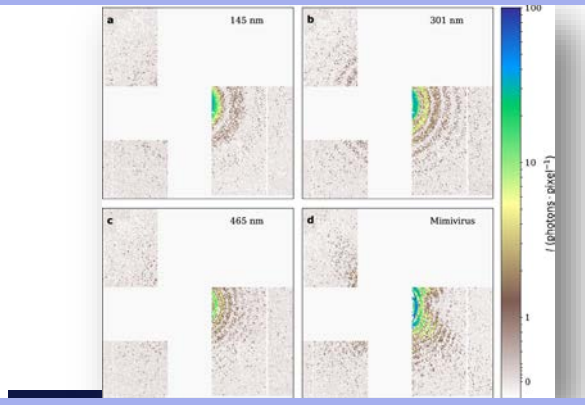
- User Operation - Sep 2017 (32 images per train only)
- Current status: systems run stable providing up to 351 images/train with intra-train repetition rates up to 4.5 MHz
- Collected raw data: > 10 PiT
- 11 scientific publications (another one close to be published)



Single Particles Imaging

- Requirements: **low noise (single ph) and high statistics**
- Data collected at 9.2 and 6 keV (> 10 M images)
- Order-of-magnitude increase in data collection efficiency along with much higher imaging resolution

Examples of scattering patterns from IrCl3 and Mimivirus.



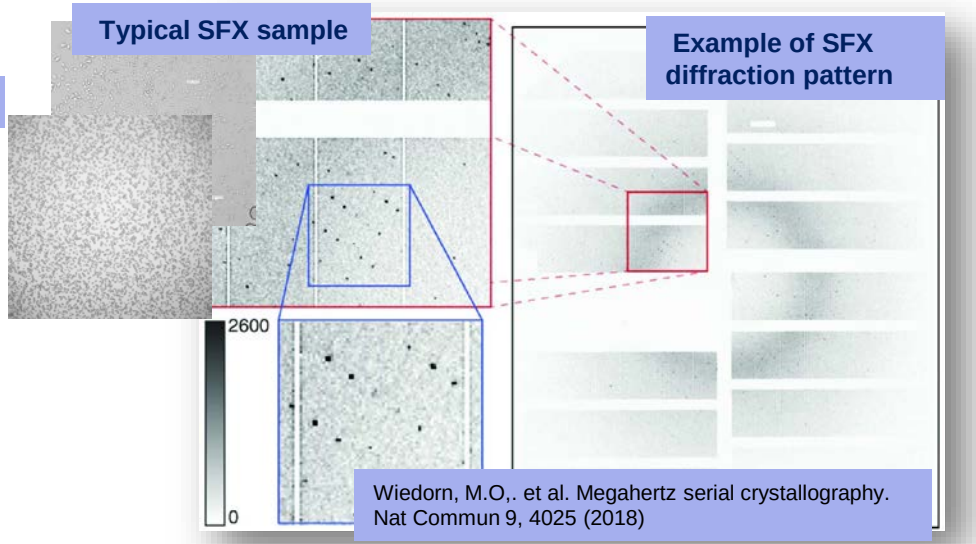
Sobolev, E. et al. Megahertz single-particle imaging at the European XFEL. Commun Phys 3, 97 (2020)

Serial Femtosecond Crystallography

- Requirements: **high dynamic range**

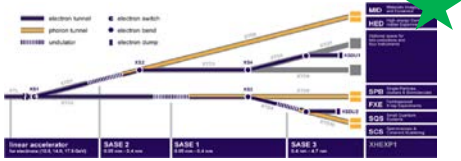
Typical SFX sample

Example of SFX diffraction pattern



Wiedorn, M.O,. et al. Megahertz serial crystallography. Nat Commun 9, 4025 (2018)

1M AGIPD at MID instrument

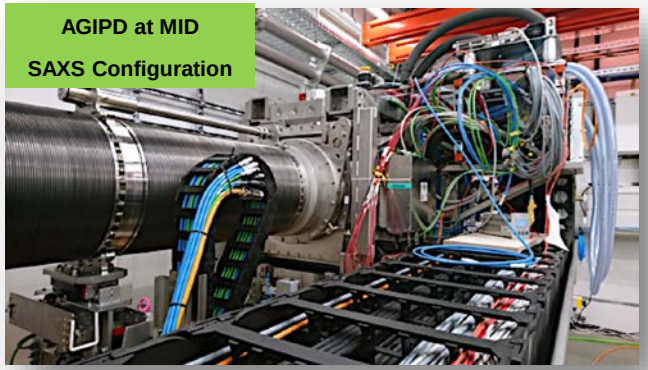


Material Imaging Dynamic – MID

- Hard X-ray beamline at SASE-II (design for 5-25keV), mostly operated at < 10 keV and 2.2 MHz
- Structure determination of nano-devices and dynamics at the nanoscale

