# Diagnostics and Feedback Controls of Lasers for Accelerators

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

# The FS-LA electronics team

## for reliable laser systems running 24/7, we have to provide…

### Diagnostics

- average power, pulse energies, beam profiles and positions

### Laser controls

- set laser parameters (pulse pattern, power,…)
- adjustment of optical elements

### Laser timing

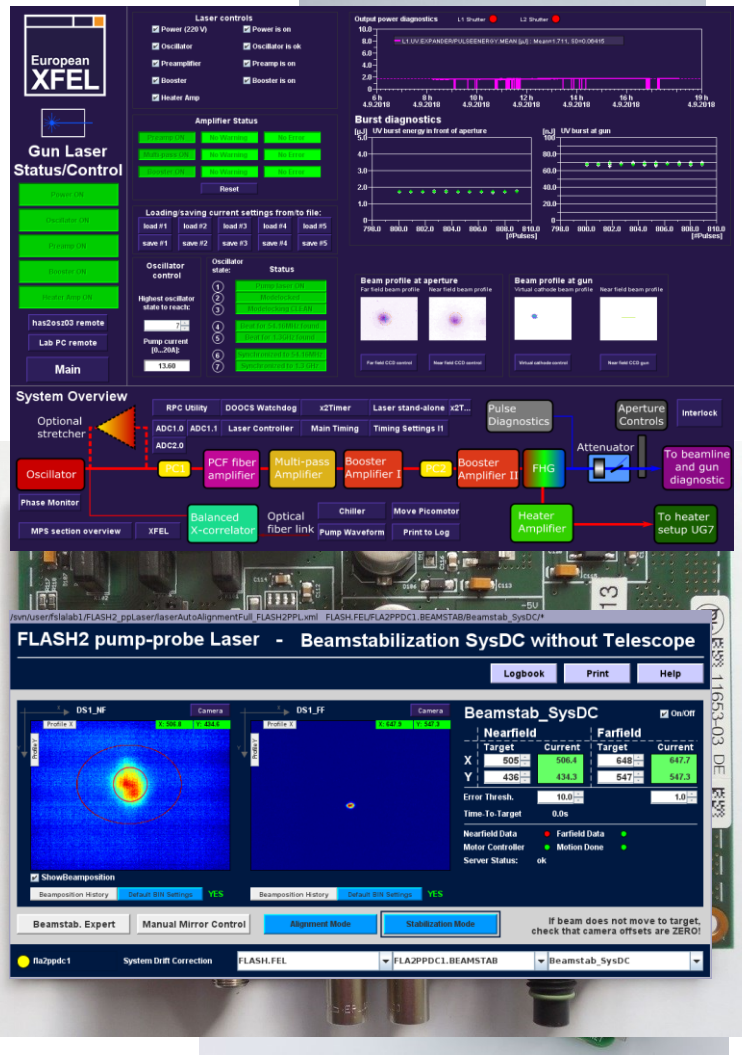
- generate triggers for amplifiers, pulse picking

### Development of customized electronics

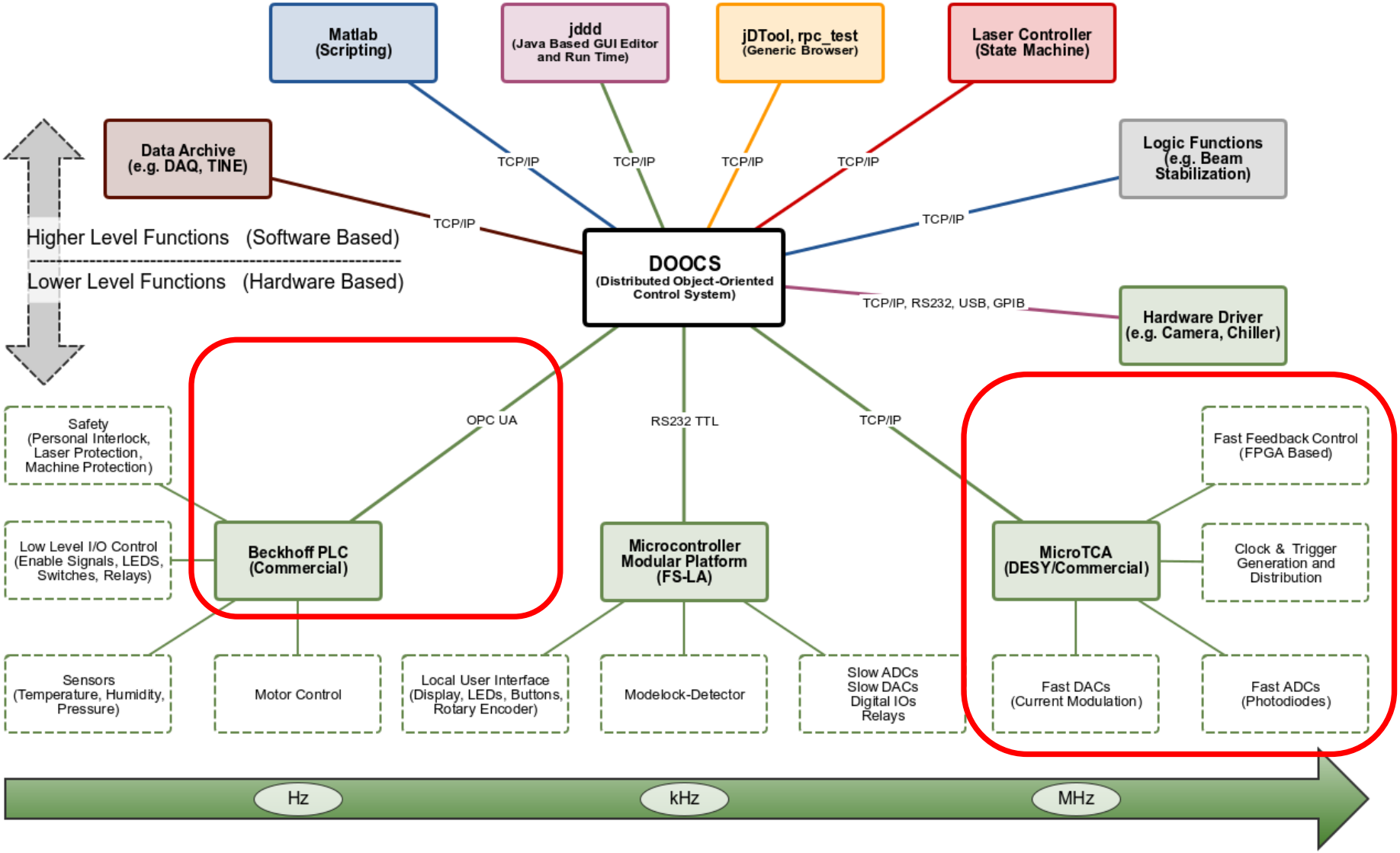
- in many cases, no off-the-shelf devices are available

