The Adaptive Gain Integrating Pixel Detector for fast experiments at the European XFEL.

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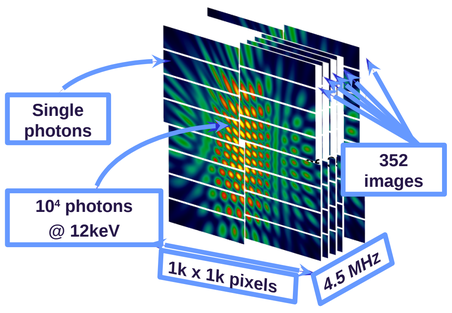
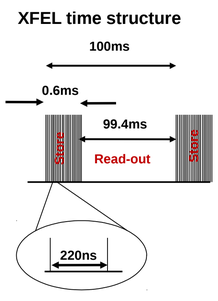
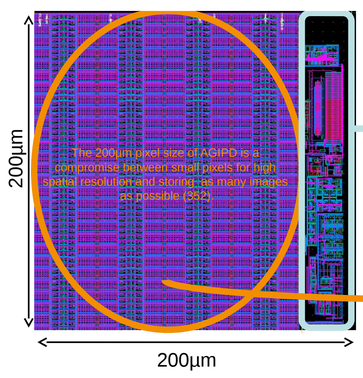
The European XFEL constraints and AGIPD features

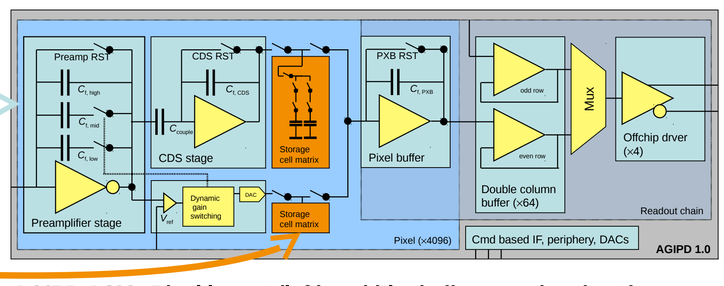
Scientific opportunities:

- Study of a very small objects: single (bio-)molecules
- Imaging of a non-regular structures: up to non-crystals
- New materials and fast processes studies









AGIPD ASIC: Pixel layout (left) and block diagram showing the analogue readout chain (top)

Collaboration between DESY, PSI, UHH and Uni Bonn

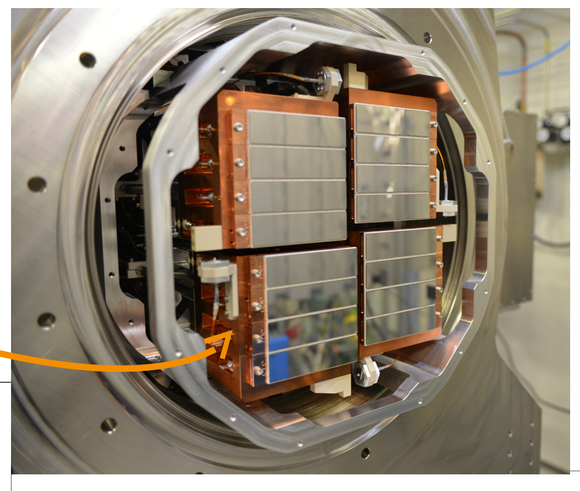
Main parameters

Operating principle	Charge integrating
Energy range	6 keV-18 keV
Frame rate	> 4.5 MHz (burst mode)
Memory depth	352 frames
Pixel size	(200 µm)²
Pixel technology	Hybrid Pixel Technology
Detector spatial configuration	Variable (modular)
Module size	2.5 × 10.5 cm², 128 × 512 pixels
Dynamic range	1 to 10^4 photons/pixel/frame at 12.4 keV
Dynamic gain switching	Yes (3 gains)
Veto/Trigger	Yes (overwriting of frame RAM)
Single Photon sensitivity	Yes (in high gain)

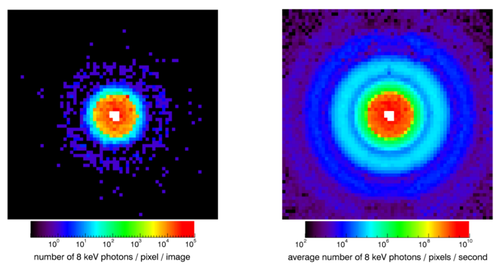
- Preamplifier with adaptive gain by insertion of additional feedback capacitors to lower sensitivity and increase dynamic range once a defined threshold is crossed
- Correlated Double Sampling (CDS) stage to remove reset noise and reduce low frequency noise, 2 selectable gains possible
- Analogue memory, 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 trains (within 25 ms out of 99 ms)

