

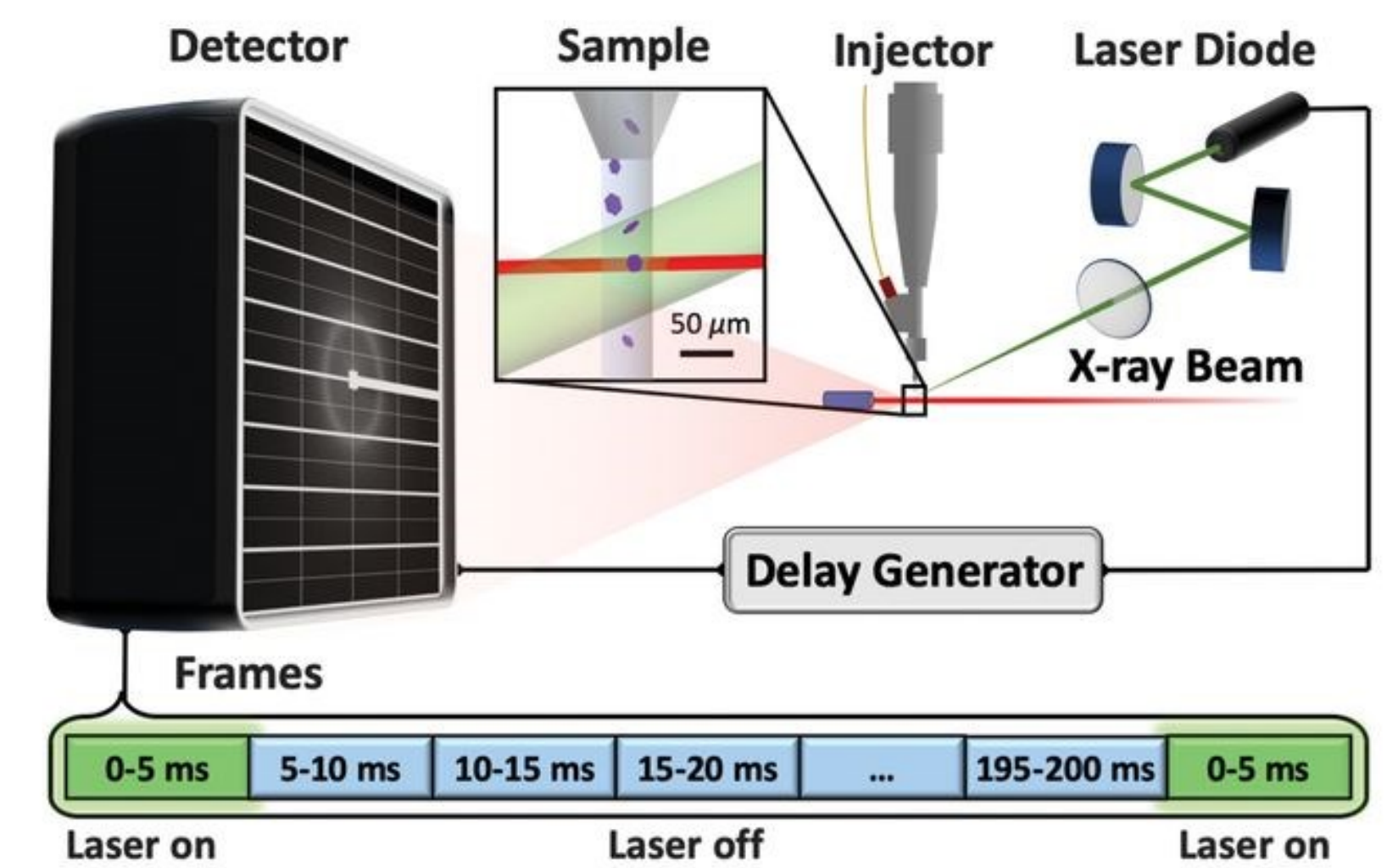
Jungfrauoch: Data Acquisition and Real-Time Image Analysis System for KiloHertz X-Ray Pixel Array Detector