### Integration of all control electronics into DOOCS

- remote control, logging of performance data



# Control System Overview

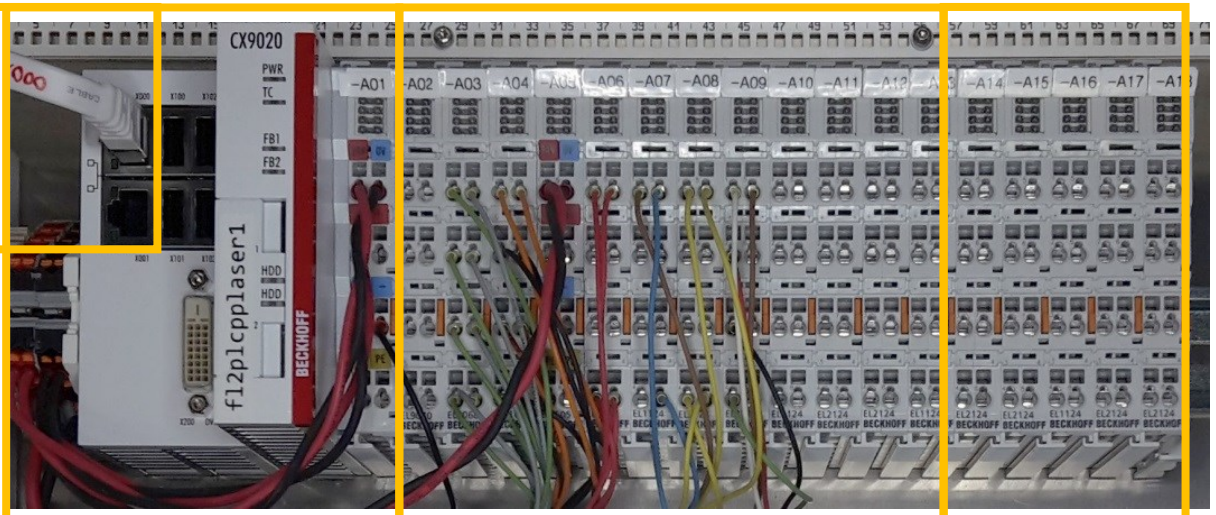


# PLC controls OPC UA to DOOCS

# PLC based controls

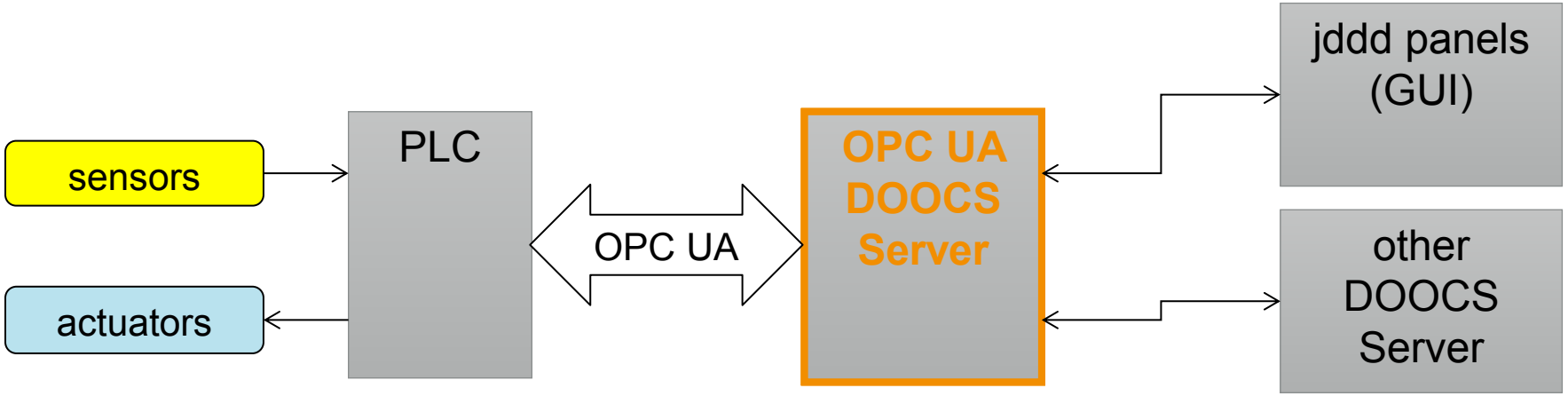
## “slow” signals, update rates up to a few Hz

- **P**rogrammable **L**ogic **C**ontroller: industrial automation technology



# OPC UA to DOOCS interface

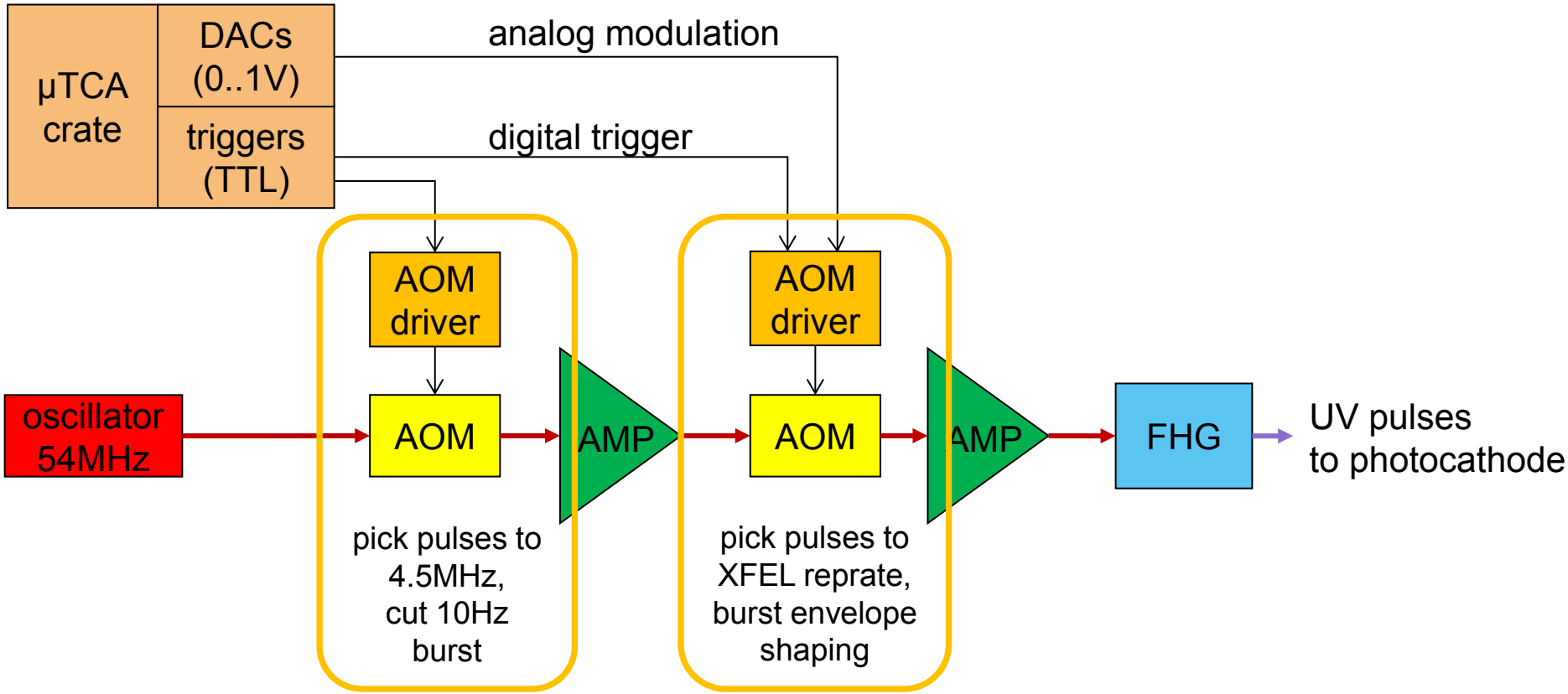
- OPC UA: **O**pen **P**latform **C**ommunication **U**nified **A**rchitecture
  (open standard for machine-to-machine communication)
- **Generic DOOCS server** to communicate with PLCs using OPC UA
- Easy, automated set-up
  1. PLC publishes list of variables and methods
  2. DOOCS properties are automatically generated



