FEL diagnostics and control system

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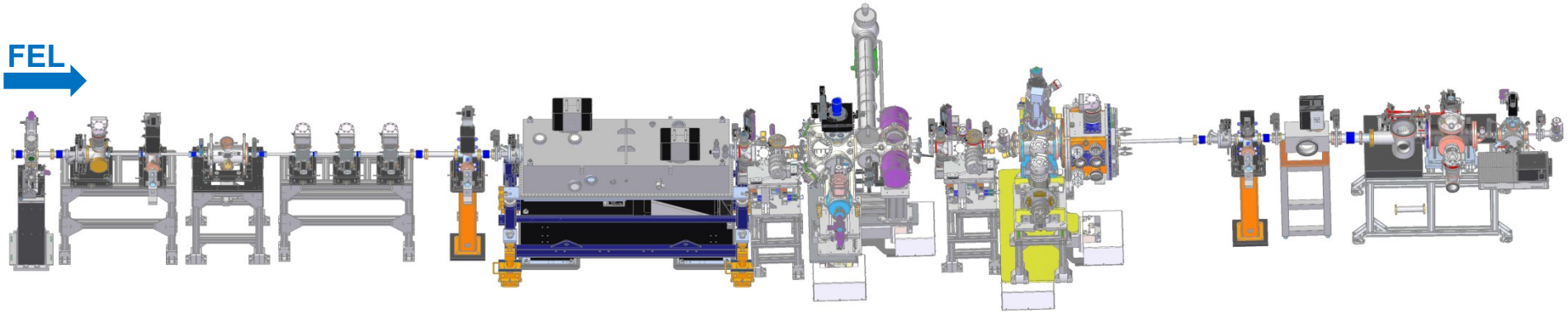
Outline

- FEL diagnostics
  - Overview
  - Imagers
  - Alignment laser
  - Intensity monitor
- Control and DAQ system
  - Control system overview
  - Karabo
  - PLC system
  - DAQ system

Overview on the diagnostics of the SQS beamline

Upstream diagnostics | **KB Mirrors** | **F1 / F1'** | **F2** | **Downstream diagnostics**



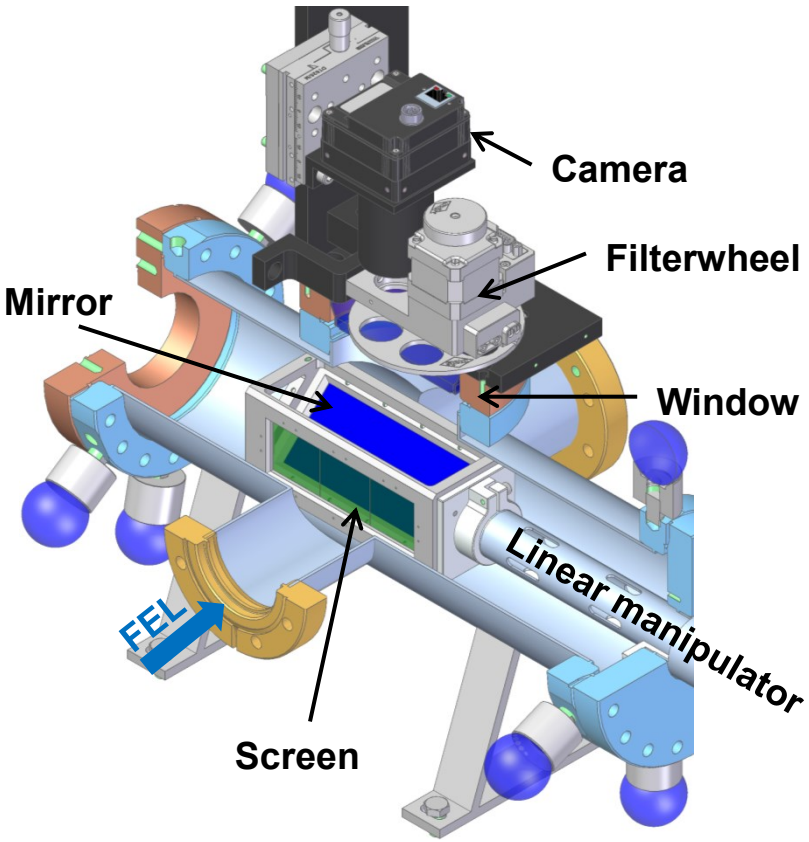
Alignment laser
Slit system
Imager
Intensity monitor
Slit system
Imager
Slit system
Imager
Diagnostic paddle
Slit system
Imager
Diagnostic paddle
Slit system
Imager
Wavefront sensor
Imager
Slit system
Spectrometer
Timing diagnostics (with Imager)

