CW Control System for the KALDERA Laser Plasma Accelerator at DESY

The 12th MicroTCA Workshop for Industry and Research

T.Jezynski[1], L.Butkowski[2], C.Duelsen[1], O.Hensler[3], P.Huesmann[2], J.Jaeger[3], Y.Janik[3], S.Jalas[1], H.Kay[2], M.Killenberg[2], M.Kirchen[1], G. Palmer[1], F.Peters[3], V.Petrosyan[3], D.Rothe[2], Holger Schlarb[2], H.Sotoudi[1], L.Winkelmann[1], P.Winkler[1], T.Wilksen[3], A.Maier[1]

1 – MLS-DESY
2 – MSK-DESY
3 – MCS-DESY

Tomasz Jezynski

tomj@desy.de

mls.desy.de
kaldera.desy.de

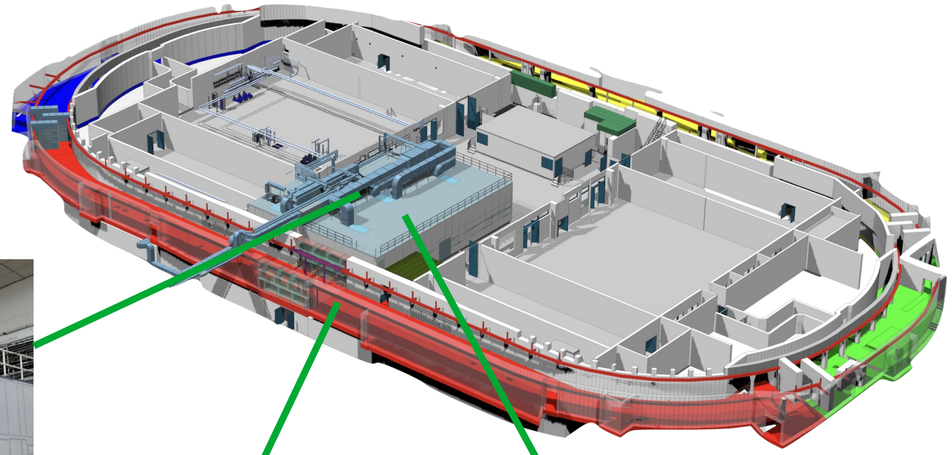
HELMHOLTZ

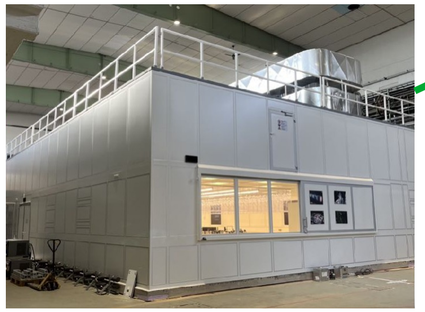
DESY.

Outline

- Introduction to KALDERA
- CW vs pulsed machine timing
- KALDERA control system
- Camera data processing
- DOOCS for CW KALDERA

Kaldera: Next-Generation Laser-Plasma Accelerator





KALDERA Laser Labor

- 400m² ISO5/6 clean room
- In operation since Oct 2022

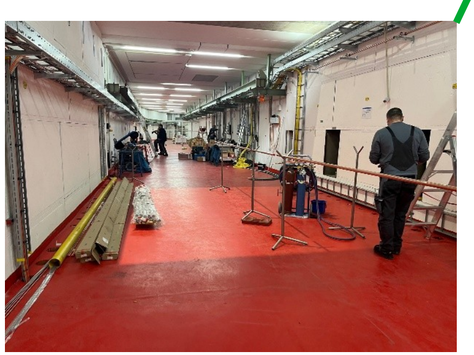
Plasma accelerator with high rep rates

- Active Stabilisation
- High average power
- Technology Demonstrator

Specifically

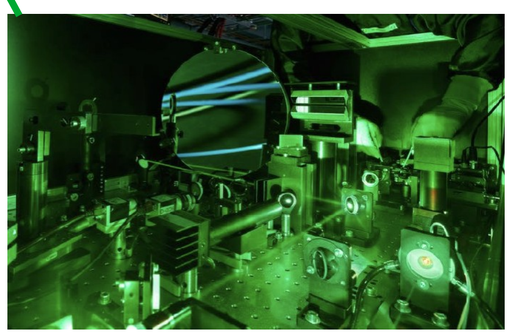
- New LPA Drive Laser and new Laser Lab
- Goal: FEL-quality electron beams @1GeV

