µTCA based 1kHz camera readout for beam stabilization for KALDERA at DESY

Carsten Dülsen, Patrick Huesmann, Sören Jalas, Tomasz Jezynski, Hamed Sotoudi, Lutz Winkelmann, Andreas R. Maier
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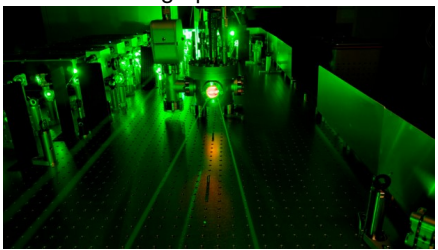
Introduction

KALDERA

KALDERA project

- New plasma-accelerator drive laser system
- 100 TW at up to 1 kHz rep rate
- Goal: FEL-quality electron beams @ 1 GeV electron energy

High-power laser



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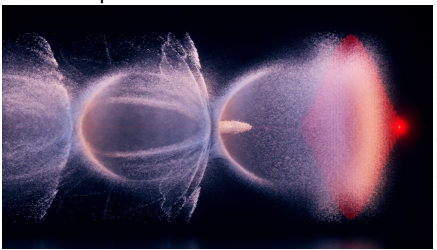
. . . drives a plasma wave to accelerate electrons



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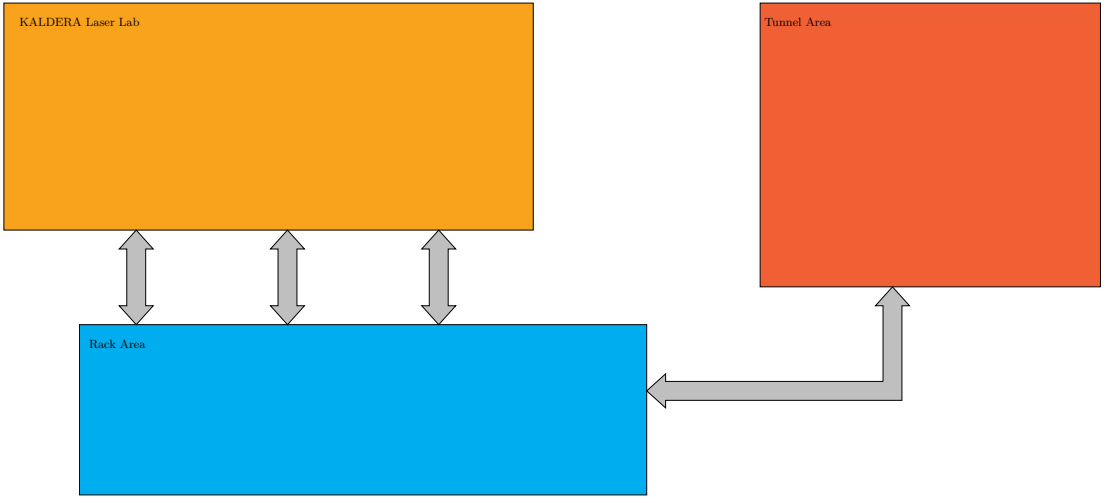
Camera Readout

System Overview



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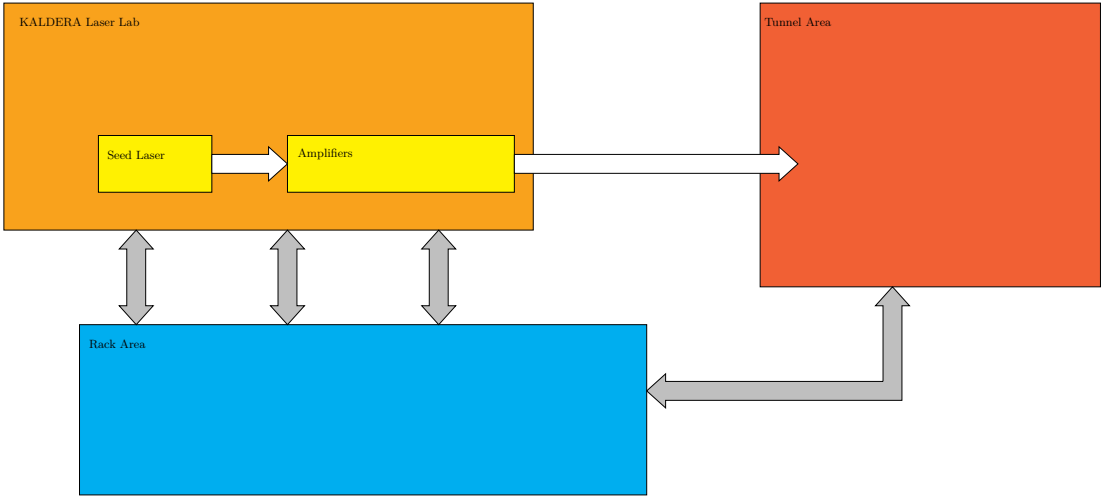