Diagnostics available on day 1 of commissioning

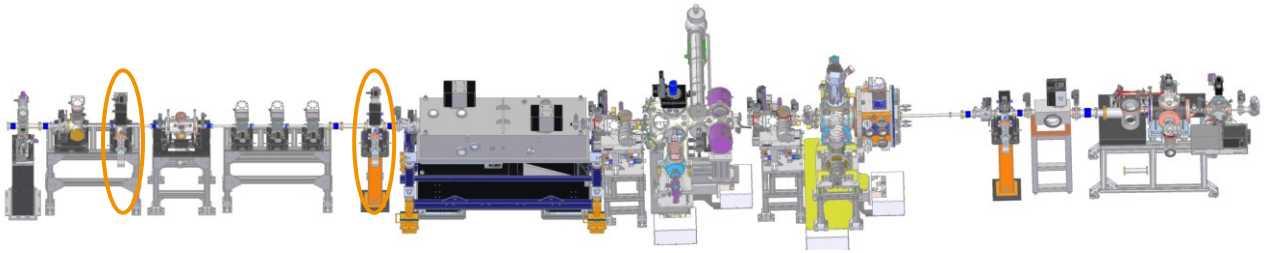
FEL imagers

Upstream diagnostic section imagers:

- Screen/Mirror unit on motorized linear manipulator.
- 90° design using a mirror.
- Space for up to three scintillators (40 x 40 mm²).
- Scintillator: pBN, Ce:YAG.
- Basler Aviator camera, 1600 x 1200 Pixel, 55 fps.
- Field of view: 50 x 38 mm².
- Resolution: 32 µm / Pixel.



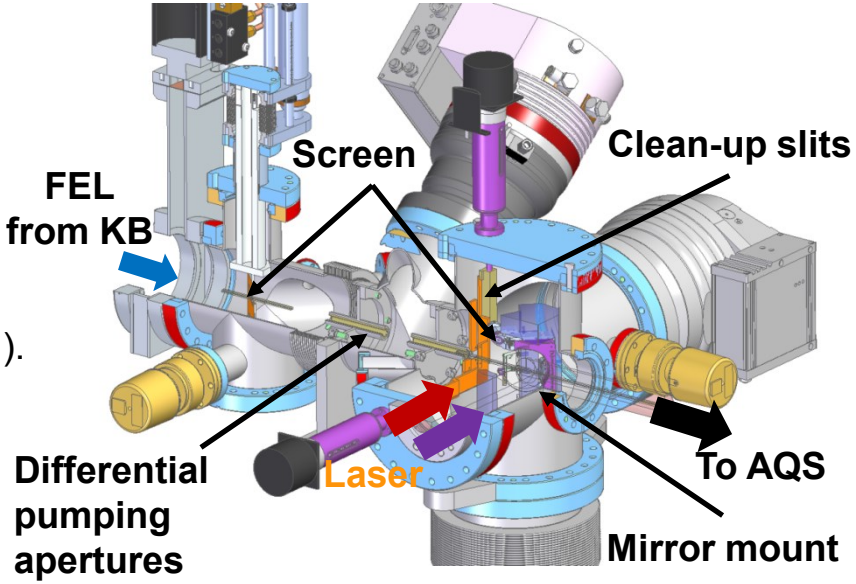
- Designed in collaboration with European XFEL WP-74.



FEL imagers

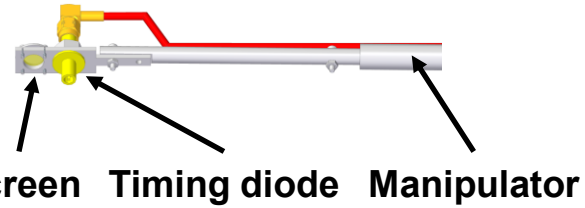
Differential pumping section:

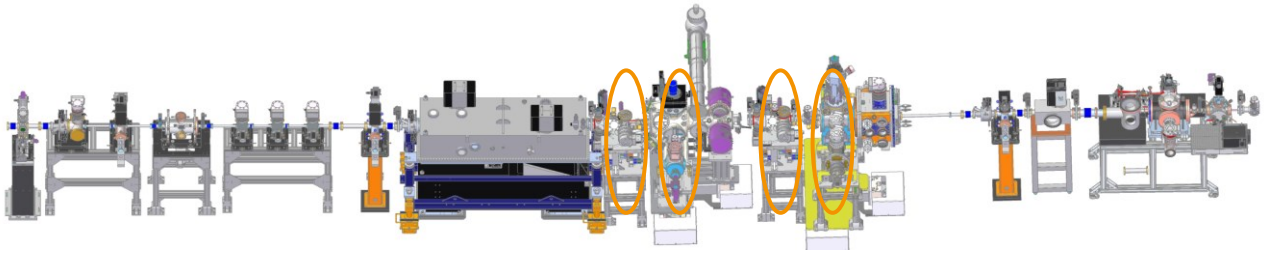
- One screen upstream of differential pumping (50°).
- One screen on the back of the in-coupling mirror (35°).
- Basler Aviator camera, 1600 x 1200 Pixel, 55 fps.