# Laser pulse picking and burst shaping

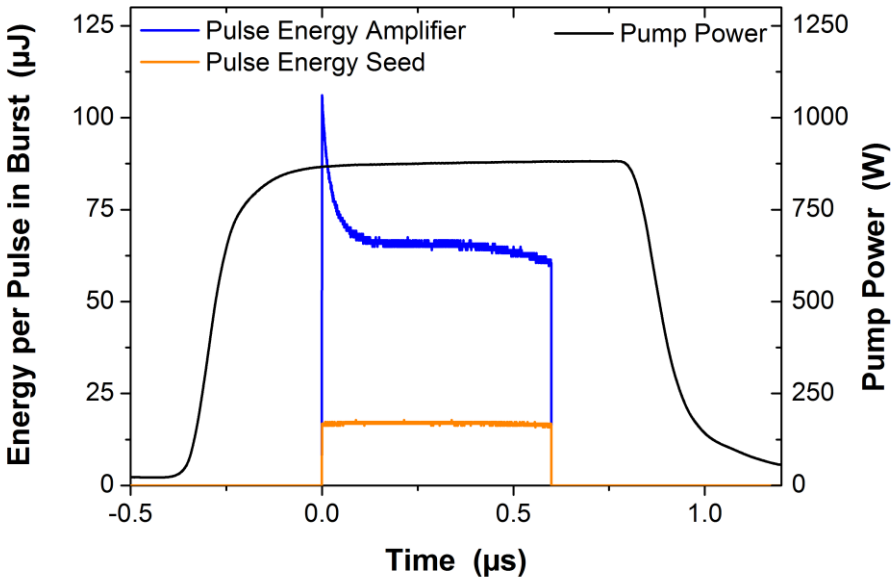
# Pulse picking and burst shaping

## AOMs between amplifier stages used for pulse picking and amplitude shaping



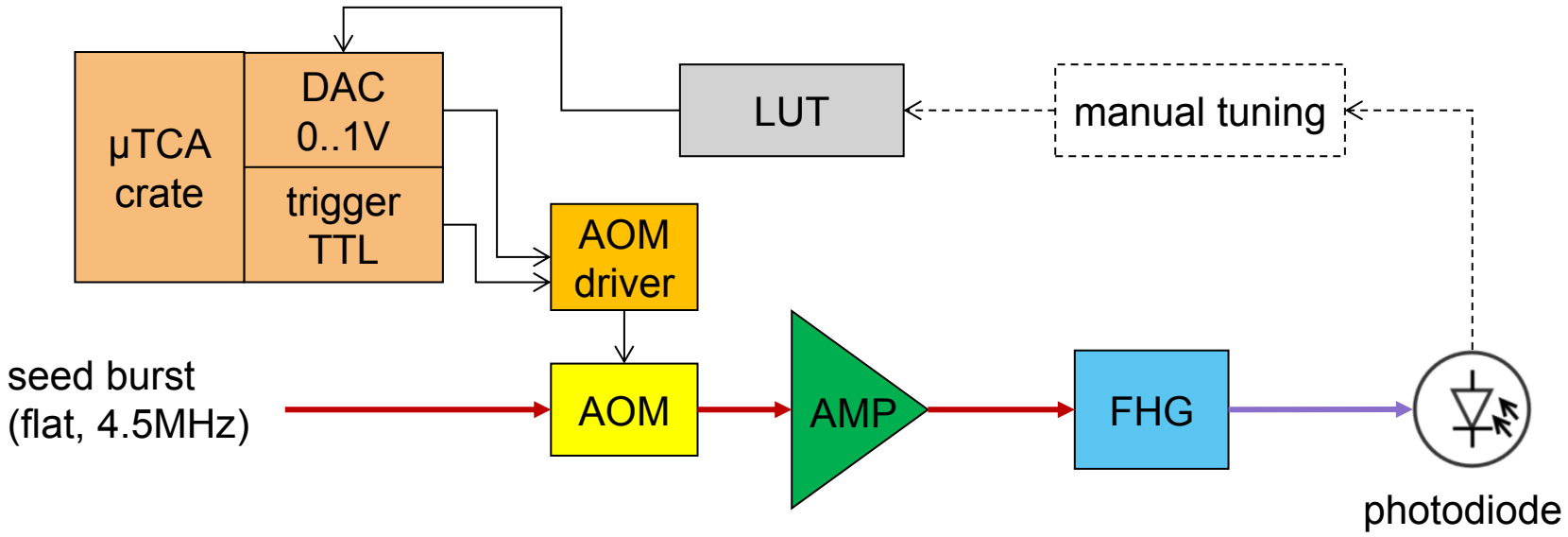
# Creating a flat laser burst

- 10Hz burst operation is challenging for laser operations
  - crystals heat up during burst
  - pump energy is stored in cyrstals for µs to ms
- **No equilibrium state is reached**, gain is non-uniform, burst is not flat
- Ways to solve this:
  - from a longer burst, cut out a part which is relatively flat
  - modulate the pump power of the amplifier
  - intensity-modulate each seed laser pulse (using AOMs)