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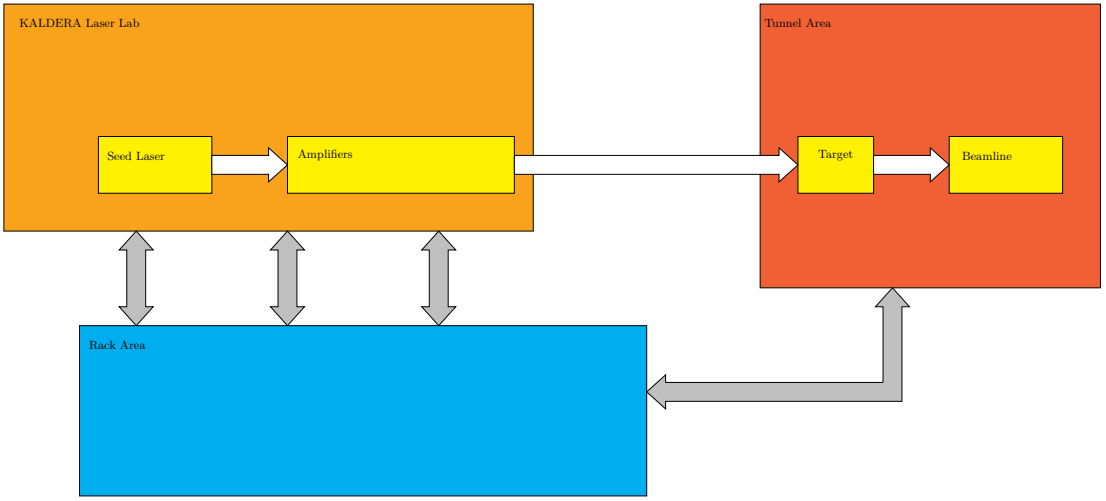

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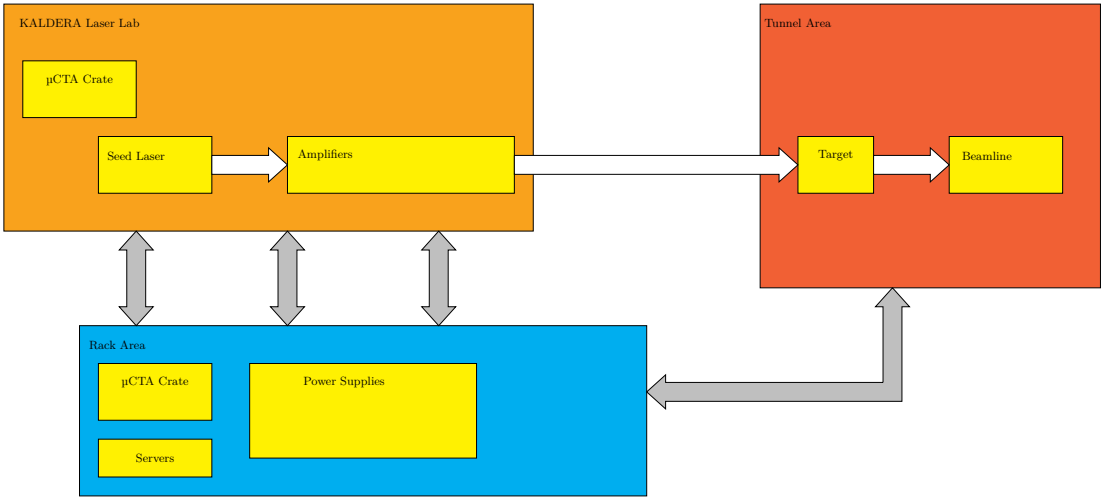