Diagnostic paddle:

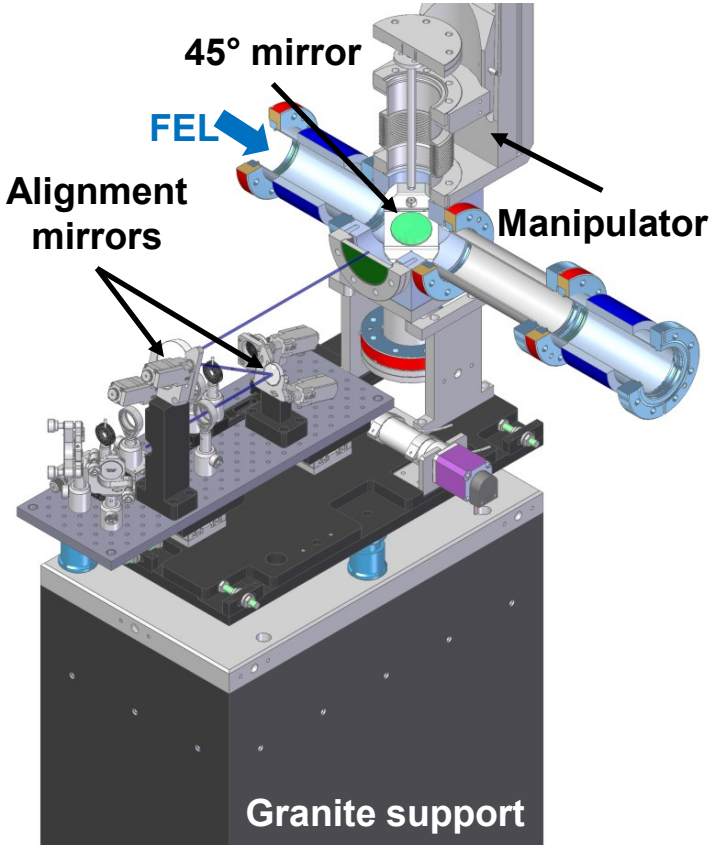
- Screen (8 mm diameter) and timing diode.
- Inserted to interaction region.



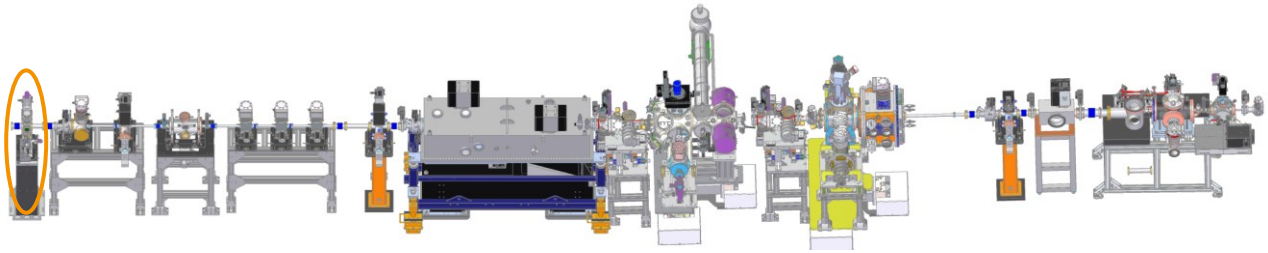


Alignment laser

- Laser follows the FEL path to help experiment alignment.
- Two motorized kinematic mirror mounts (16°).
- 45° in vacuum mirror (magnetic base).
- Laser and optics on small breadboard.
- Shift of beam position in different operation modes:
  - Vertical shift (Monochromator or pink beam)
  - Horizontal shift (M2 mirror)
- Alignment procedure using two imagers.

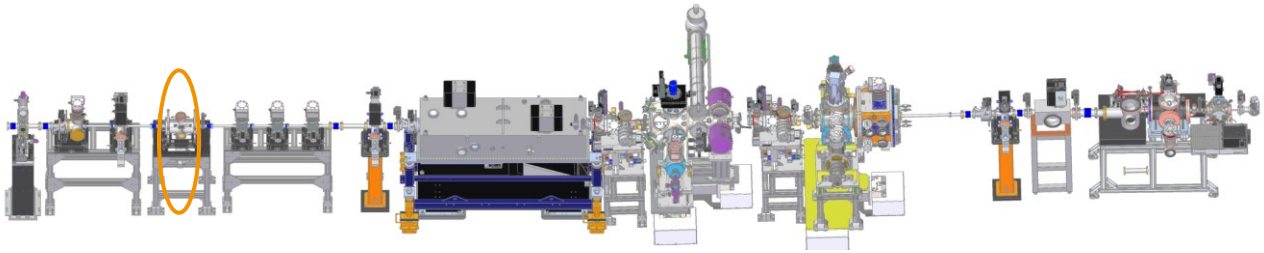


- Designed in collaboration with European XFEL CIE.