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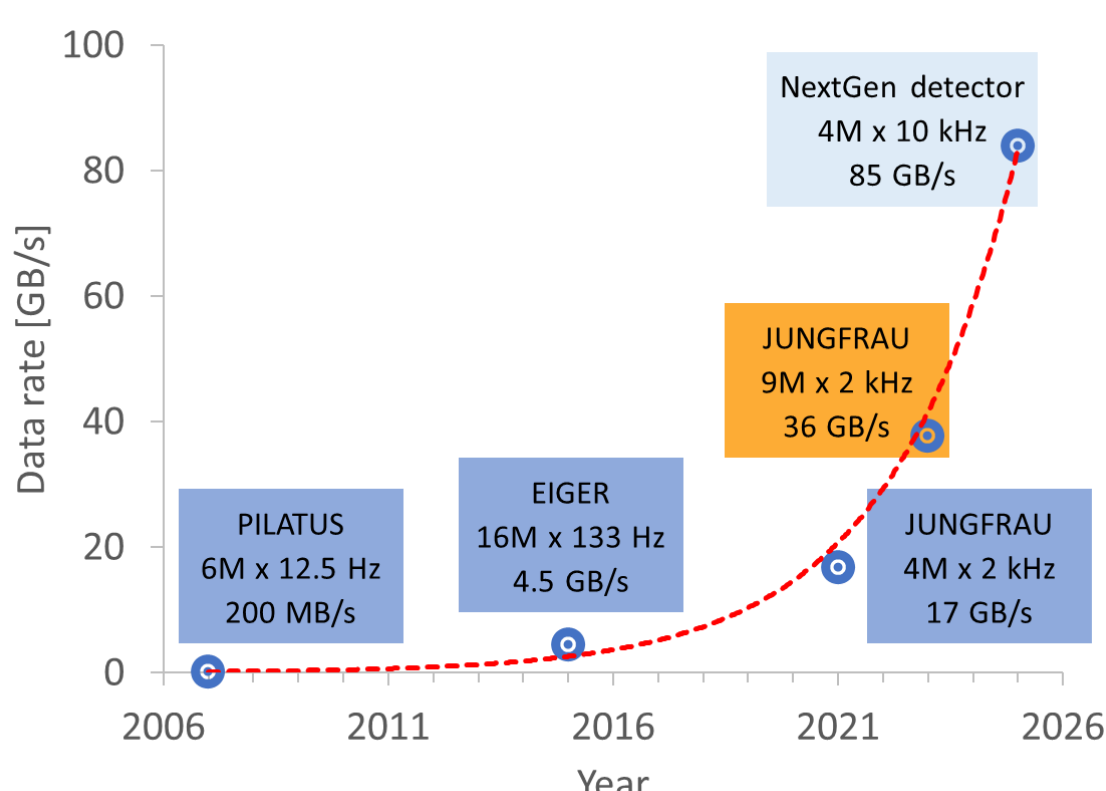
Science application: serial crystallography

Serial crystallography solves protein structures with diffraction images from thousands of crystals. This is the most data intensive technique for macromolecular crystallography, as it requires surplus of diffraction images (up to 1 million) and high frame rates (few kHz), especially in time resolved mode.

At Paul Scherrer Institute (PSI) serial crystallography is performed at **SwissFEL** (Alvra / Crystallina) and **Swiss Light Source** synchrotron (VESPA endstation at X06SA).



T. Weinert et al. (2019). *Science*, **365**, 61-65.



Detector data rates double every two years for PSI MX beamlines. Exponential increase in data rates is a challenge for data infrastructure, as modern CPUs develop slower.

JUNGFRAU 9 Mpixel detector: 36 GB/s stream challenge

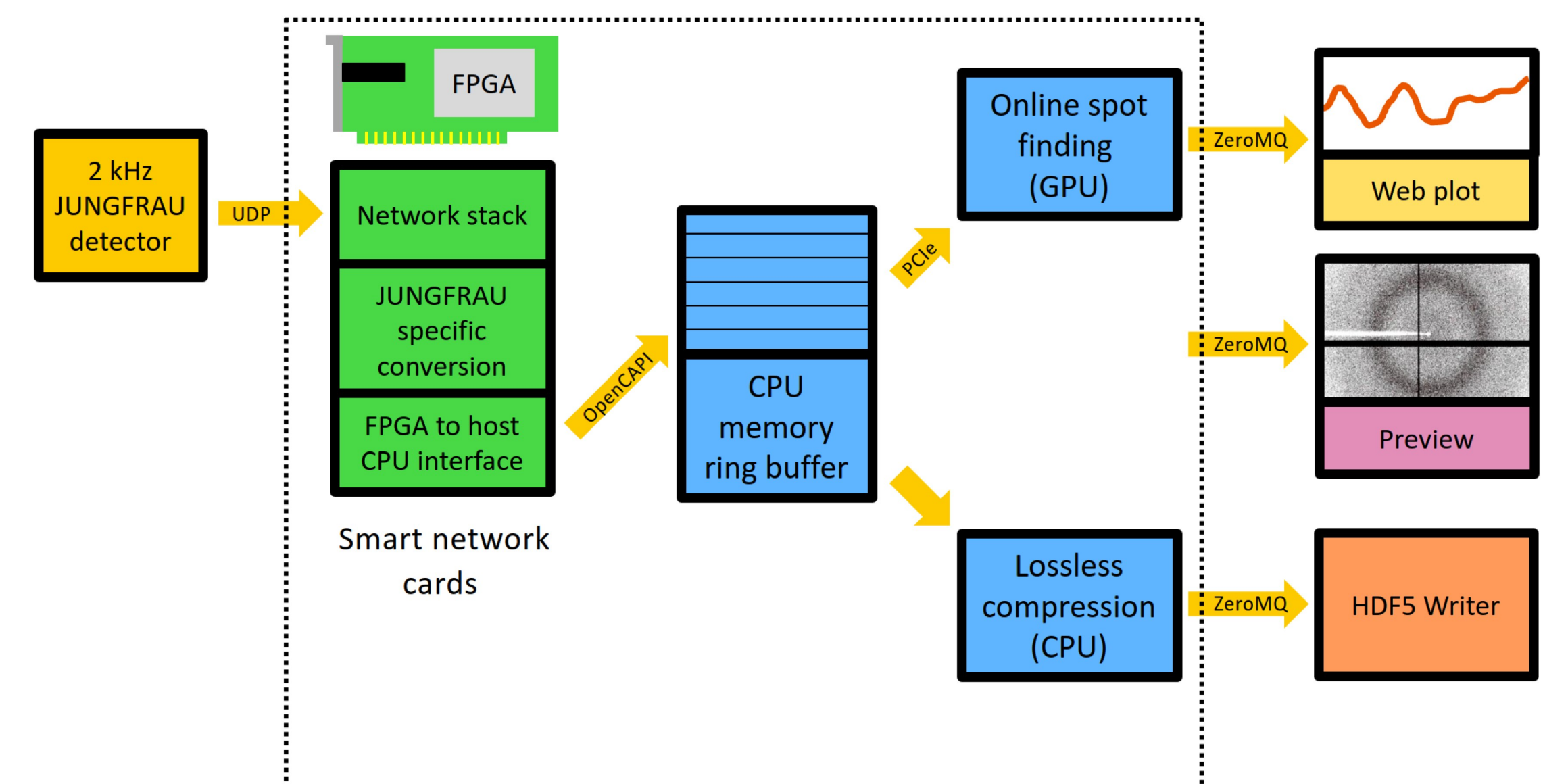
JUNGFRAU is an adaptive-gain charge integrating X-ray pixel array detector developed at the Paul Scherrer Institute. For the X06SA beamline at the upgraded SLS 2.0, PSI is currently commissioning a 9 Mpixel detector, able to operate up to 2.2 kHz frame rate.