# Burst shaping at XFEL photocathode laser 2

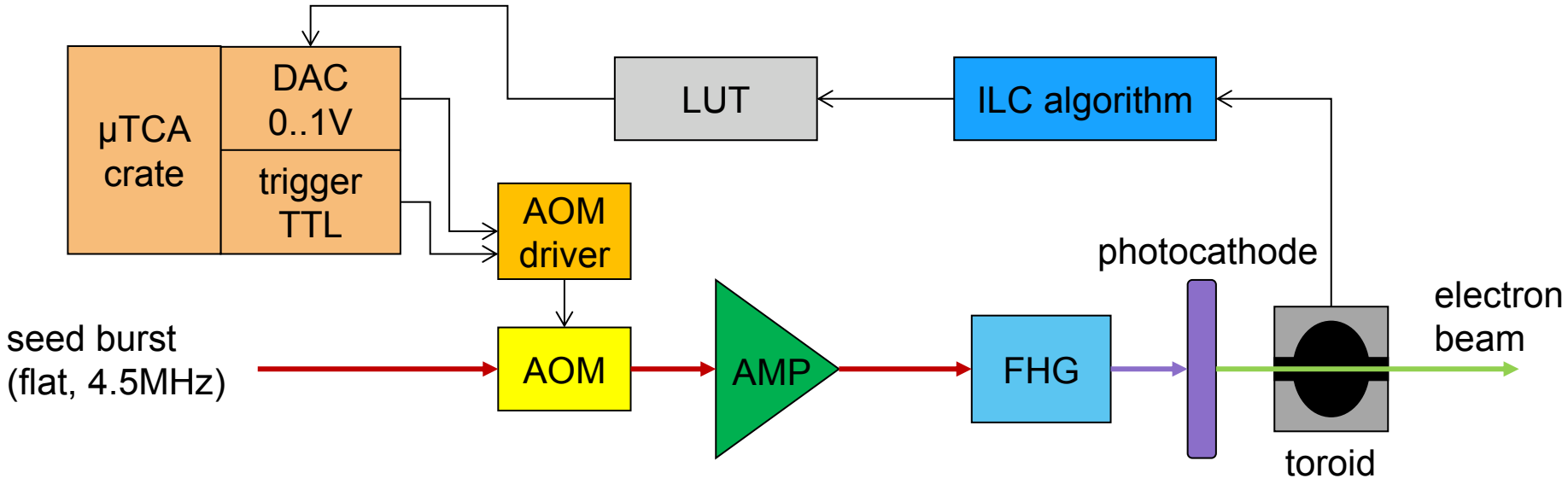
- AOM before the last power amplifier pre-distorts the seed burst to achieve a flat UV burst
- First implemented: manually tweaked look-up-table (LUT)



# Adaptive Feed Forward Amplitude Shaping

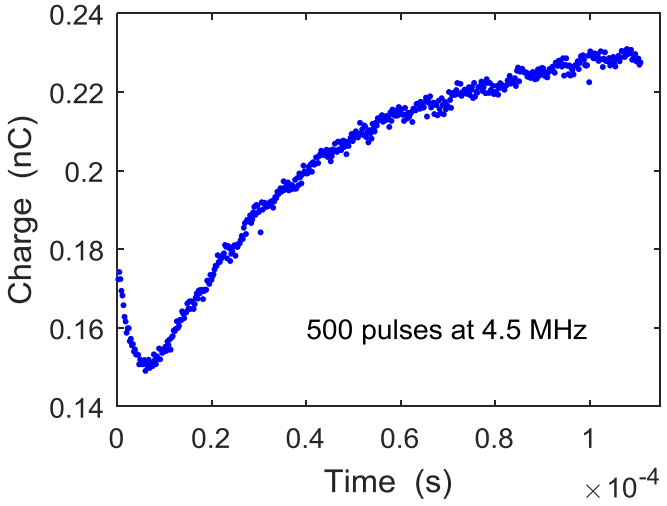
## using Iterative Learning Control (ILC)

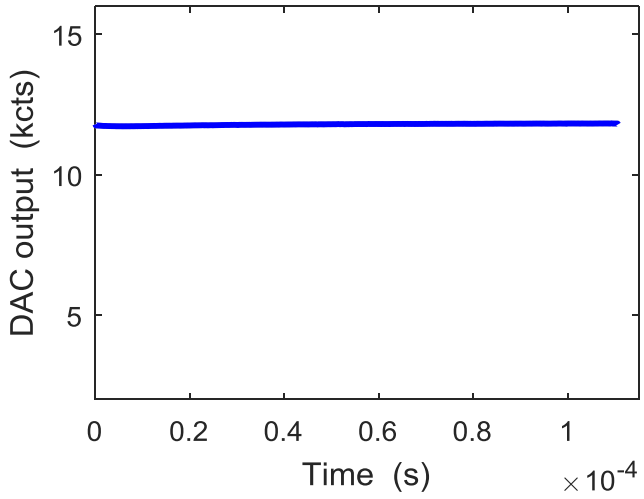
- Development in collaboration with Sven Pfeiffer (DESY MSK group)
- Controlling the electron bunch charge
- ILC algorithm optimizes the LUT for a flat charge over the burst
- Optimized LUT can be saved for each laser operation mode (frequency, number of pulses) and be reloaded automatically