Initiated by Wim



KALDERA Tunnel

- Generic structure for plasma accelerators
- Supports up to 1GeV @ 1kHz
- 1st plasma accelerator is being built up

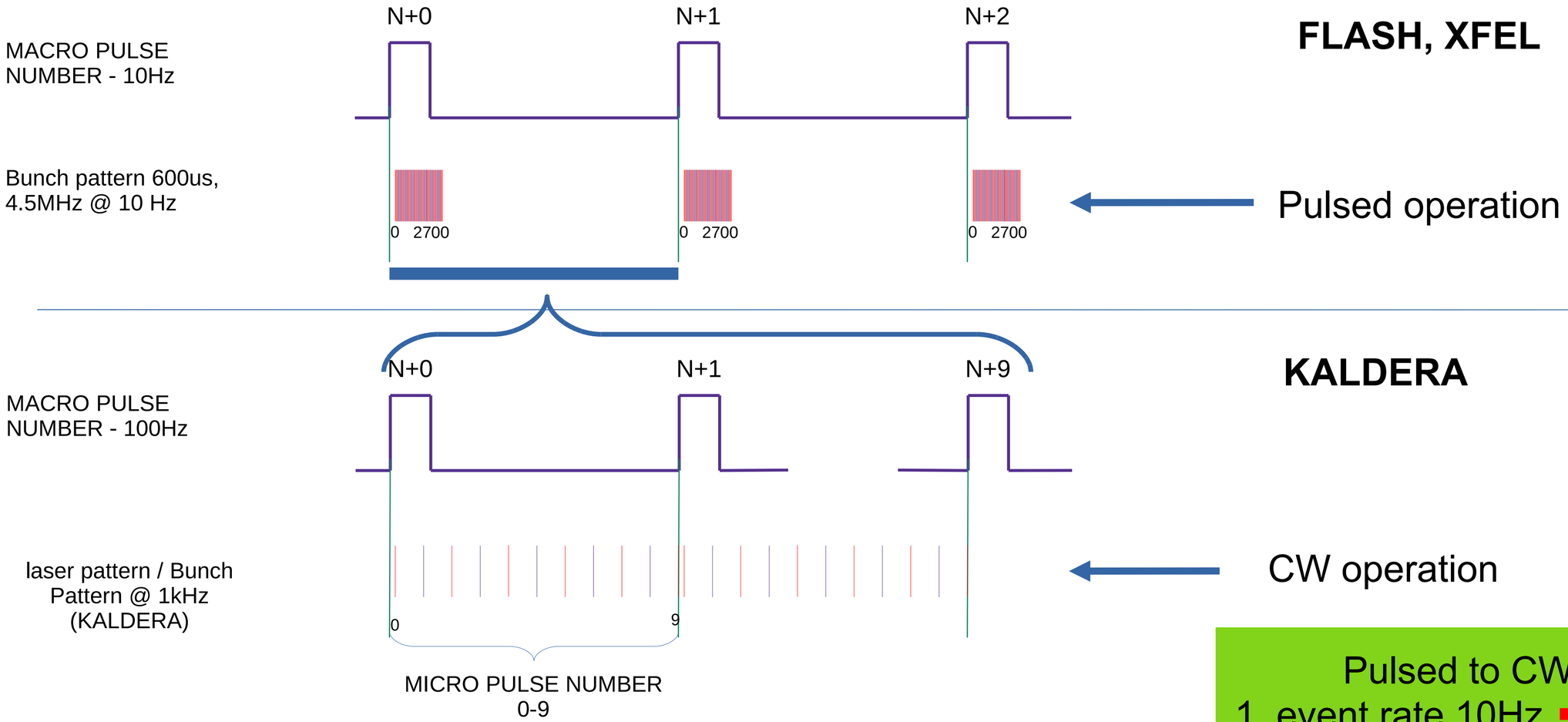


KALDERA Laser (under development)

- 100 TW @ up to 1 kHz
- 3J in 30 fs
- Active Stabilisation & Feedback

Pulsed and CW machines timing

FLASH, XFEL and KALDERA timing



Pulsed to CW operation:

1. event rate 10Hz → 100Hz
2. 2700 bunches @4.5MHz

↓ 10 bunches ↓ @1kHz

Control system

Functional requirements

constant performance monitoring of the laser and the plasma accelerator - ~seconds, rolling mean and std calculated over, e.g., 100-1000 events) and visualize the trends, environmental data, temperature in different parts of the laser, diode currents, cooling water temperature.

performing machine studies – 100Hz (1kHz), require a possibility to correlate machine data from individual events, a rare loss of data for individual events is acceptable, a raw camera data from selected cameras may be required

autonomously tuning the laser and plasma accelerator – fast and reliably set to a known operating point

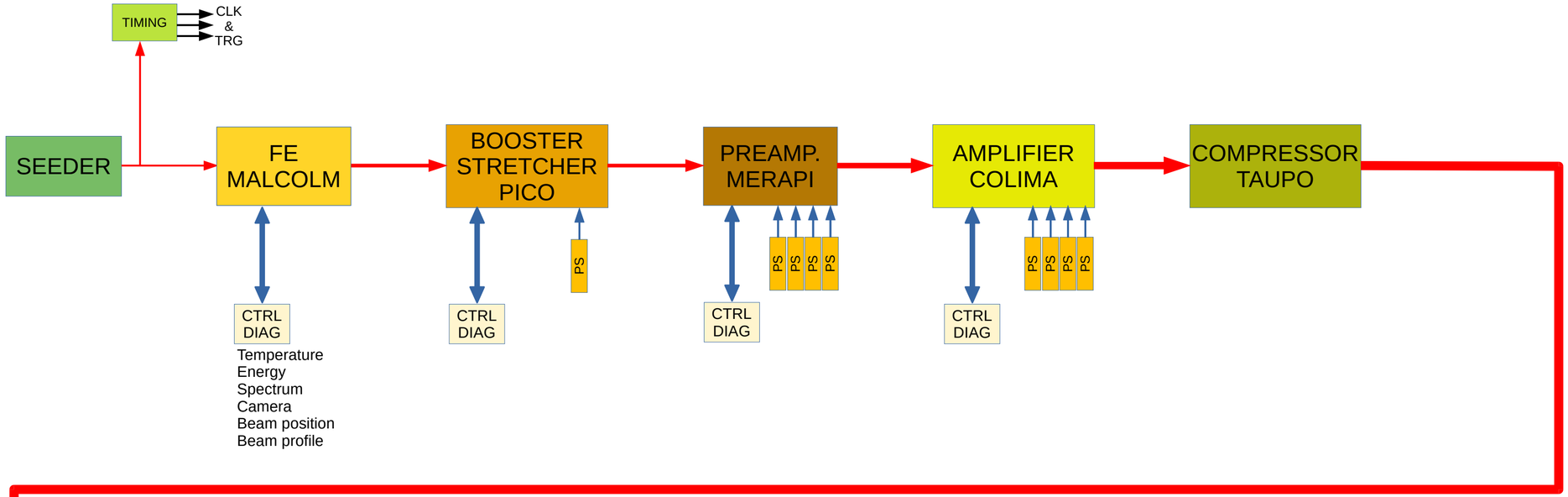
active drift compensation – slow, active stabilization based on servers, update rate 0.1-10Hz (cameras, energy matters, spectrometers, stepper motors)

active fast compensation – based on dedicated hardware, controlled by the CS, update rate 100-1000Hz (cameras, spectrometers, piezo actuators, ...)

store data for later analysis – no data lost, data consistency check, fast, distributed, scalable data base