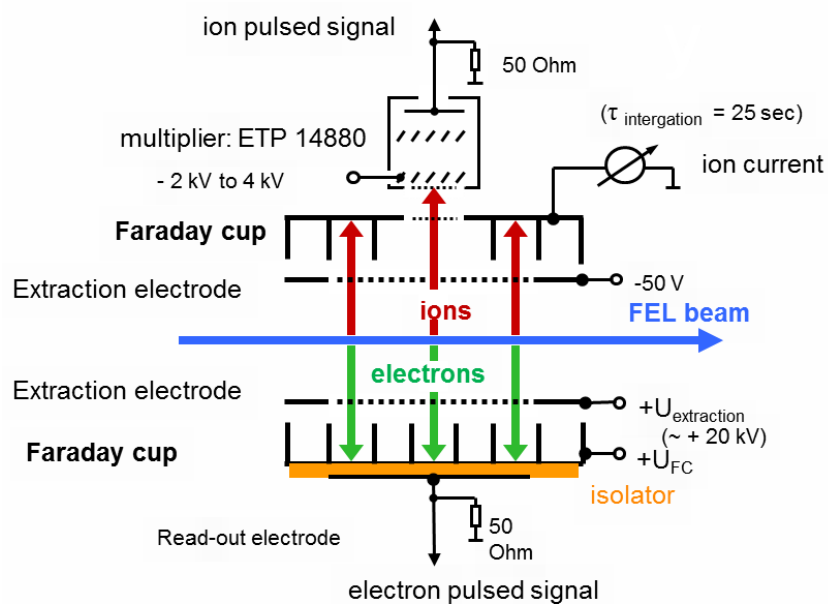
Intensity monitor: GMD (Gas Monitor Device)

- Measurement of FEL intensity from photo-ion current.
- XGM in the XTD10 tunnel.
- Simplified GMD in upstream diagnostic section of SQS.
- Built by DESY (K. Tiedtke, *et al.*).

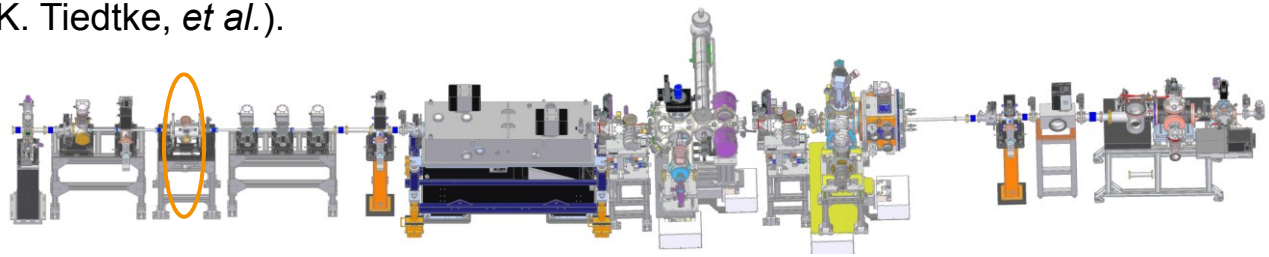


Intensity monitor: GMD (Gas Monitor Device)

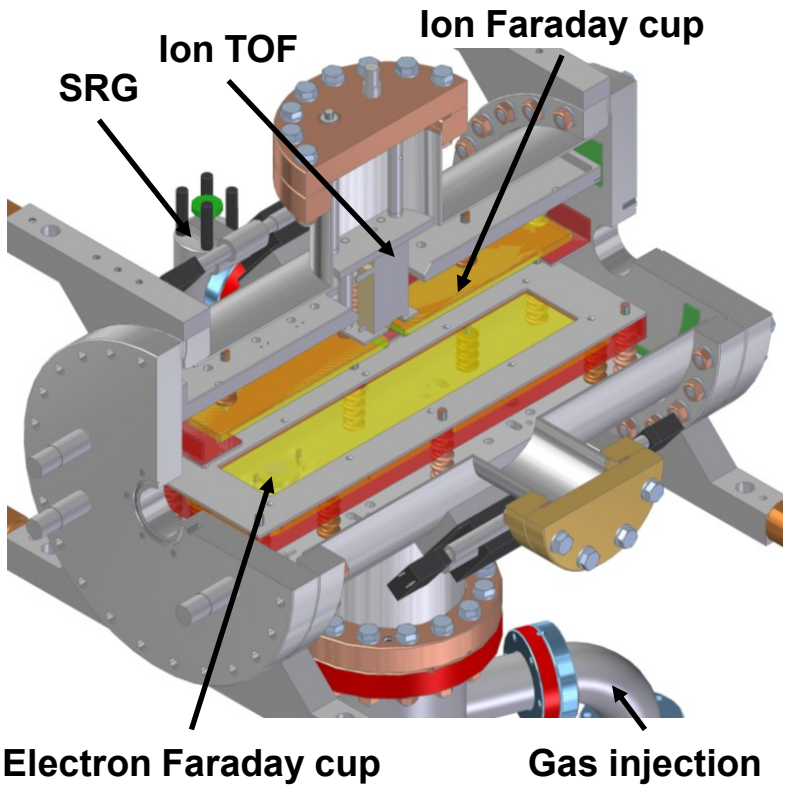
- Target gas Ne, Ar, Kr, Xe, depending on FEL energy.
- Operating pressure 10^{-6} – 10^{-4} mbar.
- Slow ion current measurement.
- Fast ion signal from TOF measurement.
  - Time resolution < 200 ns.
- Additional electron current measurement.
- Spinning Rotor Gauge for pressure measurement.
- Uncertainty for the pulse energy < 10%.
- Calibration measurement with 2nd GMD during commissioning.
- Collaboration with DESY (K. Tiedtke, *et al.*).