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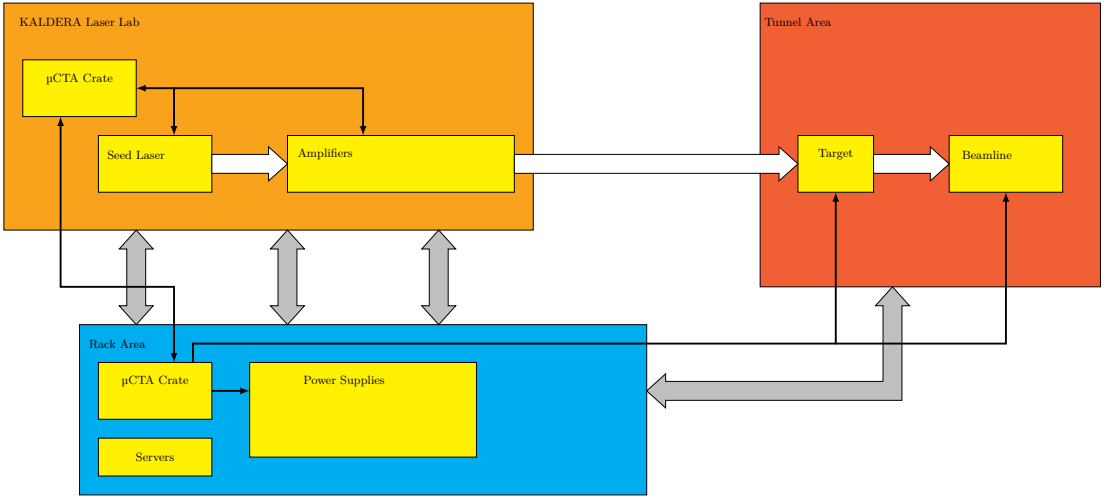

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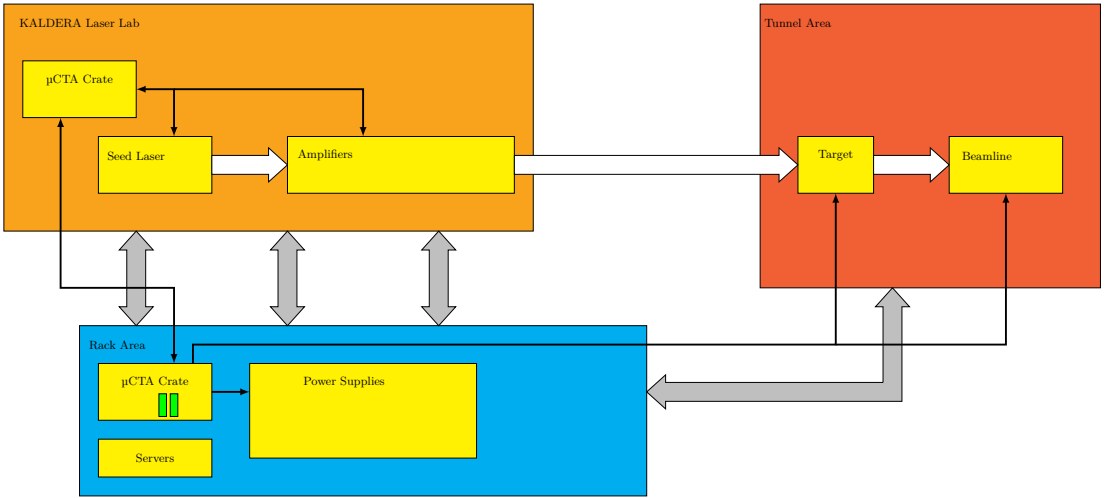


DAMC-FMC2ZUP Board

Board type: DAMC-FMC2ZUP

- Carrier board for up to 2 addon cards (1x FMC+ / 1x FMC)
- Houses a System on Chip (FPGA + ARM cores)
- Provides a 1 Gb/s network and a Gen 3 x8 PCIe backplane connection
- Receives timing information from backplane