During acquisition the detector is producing **36 GB/s** of data, which needs to be handled by IT infrastructure during long, continuous measurements.

Solution for data challenge: Jungfrauoch data acquisition system

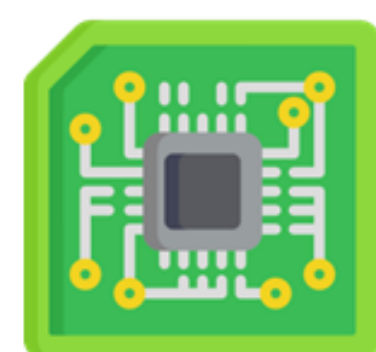
Jungfrauoch is a single-server solution to handle high data rates from pixel array detectors. Currently the system is targeting charge-integrating detectors. **We have successfully acquired data with 36 GB/s JUNGFRAU 9 Mpixel using Jungfrauoch.**

Now, we develop **on-the-fly rejection of images without crystals** (approx. 90%) and lossy compression. Also, recently work has been started with leading X-ray detector company, **DECTRIS**, to evaluate the system in operation with their photon-counting systems.



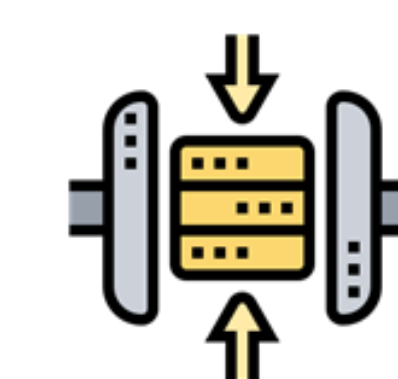
“Black box” design

Like DECTRIS Detector Control Unit: all-in-one
 Optimized for MX science case



From specialized CPU to mainstream architecture

IBM POWER/OpenCAPI (2021)
 X86/PCI Express (2023)

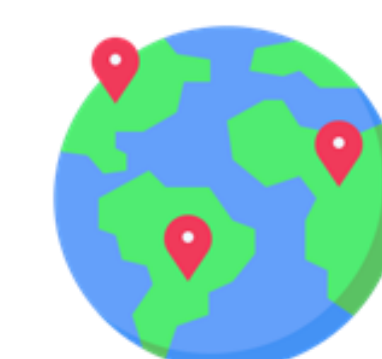


Community accepted interfaces for file writing (HDF5/NXmx) and streaming (DECTRIS Stream2)



HW and SW platform

FPGA smart network card
 Image analysis on GPU
 Compression on CPU



Simple deployment of JUNGFRAU for MX beamlines: tested at SLS (CH), MAX IV (SE) and KEK (JP)

Funding

Innosuisse: NextGenDCU Innovation Project with DECTRIS
 ETH Council: Open Research Data Contribute Project
 Swiss Data Science Center: RED-ML Project



On-the-fly analysis algorithms

Spot finding
 Bragg peak indexing
 Radial integration

For more information

F. Leonarski et al. (2018). *Nat. Methods*, **15**, 799–804.
 F. Leonarski et al. (2020). *Struct. Dyn.*, **7**, 014305.
 F. Leonarski et al. (2022). *J. Synchrotron Rad.*, **30**, 227-234.
 F. Leonarski, J. Nan, et al. (2023). *IUCr*, accepted.

<https://gitlab.psi.ch/jungfrauoch/jungfrauoch>