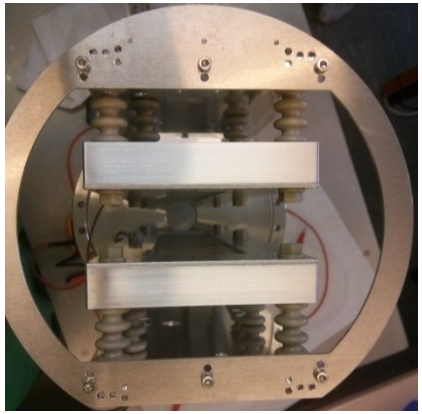


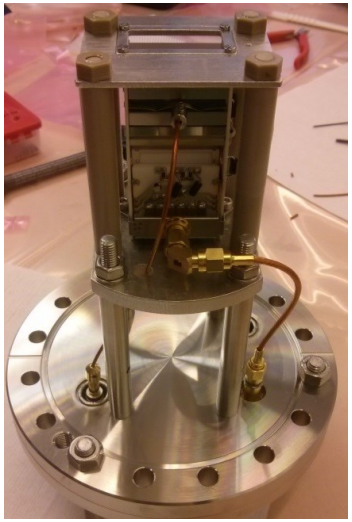
K. Tiedtke *et al.*, J. Appl. Phys. **103**, 094511 (2008)



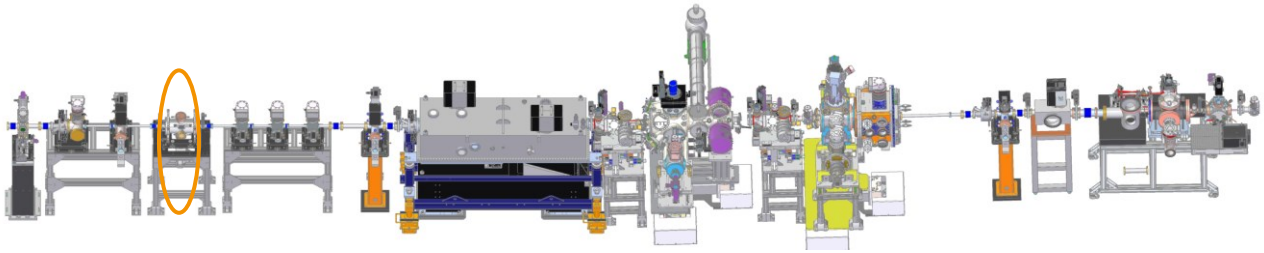
Intensity monitor: GMD (Gas Monitor Device)







TOF electron multiplier:
ETP 14880 (dynode)
Pulse width: 2 ns
Gain; 10^6



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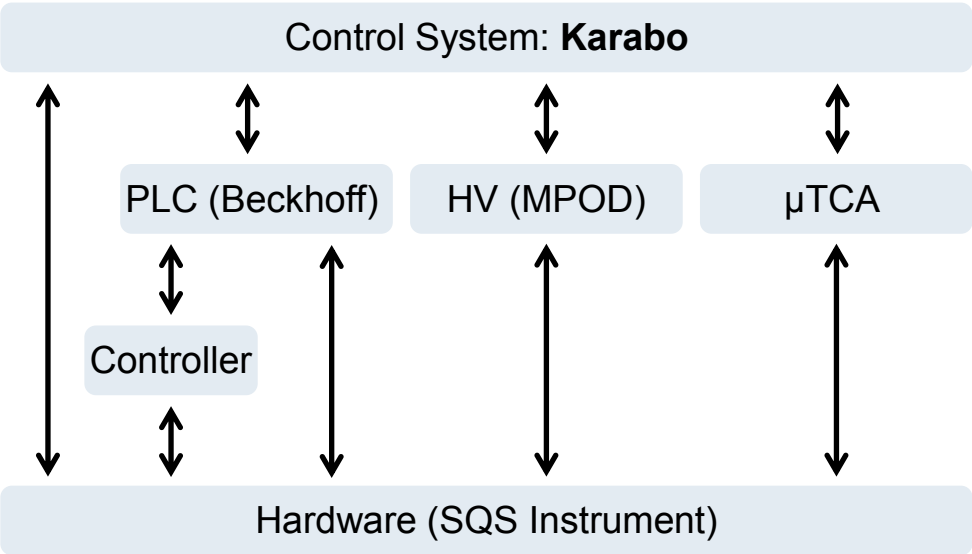
  - Karabo
  - PLC system
  - DAQ system