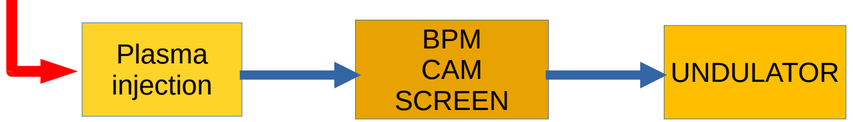
Laser Plasma Accelerator

Control system elements



LASER

ACCELERATOR

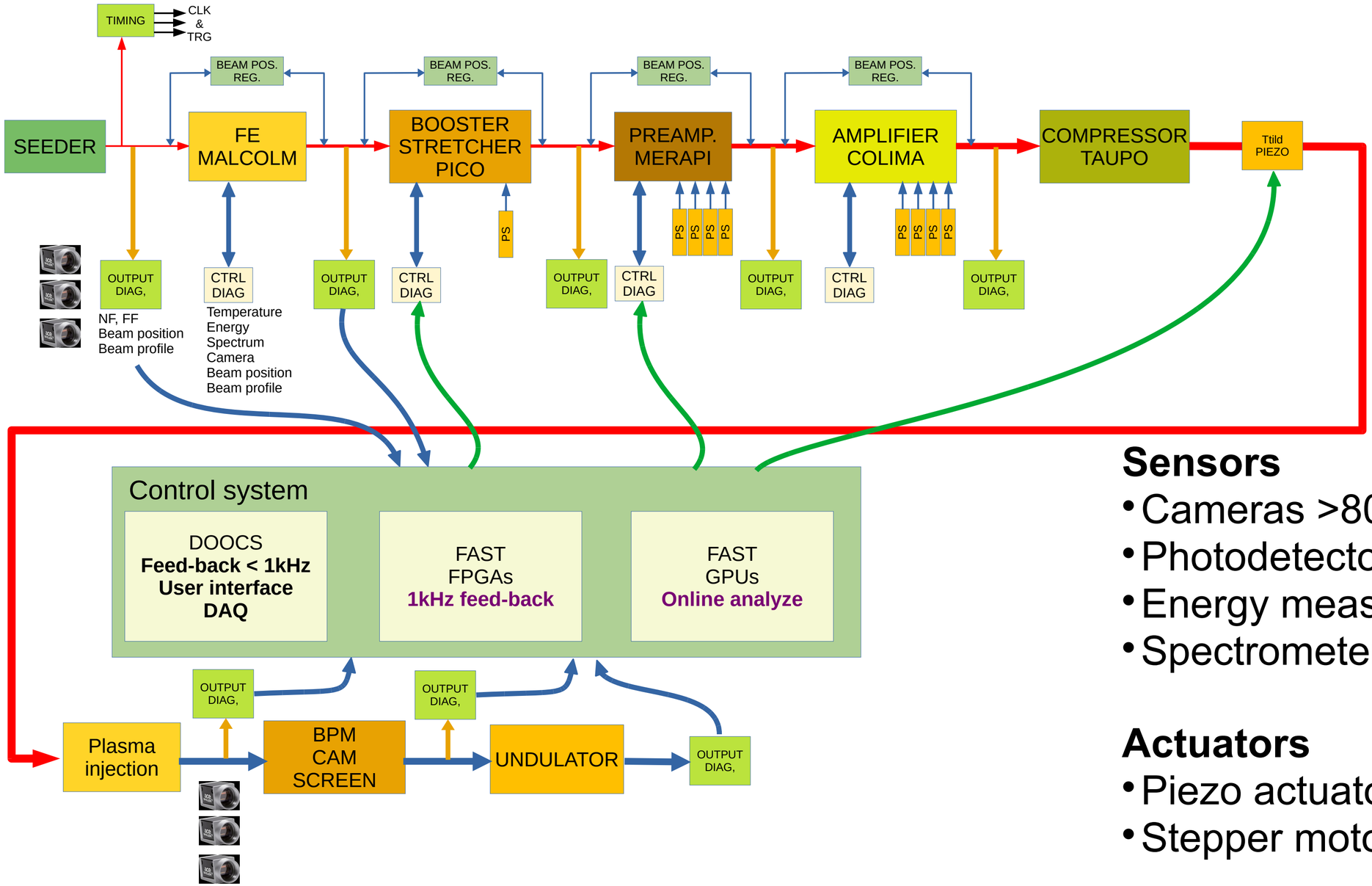


- Pump lasers
- Chillers
- Temperature control
- Temperature sensors
- Cameras >80

- Photodetectors >20
- Energy measurement >25
- Spectrometers >16
- Piezo actuators > 25
- Stepper motor > 60