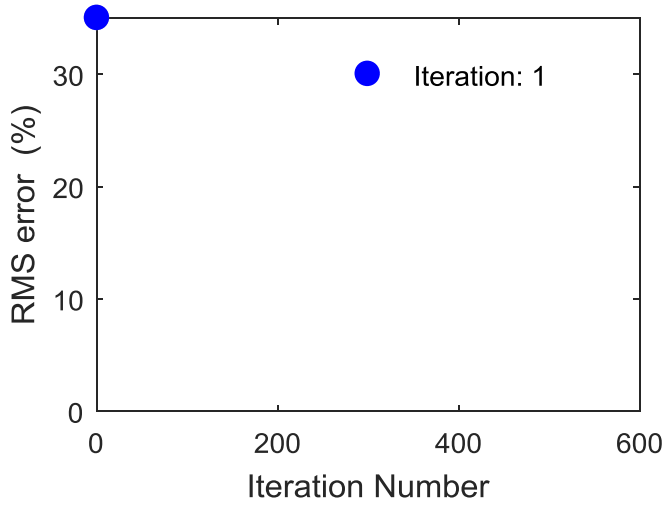


# Adaptive Feed Forward Amplitude Shaping

## Iterative Learning Control (ILC)



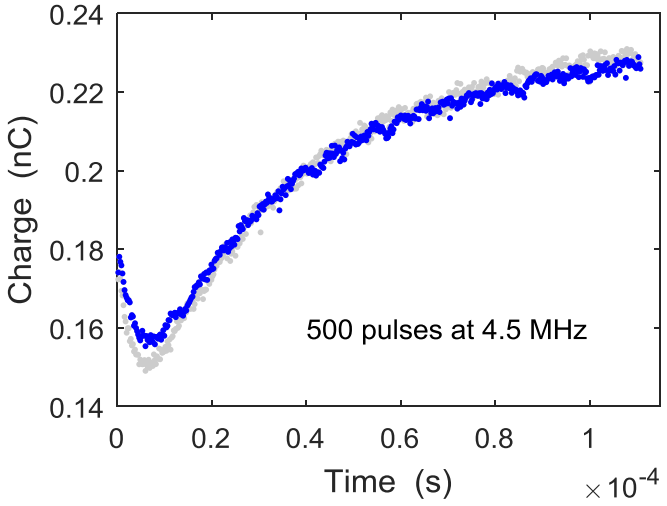



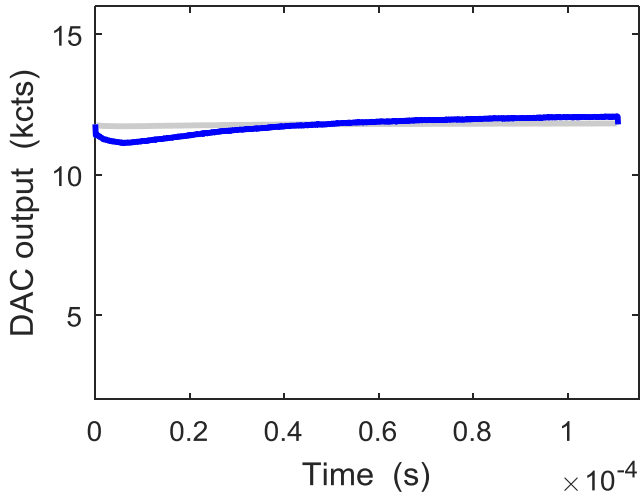



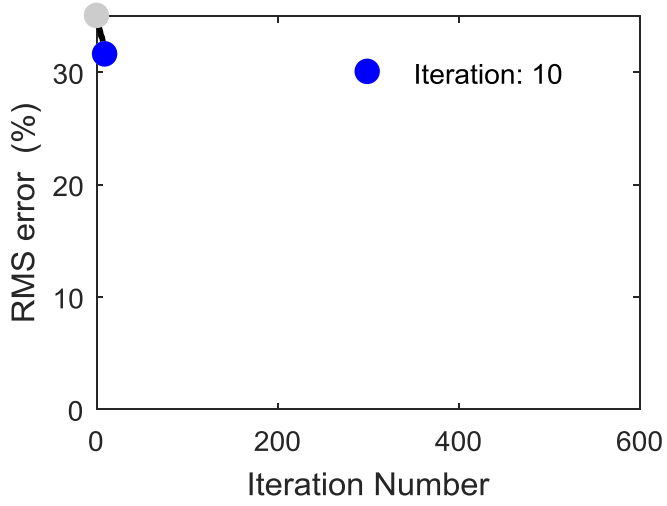

- Starting from flat DAC control signal.

# Adaptive Feed Forward Amplitude Shaping

## Iterative Learning Control (ILC)




- Running ILC algorithm

# Adaptive Feed Forward Amplitude Shaping

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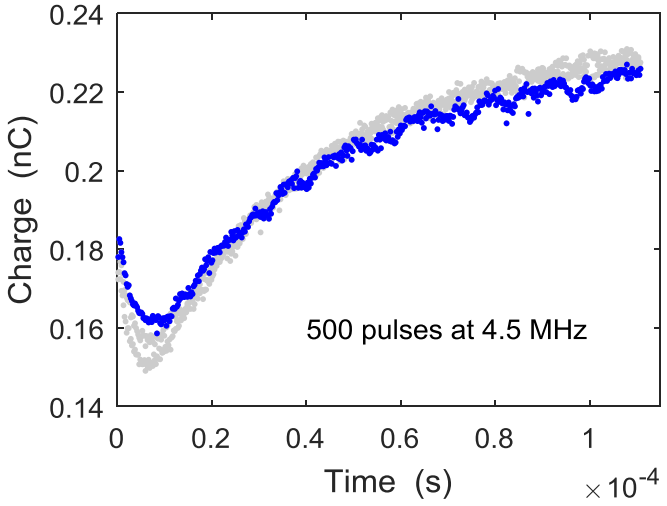


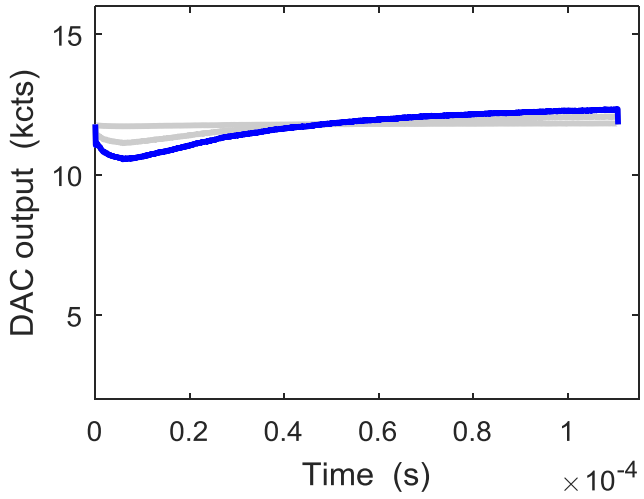


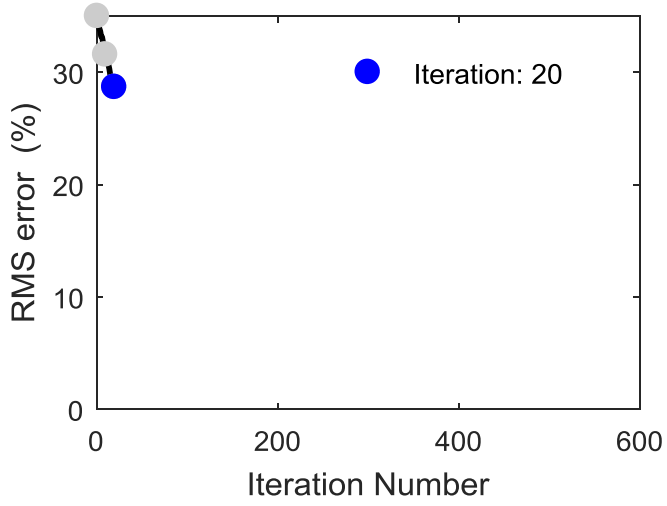


- Running ILC algorithm

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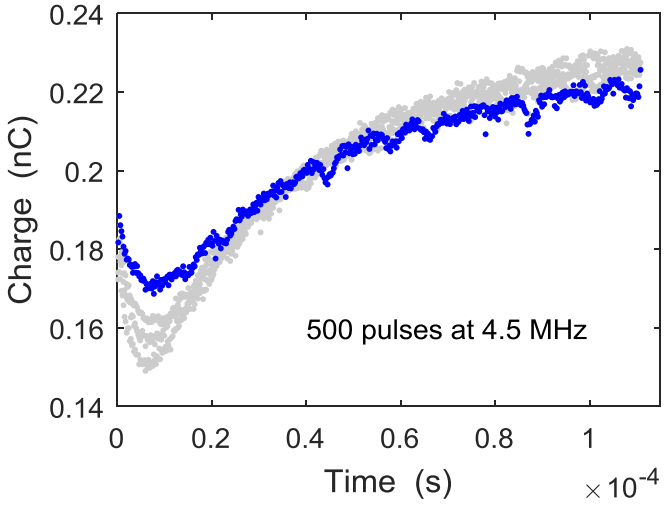