Control system overview

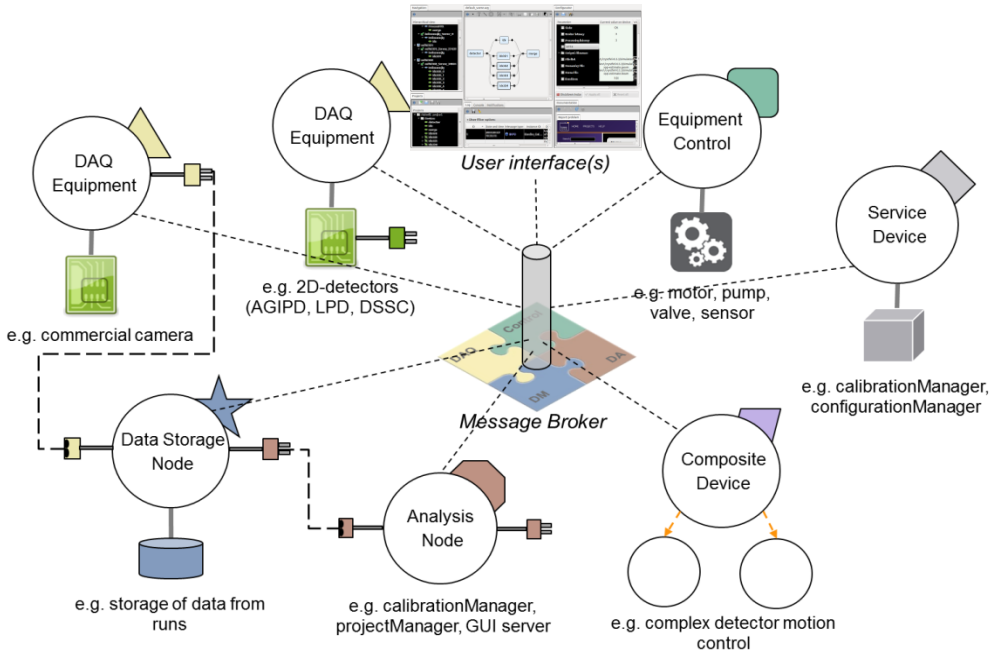
- General requirements:
  - Instrument in hutch => remote control
  - One common system for all hardware
  - Interlocks
  - DAQ system for 4.5 MHz operation



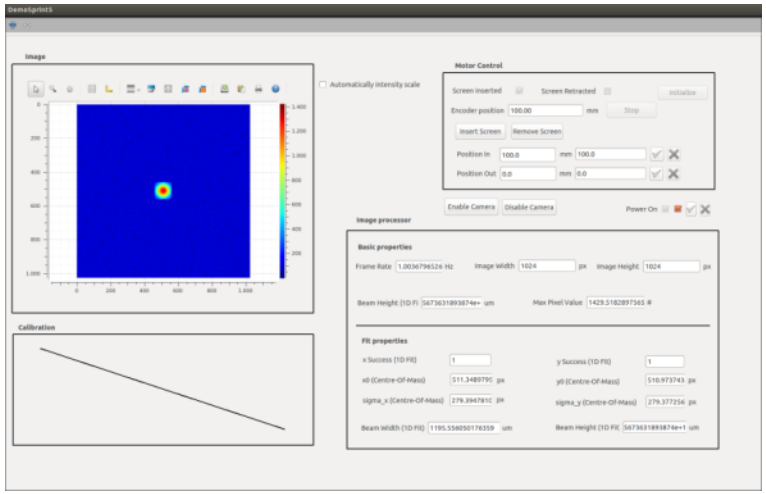
- Control system: **Karabo**
  - Slow controls
  - Fast DAQ
  - Data processing
- PLC (Beckhoff) for hardware control
  - Motors, pumps, valves, gauges, …
  - Interlock system
- Micro TCA for fast DAQ
  - Digitizers
  - Timing system
  - FPGA programming
- High voltage supplies in Wiener MPOD
- Direct connection (e.g. Cameras)