Laser Plasma Accelerator

Multi-input, mulit-output controller



Sensors

- Cameras >80
- Photodetectors >20
- Energy measurement >25
- Spectrometers >16

Actuators

- Piezo actuators > 25
- Stepper motors > 60

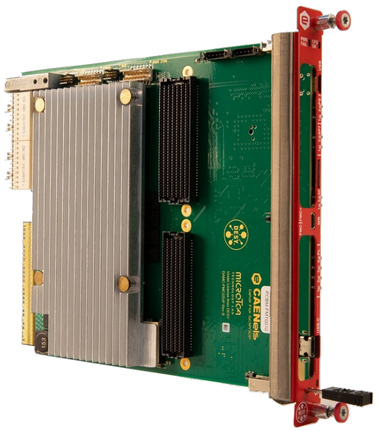
Control system

Hardware, firmware and software

	Component	Form factor	Software/Firmware
Timing	DESY x2timer	mTCA	MCS
	Splitters, converters, DESY FS-LA	custom	
Digitizers	16-bit, 125MHz, DESY/Struck	mTCA	MSK, MCS
	10-14 bit, ~kHz PLC,DESY, MCS	19“ crate	
Pizeo driver	DESY, PZT4	mTCA	MSK, MCS
Data processing	DESY, DAMC-ZUP2	mTCA	MSK, MCS
	GPUs Servers	19“ crate	
Sensors	Photo det., front-end DESY, FS-LA	custom	FS-LA
Control system	DOOCS DESY		MCS
Camera data processing	GigVision Core, DESY	-	TechLab, ITT

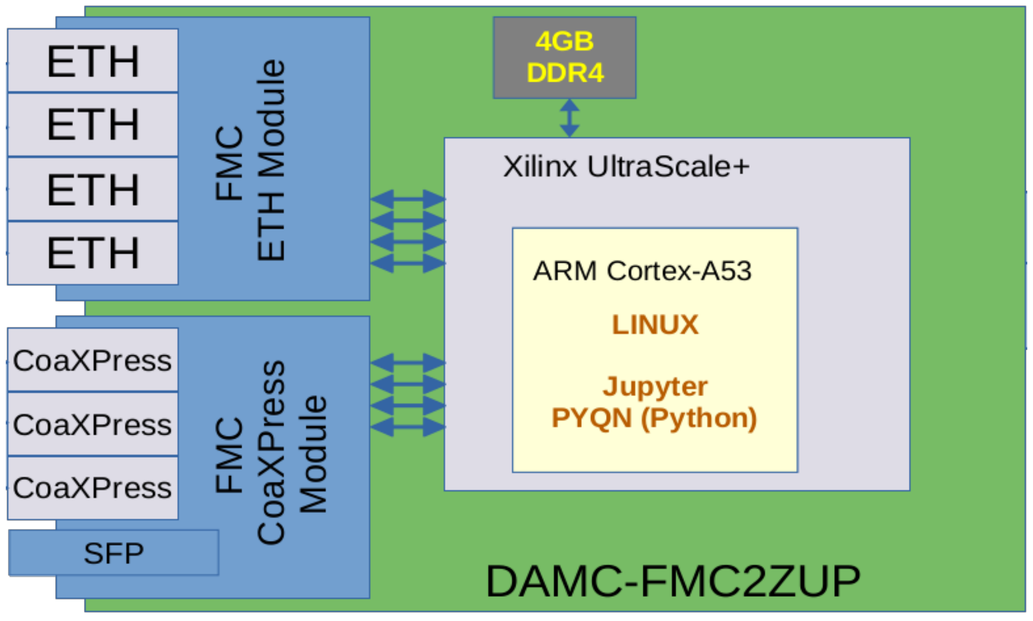
Camera Data Processing in FPGA

MSK Framework



FWK
FPGA firmware framework





Open Source FPGA Framework developed by MSK-DESY

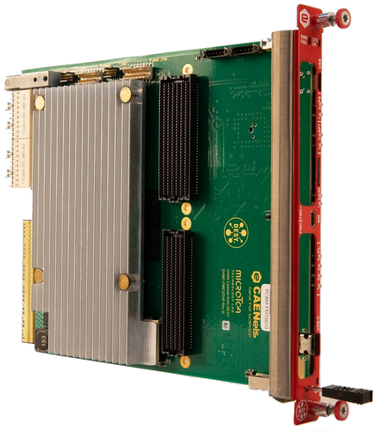
- access to peripherals
- intergration of timing system
- possibility of adding your own modules - for KALDERA **GigVision** core
- space for user applications – e.g. cam. data pre-processing
- Interface to the control system – ChimaraTK and **DOOCS**
- User Python code at resonable speed