AGIPD 1Mpix systems @XFEL

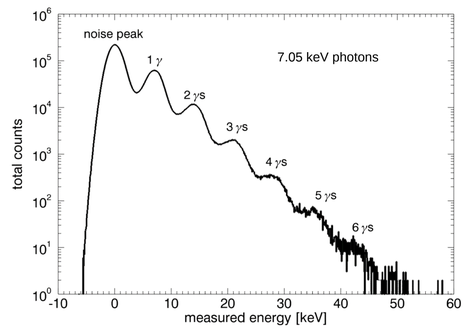
- One 1MPix AGIPD operational at SPB/SFX instrument
- Second 1MPix AGIPD is ready for MID instrument
- Operation in vacuum
- Detector integrated into the cage at the beamline



ASIC performance



- Image of colloidal sample, left single image, right time average
- Absence of photons encoded as black color in logarithmic scale
- Each image contains pixels in all three gain stages simultaneously.
- No beam stop: direct synchrotron beam was recorded besides scattering pattern



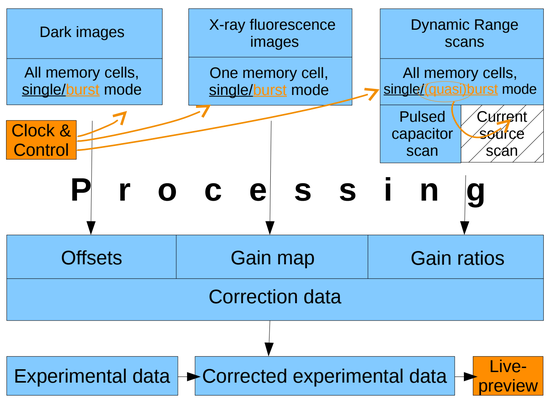
- Histogram of data from a single pixel
- Average intensity: 0.3 photons per 200 ns, corresponding to a count rate of 1.5 Mcps/pixel or 37.5 Mcps/mm²
- RMS noise of 320 electrons at 5.2 MHz

Data processing and calibration at DESY

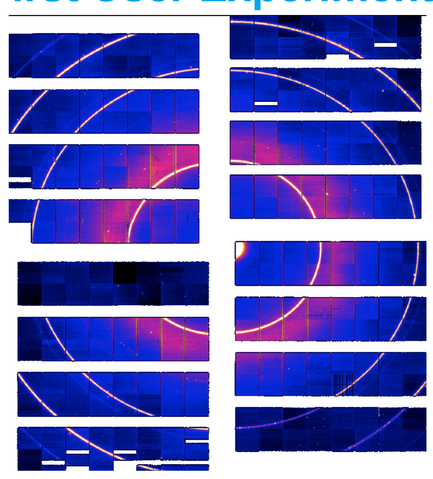
Data rate	~15 GB/s
Calibration constants	~3 billion
Calibration raw data	50 TB
Calibration processing - sequentially	> 10 days
Calibration processing - in parallel and optimized	< 4h

- HiDRA software for data transfer between detector PC and storage system
- ASAP3 (GPFS) for data storage
- For each memory cell 8 constants have to be determined: ~ 3 billion constants in total
- Calibration pipeline has been developed
  - Processing on Maxwell cluster
  - Parallelization in order to reduce processing time
  - Optimization ongoing

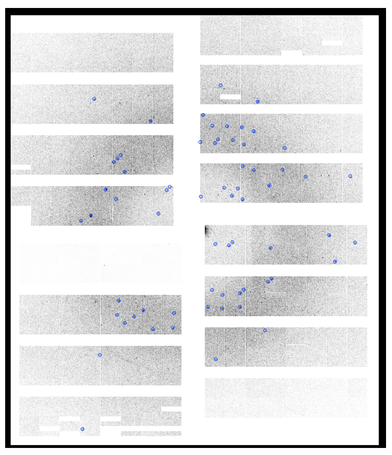
Calibration flows: CFEL lab and XFEL cases