AGIPD at MID

SAXS Configuration



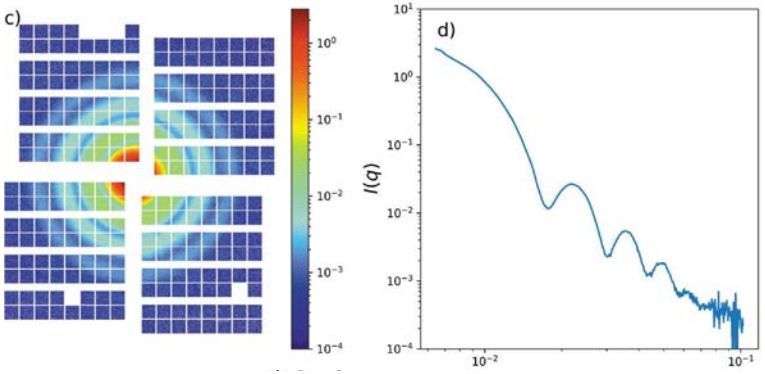
1M AGIPD system installed at MID in Nov. 2018

- User Operation - May 2019
- Current status: systems run stable providing up to 351 images/train with intra-train repetition rates up to 4.5 MHz
- Collected raw data: > 7 PiT
- User scientific publication: in preparation

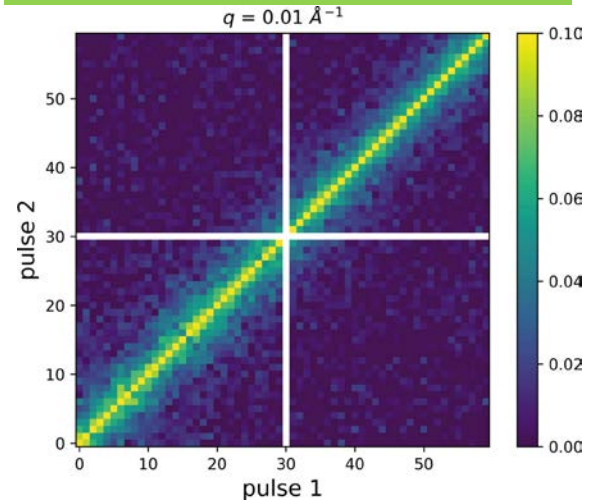
MHz XPCS

- Requirements: **low noise (single ph. sensitivity), spatial and temporal stability**

Example of small-angle X-ray scattering data of an aqueous silica nanoparticle solution



Example of two-time correlation function



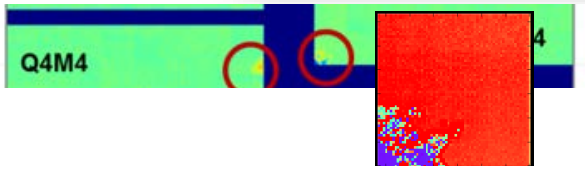
A. Madsen et al., "Materials Imaging and Dynamics (MID) instrument at the European X-ray Free-Electron Laser Facility", Journal of Synchrotron Radiation, 28:637–649, (2021)

Operational Experience with 1MPix AGIPDs

Experience with operation of the detectors

- Optimization is a continuous process
  - needs proper detector characterization and validation with scientific data
  - **involvement of instrument scientists and detector developers is mandatory**

- Incidents happen → interlock and online monitoring is a must:
  - accidentally unplugged chiller, cooling water failure
  - vacuum quality during liquid jet injection, pump failure or power cu
  - Radiation damage



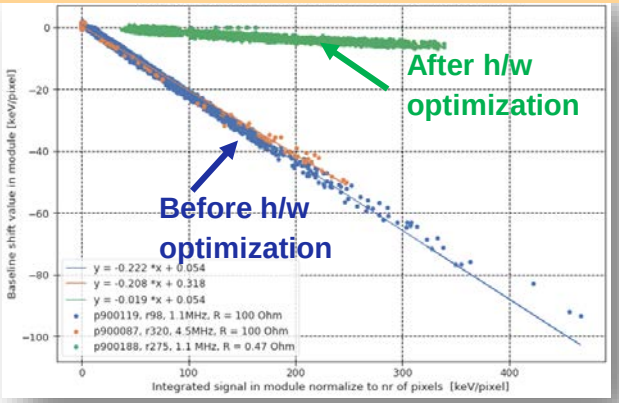
- Hardware failure happens (in the worst moment):
  - Spare parts
  - Relatively easy access to the electronics outside vacuum → electronics boxes were opened > 10 times
  - FEM modules can be relatively easily installed (~day) → done several times for both systems
  - Opening the back of the system is time consuming and complicated (~ weeks) → done twice at SPB/SFX

Main activities

- Characterization and optimization of the detector
  - Optimization of hardware and configurations for the detectors
    - ► Hardware update to reduce so called baseline shift
    - ► AGIPD1.2 for LG-MG separation → S. Stern's talk
    - ► Investigation of usage longer integration time
  - Optimization of calibration methods → M. Cascella's talk

- Support of User operation

Baseline shift as a function of X-ray intensity



Thank you