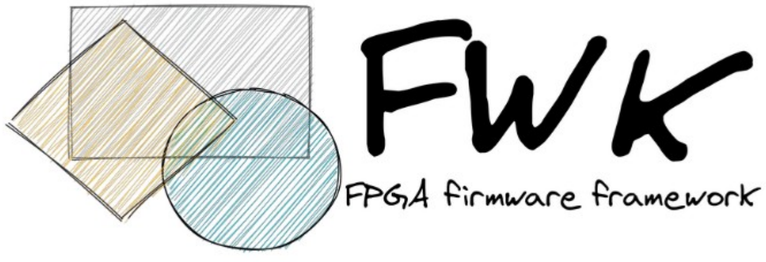
Use in:

- FPGA data processing (cameras)
- Machine protection
- Fast feed-back (e.g. camera→ piezo)

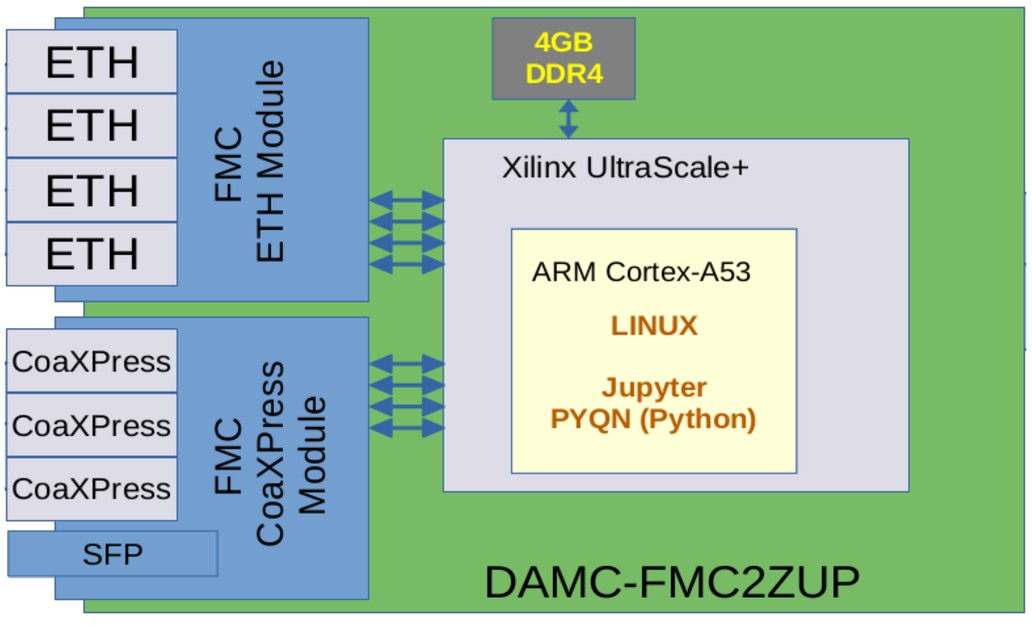
Camera Data Processing in FPGA

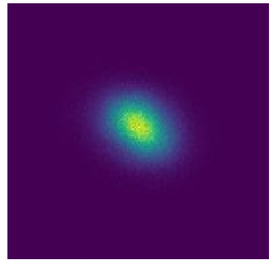
MSK Framework





- Camera data is processed @1kHz
- ChimeraTK and DOOCS interface
- Beam parameters calculated in FPGA
  - Beam diameter, min, max, last 100s
  - Centroid XY, min, max, average last 100s