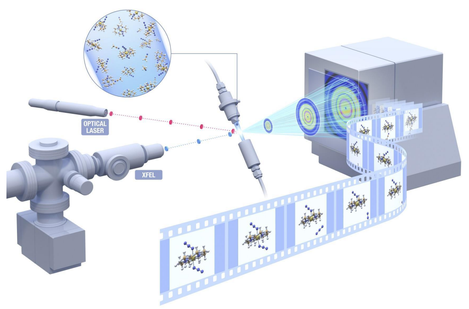
First User Experiments @ European XFEL



- 1MPix AGIPD system has been used in 5 of 6 first experiments at SPB/SFX instrument
- Frame rate 4.5 MHz
- 30 pulses @1.1MHz/train
- E=8keV
- Powder diffraction from lithium titanate (left)
- Automatic indexing (right)
- Reconstruction of Lysozyme (bottom)



A femtosecond experiment



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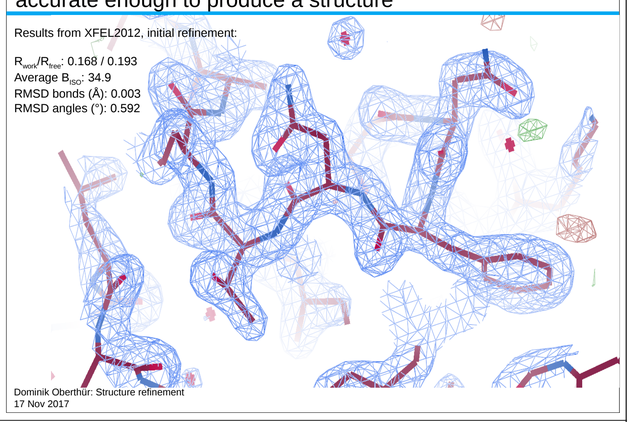
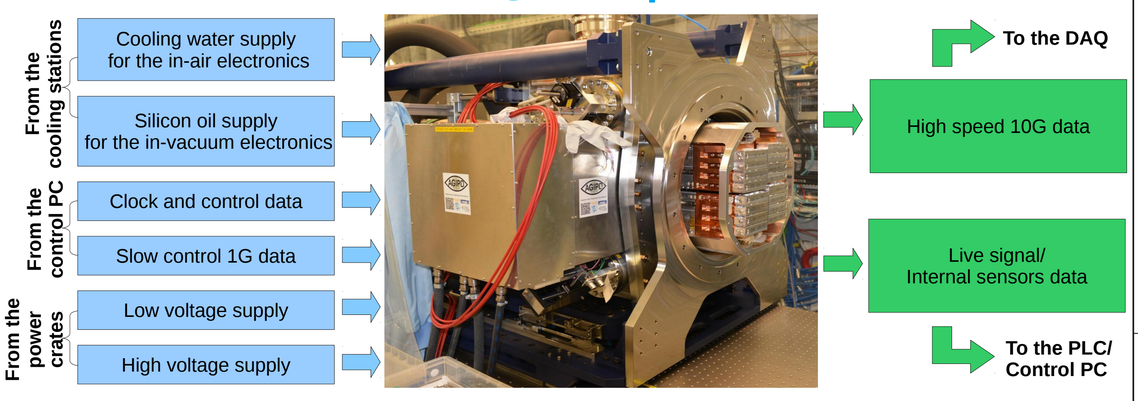
First round of reflection intensities from XFEL2012 data are accurate enough to produce a structure



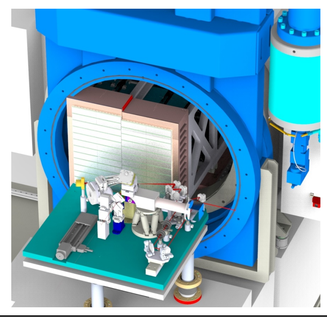
Detector infrastructure @ European XFEL



Future systems: in-vacuum read-out

4MPix AGIPD for SFX at SPB/SFX instrument

- Si sensors
- 56 sensor modules – divided into two halves
- 22cm x 44cm sensitive area each
- 400 mm travel range along the beam
- Delivery December 2018



1MPix AGIPD for HiBEF at HED instrument

- High-Z sensors
- 16 sensor modules – one monolithic block
- Delivery with Si sensors in November 2018
- Upgrade to High-Z in summer 2019

Commissioning tasks for the AGIPD @XFEL

- Remote upgradeable over Ethernet firmware
- XFEL format compatible data output
- Accepting clock & control input
- Generating interlock input: temperature, live signal etc.
- Exchanging the front-end modules due to the HV failures
- Support the users with data correction
- Search for the first XFEL beam
- Generating output for the **official start of XFEL!**

Ongoing:

- Increasing the data output rate
- Switching to faster (25 MHz) data read-out
- Implementation of the current source scan in quasi-burst mode due to longer integration times
- Moving from double-frame read-out to Analog and Gain data as a single image (bit splitting)

Acknowledgments

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