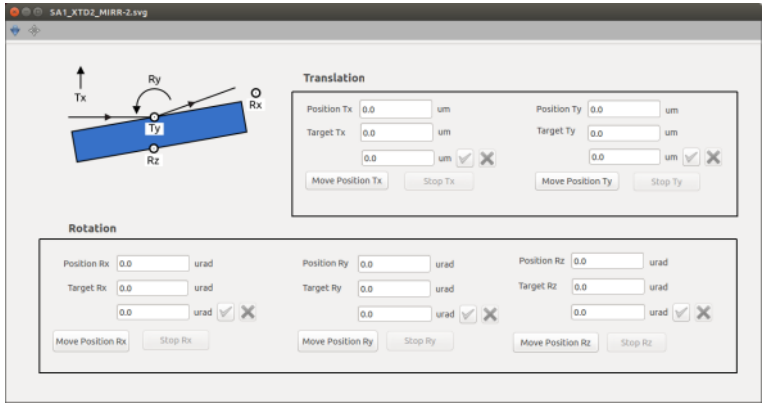
Karabo control system

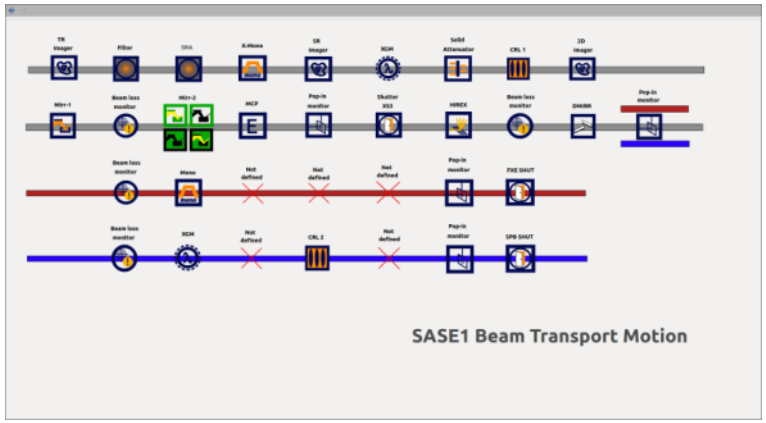
- Control system for
  - “Slow” hardware control
  - Fast data acquisition
  - Online data management
  - Online and offline data analysis
- Event based, broker based, asynchronous
- User interface (GUI, CLI)
- Scripting in Python or C++
- Tools provided for data analysis
  - Data processing (spectrometer dependent)
  - Fast pipelines for online analysis (also GPU)
  - Standard scripts for offline analysis
- Developed by European XFEL
  CAS group (S. Brockhauser, *et al.*)



Karabo control system

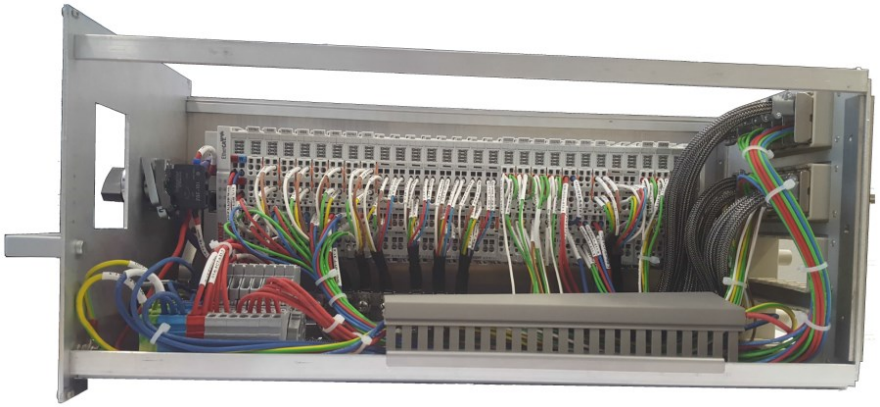


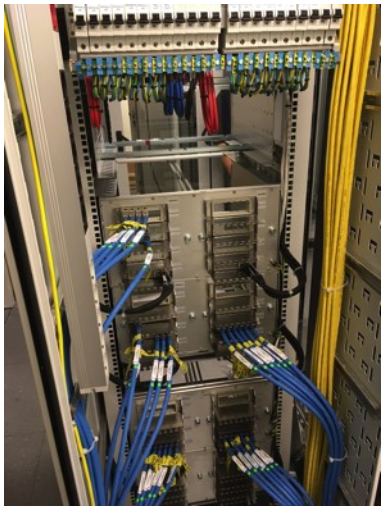




PLC (Programmable Logic Controller) system

- Terminals as interface to hardware
  - Analog I/O, Digital I/O, Motor supply, …
- PLC CPUs
  - Signal processing
  - Control programs
- EtherCAT communication interface
- Interlock system
- Standardized crates
  - Modular design
  - Decoupling of modules and cables
  - Simplifies assembly and maintenance
- European XFEL:
  - Advanced Electronics (P. Gessler, *et al.*)
  - Electrical Engineering (L. Wissmann, *et al.*)



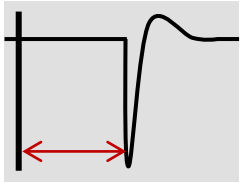


Fast data acquisition system: Example of a digitizer

Detector

Digitizer
- ▶ SPDevice
- ▶ 8bit to 14 bit
- ▶ 3 GHz
- ▶ 10 GS/s

MicroTCA crate
- ▶ Houses digitizers
- ▶ CPUs
- ▶ Clock & control system
- ▶ VETO system
- ▶ Timing system