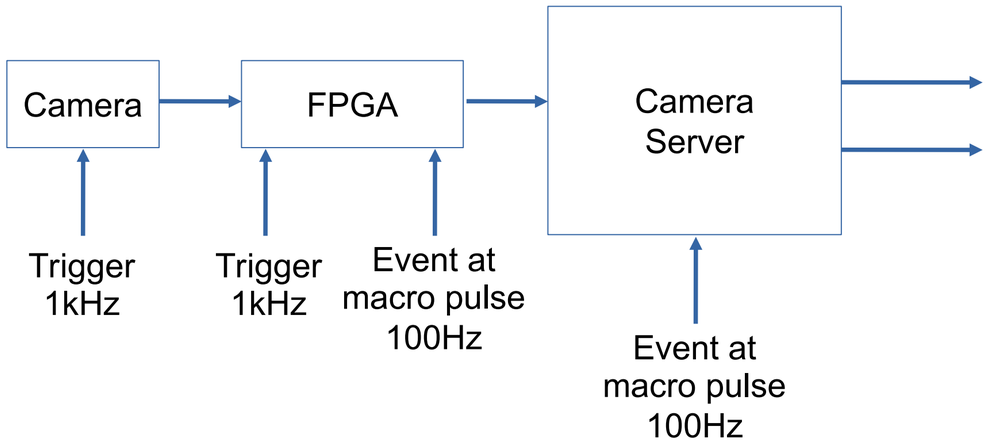


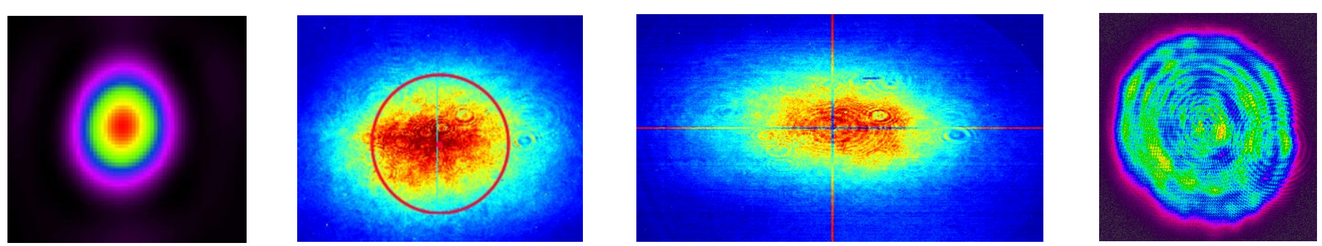
meanx	meany	stdx	stdy
212.0	90.0	14.0	10.0
212.0	90.0	16.0	9.0
212.0	90.0	14.0	12.0
212.0	90.0	16.0	10.0
212.0	90.0	15.0	12.0
212.0	90.0	17.0	13.0
212.0	90.0	16.0	11.0
212.0	90.0	17.0	12.0
212.0	90.0	17.0	12.0
212.0	90.0	17.0	10.0
212.0	90.0	18.0	13.0
212.0	90.0	17.0	10.0
212.0	90.0	18.0	13.0
212.0	90.0	19.0	12.0
212.0	90.0	18.0	11.0
212.0	90.0	19.0	13.0
212.0	90.0	19.0	12.0
212.0	90.0	19.0	11.0
212.0	90.0	20.0	13.0
212.0	90.0	20.0	12.0
212.0	90.0	19.0	12.0
212.0	90.0	19.0	13.0
212.0	90.0	19.0	11.0
212.0	90.0	19.0	13.0
212.0	90.0	18.0	13.0
212.0	90.0	18.0	12.0
212.0	90.0	18.0	13.0
212.0	90.0	18.0	11.0
212.0	90.0	17.0	12.0
212.0	90.0	18.0	12.0
212.0	90.0	17.0	12.0
212.0	90.0	18.0	12.0
212.0	90.0	17.0	13.0
212.0	90.0	18.0	11.0
212.0	90.0	18.0	13.0
212.0	90.0	18.0	12.0
212.0	90.0	19.0	11.0
212.0	90.0	19.0	12.0
212.0	90.0	20.0	11.0

DOOCS servers

CW camera to DAQ

macro pulse number	n+1										n+2										n+3									
micro pulse number	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Raw cam data (pre-processed) or centroid data for each frame	FRAME 0	FRAME 1	FRAME 2	FRAME 3	FRAME 4	FRAME 5	FRAME 6	FRAME 7	FRAME 8	FRAME 9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9





In some cases: need to save raw (or partially pre-processed) data from individual cameras (1-2) at maximum speed.

Existing servers must be adapted to this concept. Also, changes to the DAQ are required.