Addon-Card used: DFMC-SFP4

- Provides 4 SFP slots per card
- Maximum data rate depends on carrier board design (up to 28 Gb/s per channel)

Currently no RTM used

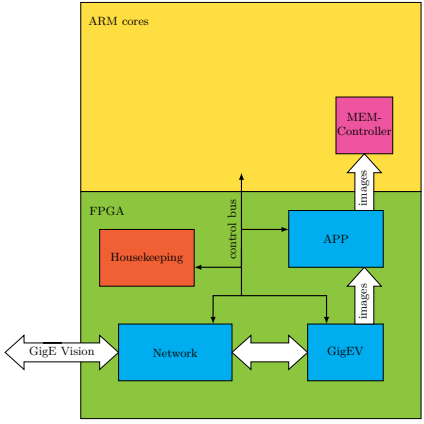
FPGA Firmware

Involved firmware modules:

- 10 Gb/s network stack (UDP/IP)
- GigE Vision core
  - Single user of the network stack, therefore directly connected
  - Handles image data, control part is done in SW
- Application module, including:
  - Beam properties calculation (beam position, size, energy)
  - Video DMA IP core to write images to main memory
- Housekeeping module for clocking, resets and diagnostic

Firmware is supporting image processing at kHz

- Processing happens in parallel to image reception

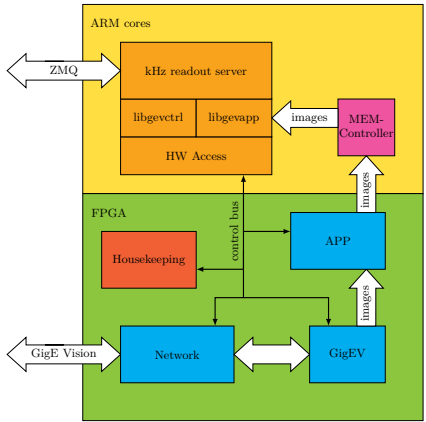


System Software

Involved software modules:

- Hardware access library (C++):
  - Enables uniform access to all firmware modules
- GigE Vision control library (C++):
  - Controls network stack and GigE Vision core
  - Establish connection to camera and configures it
- Application library (Python):
  - Ensures correct order of configuration and startup
  - Allows access to image data
- kHz readout server (Python):
  - Handles connection to outside world
  - Forwards configuration to control library
  - Sends out diagnostic data and images as soon as it's available

All C++ libraries are coming also with python bindings



User Software

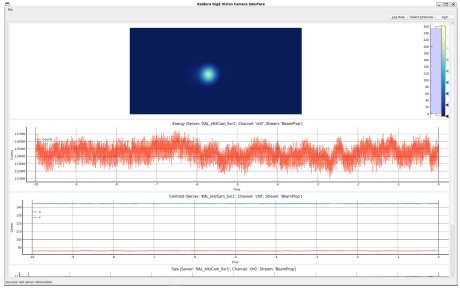
Uses central communication hub as single point of contact

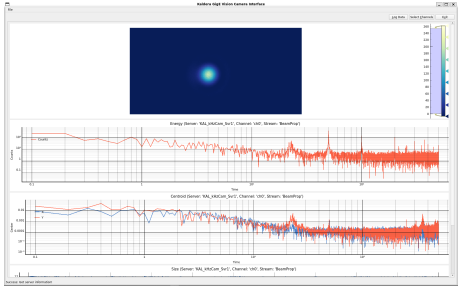
- Stores camera configuration
- Does data multiplexing (multi-user access)
  - First subscription starts channel, last unsubscription closes it

QT5 application for user access

- Displays running data
- Comes with integrated FFT analysis
- Can log data to disk

All user software is written in python





Control System Integration

KALDERA uses DOOCS as control system

- DOOCS allows only for an update rate of 100 Hz
- Need to pack 10 values before sending data

Data is timestamped in firmware, but packed in software

- Data is send out anyway via software (zmq protocol)
- Allows for better error handling and easier adaption of data rate (especially image data)
- DOOCS server can run on any server in the control network

Disadvantage:

- 1 Gb/s ethernet connection of backplane might get a problem

Outlook

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KALDERA will be fully upgraded to kHz operation eventually

- Some of the current diagnostics will need replacements

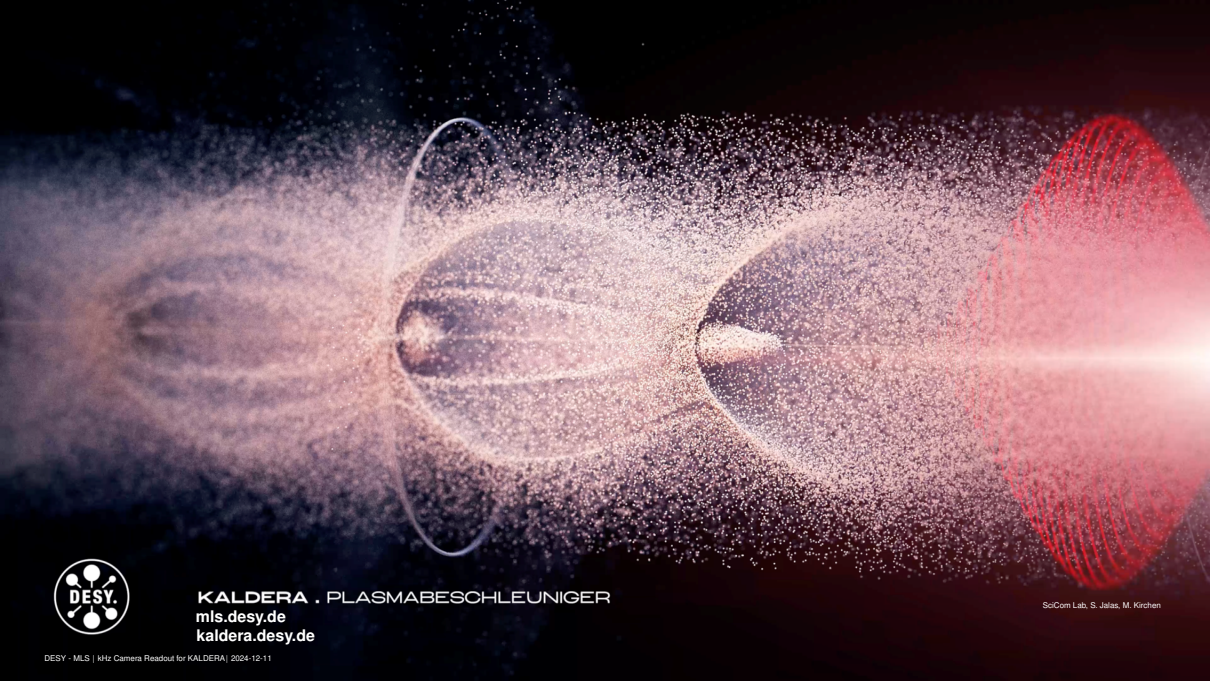
Current firmware already provides diagnostic data within FPGA

- Stabilization logic and piezo stage controller missing

Feedback might be needed before next shot

- Would result in even higher requirements

Thanks for your attention.



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Backup

Camera

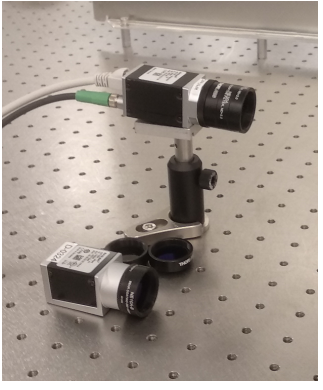
Camera type: BASLER a2A1920-165g5m

- Network interface: 5 Gb/s
- Maximum resolution: 1920 x 1200 pixels (up to 165 Hz)
- Resolution used for kHz: 320 x 160 pixels (up to 1060 Hz)
- Resolution is not due to network bandwidth, reducing line width does not result in higher frame rate

Resolution for kHz operation is quite small, need better camera

Currently preparing Baumer VLXT-06M.I camera for testing

- Network interface: 10 Gb/s
- Maximum resolution: 800 x 620 pixels (up to 1578 Hz)



Bad beam profiles