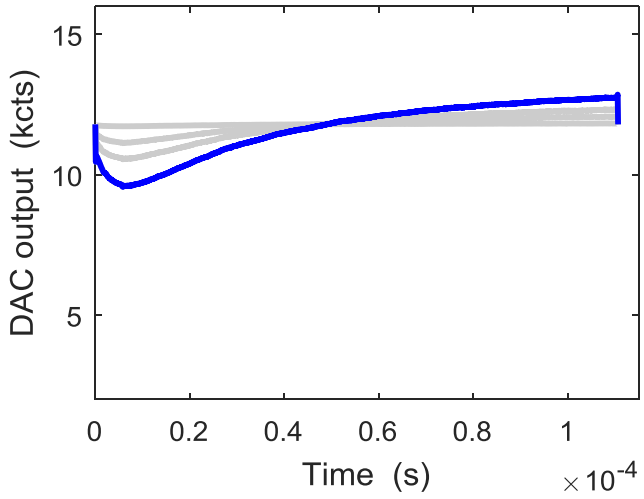


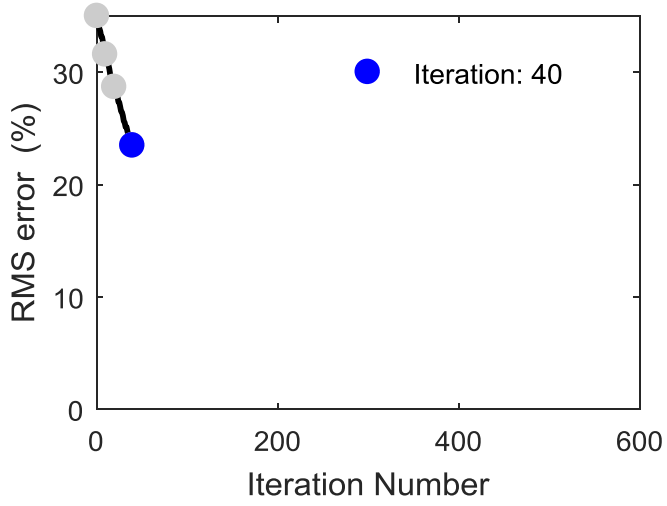


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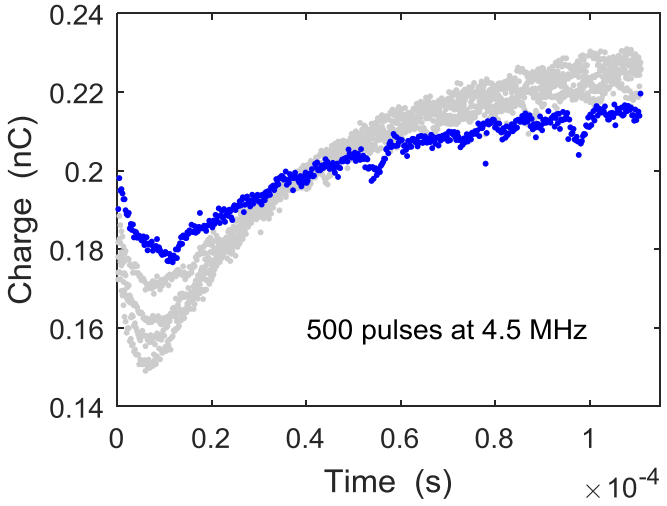
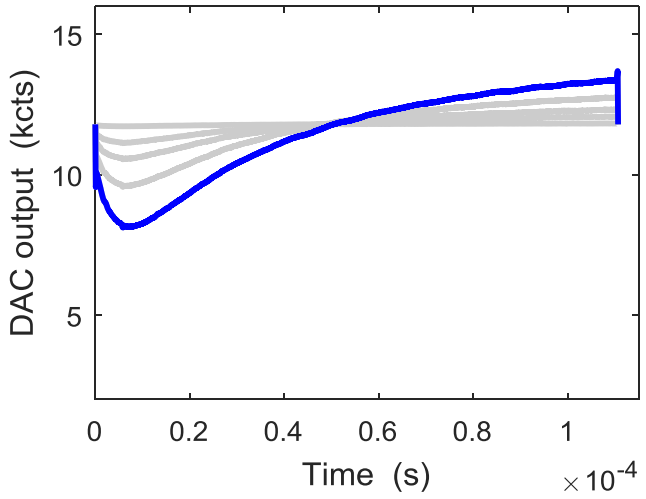
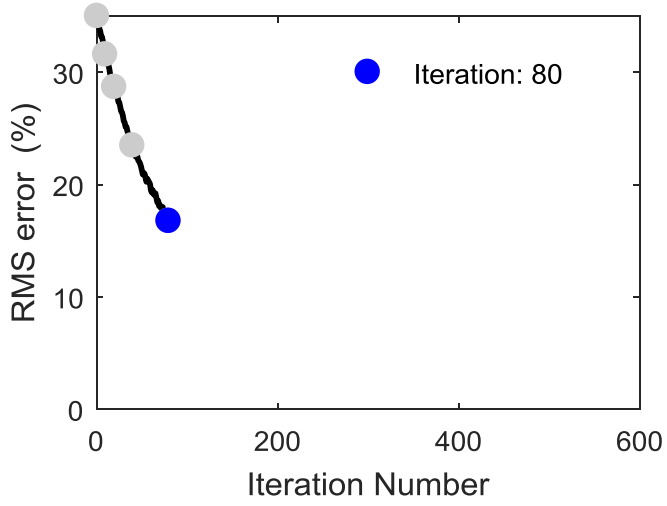