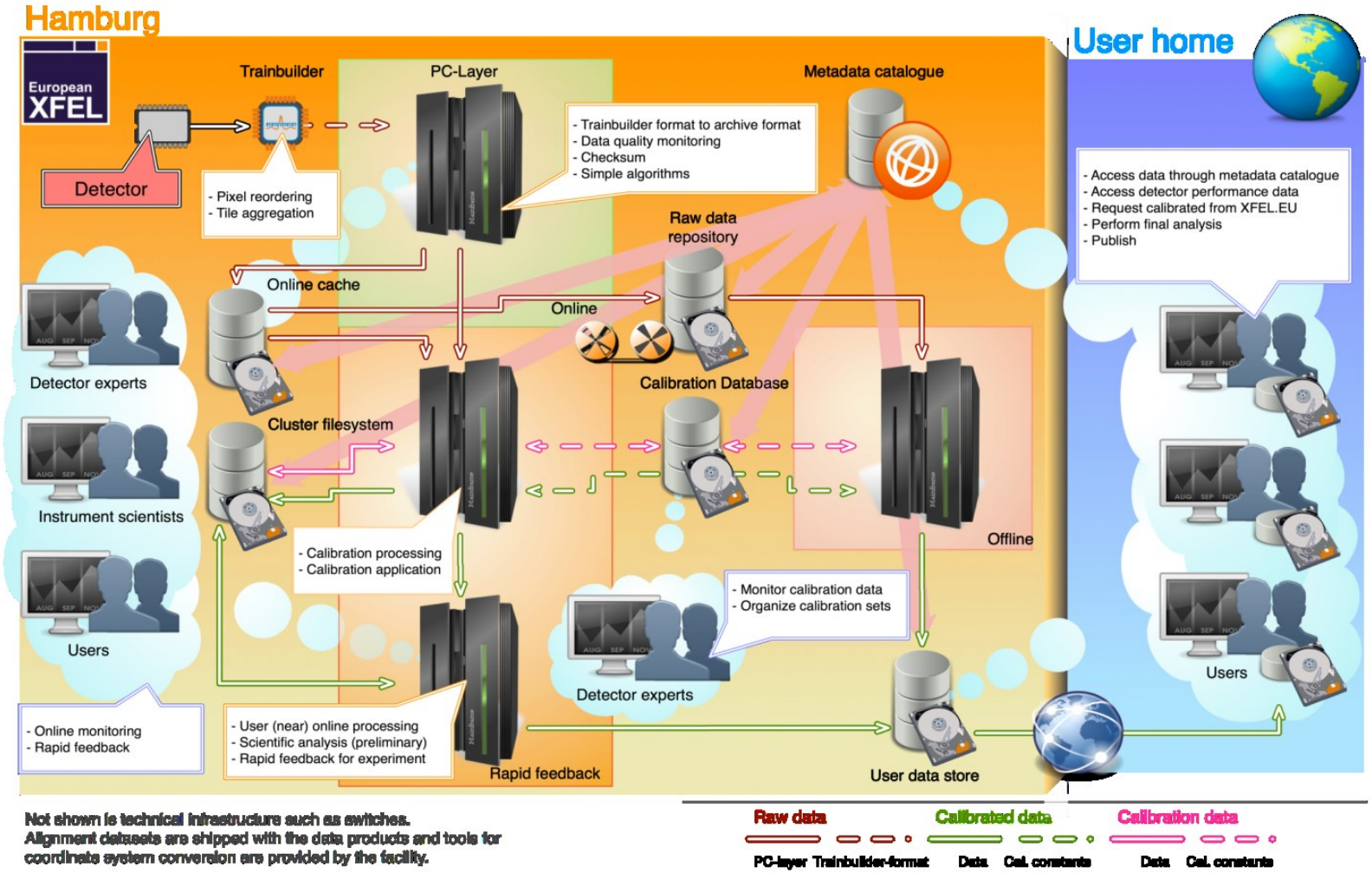


Fast data processing
- ▶ FPGA
- ▶ Pulse integration
- ▶ Zero suppression
- ▶ Peak detection

PC layer

European XFEL Advanced Electronics (P. Gessler, *et al.*)

Fast data acquisition system



Not shown is technical infrastructure such as switches.
Alignment datasets are shipped with the data products and tools for coordinate system conversion are provided by the facility.

European XFEL ITDM (K. Wrona, *et al.*), CAS (S. Brockhauser, *et al.*), WP-75 (M. Kuster, *et al.*)

Thank you for your attention!

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WP-74 (X-Ray Photon Diagnostics)

WP-75 (Detector Development)

WP-90 (Control & Analysis Software)

WP-91 (Advanced Electronics)

WP-92 (IT & Data Management)

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