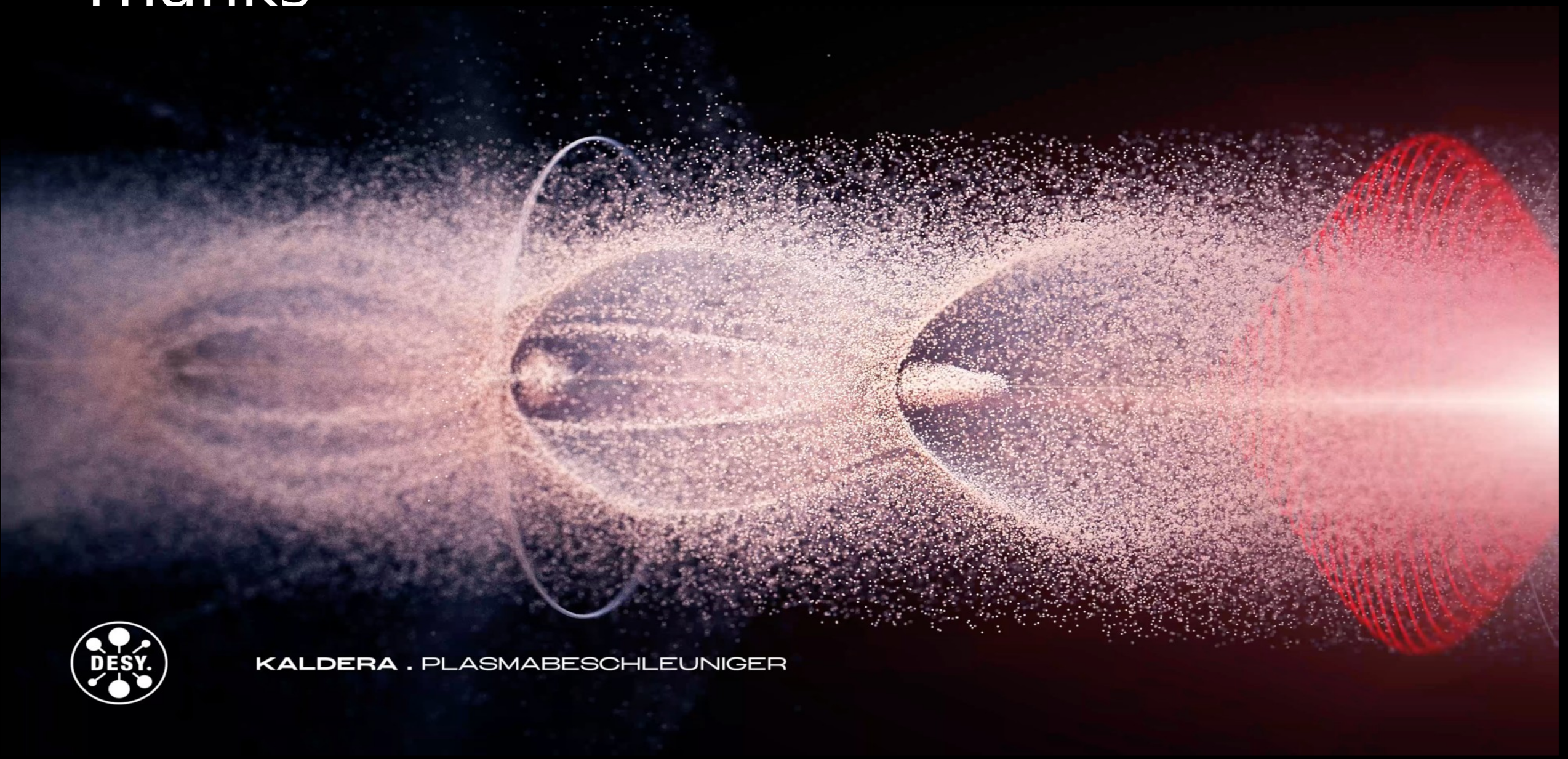
Summary

- The laser fron-end already works @1kHz, but no diagnostics integrated with CS
  - but work in progress

- Modification/development/customization of firmware and DOOCS for KALDER is ongoing

- New/improved concept needed for DAQ (discussion started)

Thanks



http://kaldera.desy.de **http://mls.desy.de**