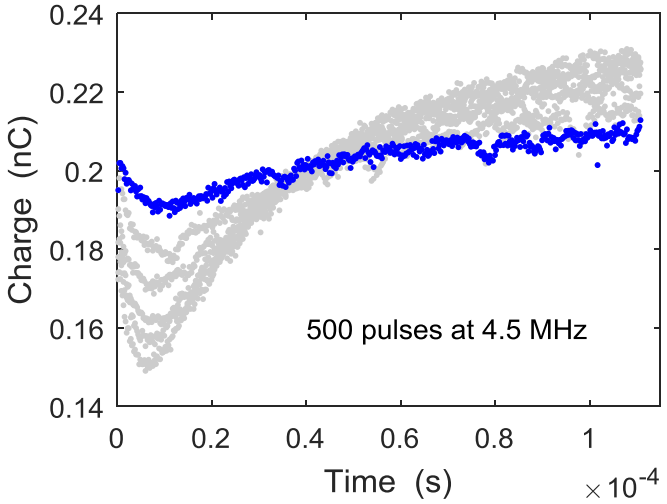



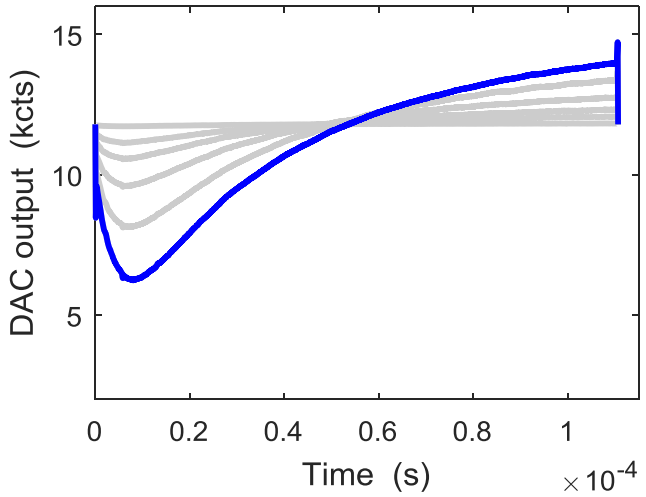



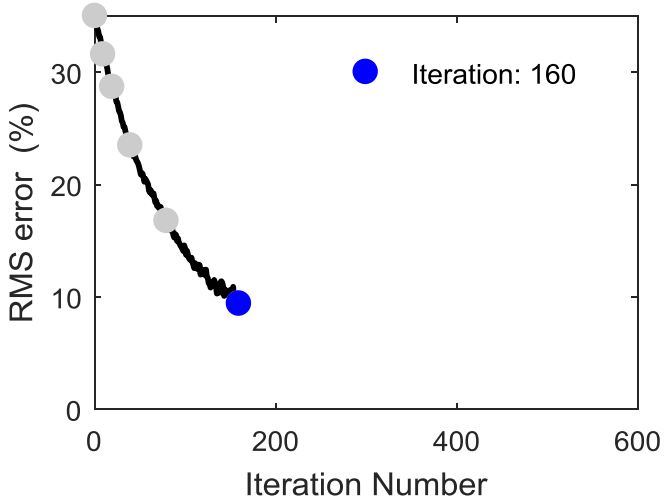

- Running ILC algorithm
- Dips in charge are problems due to a switching power supply during the time of algorithm development.

# Adaptive Feed Forward Amplitude Shaping

## Iterative Learning Control (ILC)

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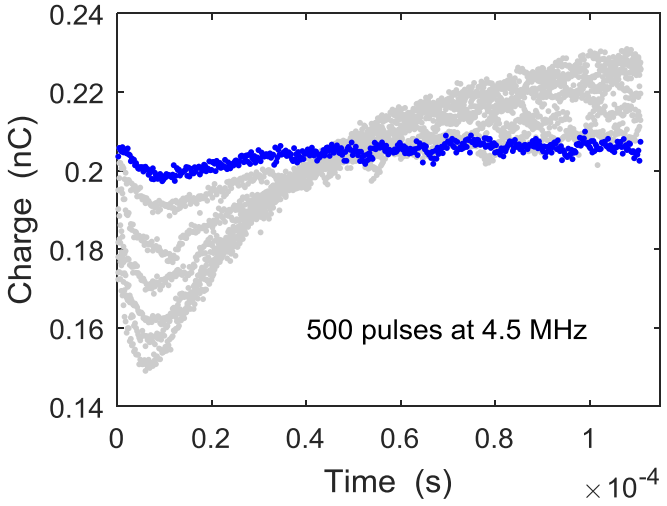


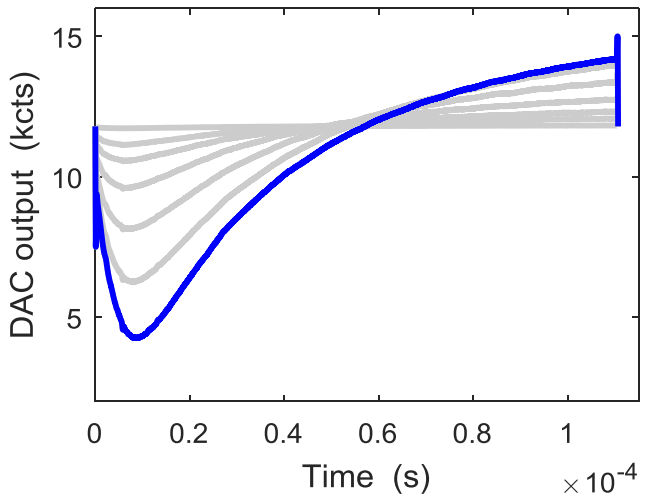


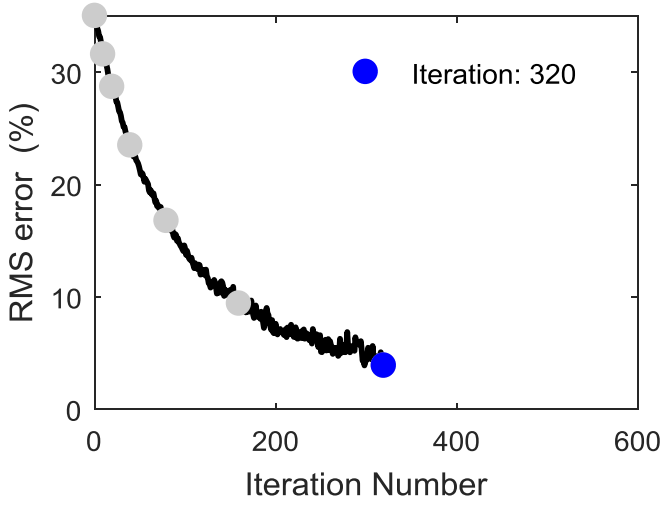


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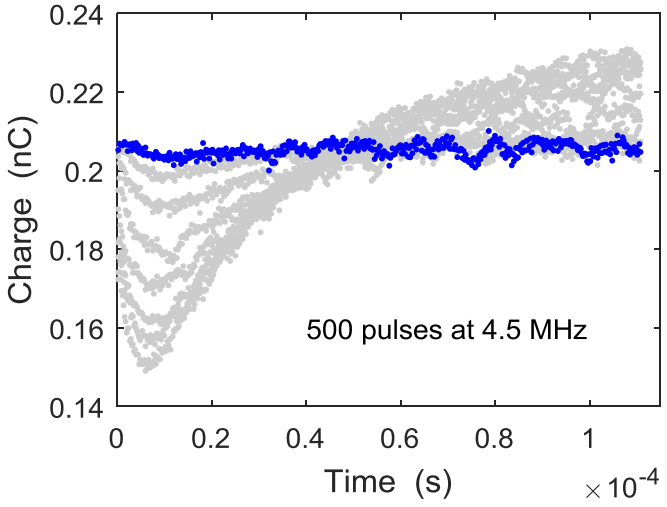
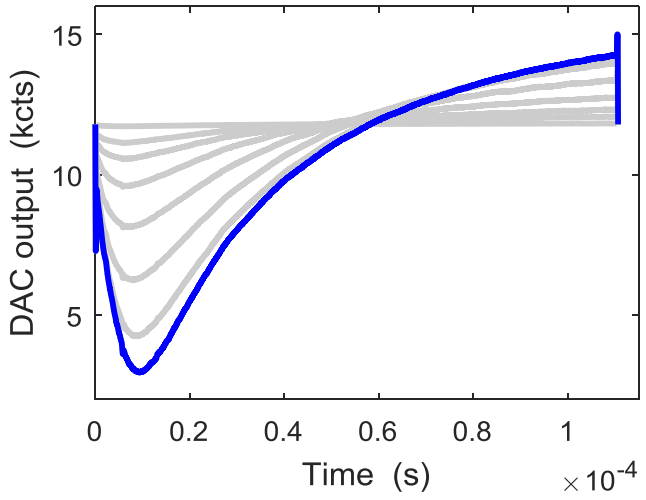
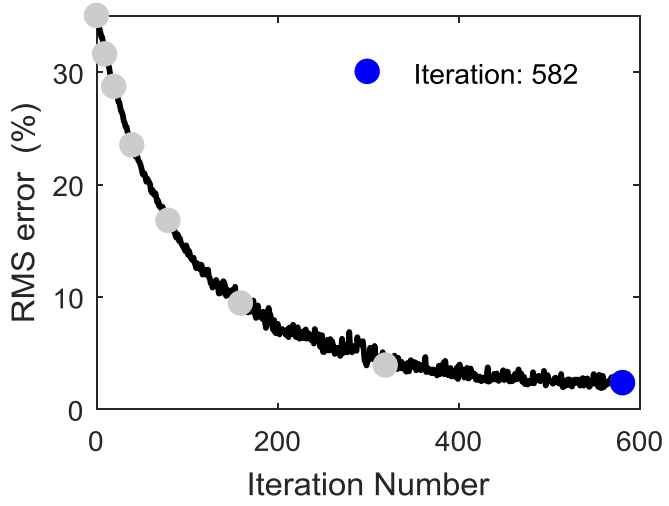
# Adaptive Feed Forward Amplitude Shaping

## Iterative Learning Control



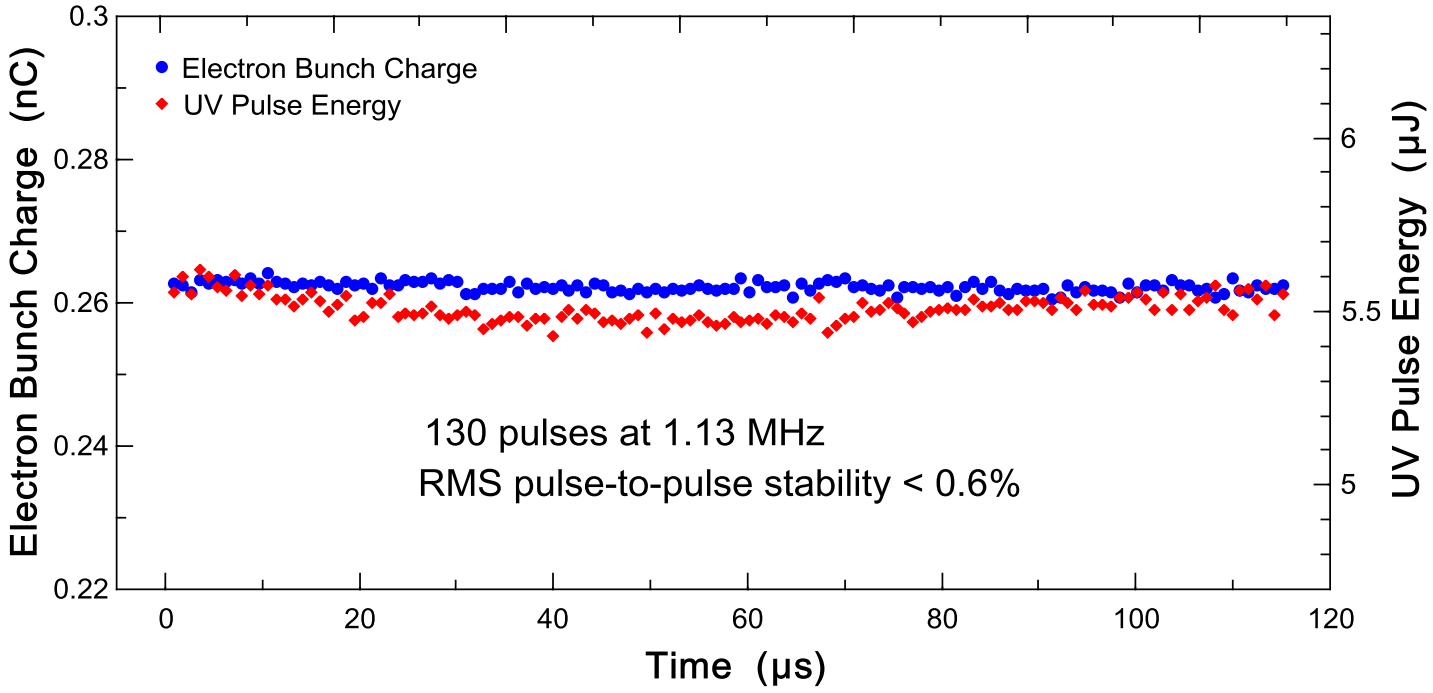




- Demonstration of convergence of algorithm (system was performing poorly at time of algorithm testing due to broken switching power supply).
- Independent of number of pulses and pulse rate.

# Adaptive Feed Forward Amplitude Shaping

## Electron bunch charge vs. UV pulse energy




- Electron bunch charge shows slight deviation from laser's UV pulse energy along the pulse train
- By using charge as input for optimization those effects can also be pre-compensated

# Summary

## Laser remote controls and online diagnostics

- Power, pulse energies and timing
- Lab infrastructure, Safety and environment
- Versatile OPC UA to DOOCS interface

## Laser burst control

- AOM used for burst envelope shaping
- Iterative feed-forward algorithm to flatten the electron charge in the burst
- Pre-compensation of distortions in amplifiers
- Various burst shapes possible

# Thank you
# for your attention!

## Contact

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