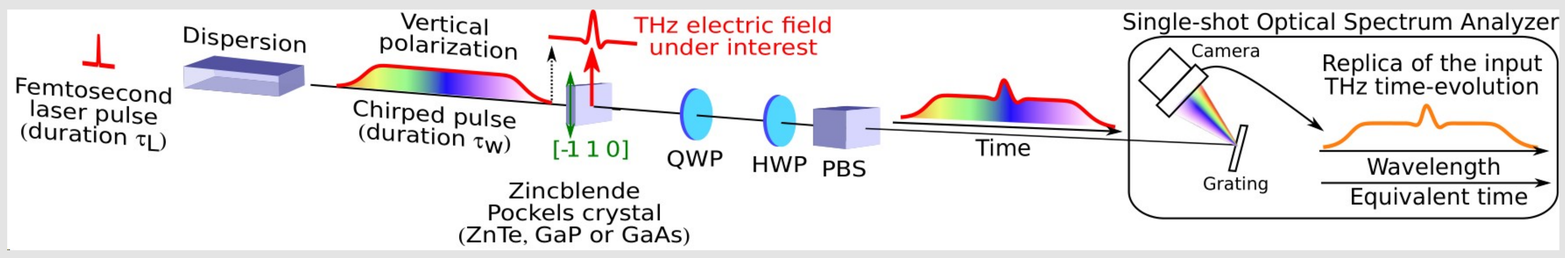
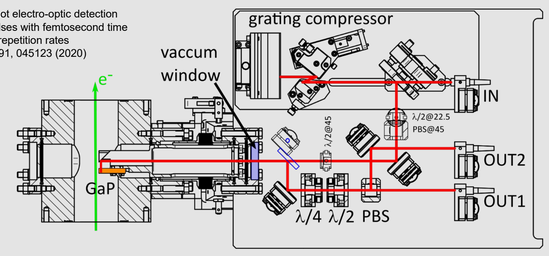
Latest Advancements of a Compact Electro-optical Bunch Length Detector.

B. Steffen, M. K. Czwalinna, Tomasz Kozak, Dietrich Rothe
(DESY, Hamburg, Germany)

Electro-Optical Spectral Decoding

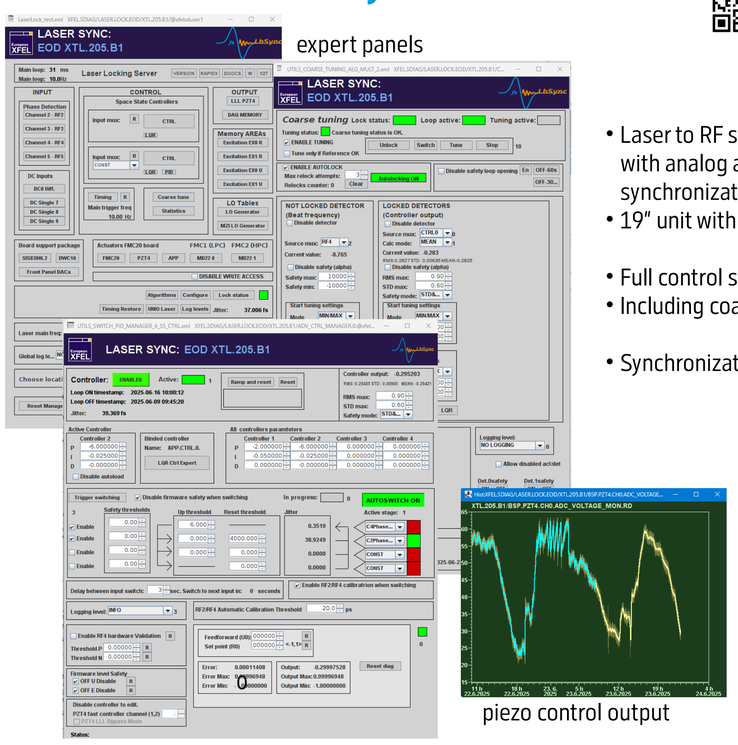


B. Steffen et al.
Compact single-shot electro-optic detection system for THz pulses with femtosecond time resolution at MHz repetition rates
Rev. Sci. Instrum. 91, 045123 (2020)



- Ytterbium fiber laser and amplifier,
- Optics set-up at the beam line vacuum chamber incl. the GaP crystal
- Spectrometer with the KALYPSO MHz line detector,
- MicroTCA.4 crate with analog and digital boards for synchronization and data readout,
- Laser to RF synchronization unit with other supporting electronics,
- Full system (including laser, detector, MTCA crate, synchronization electronics, motor drivers, power supply, ect.) 25 HU in 19" rack

MTCA based laser synchronization

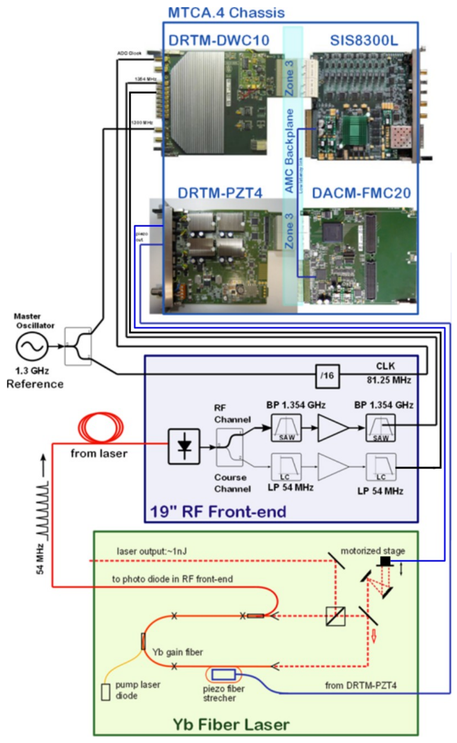


M. Felber et al.,
Compact MTCA.4 Based Laser Synchronization,
in Proc. 5th Int. Particle Accelerator Conf. (IPAC'14),
Dresden, Germany, June 2014, pp. 1823-1825,
doi:10.18429/JACoW-IPAC2014-TUPRI107

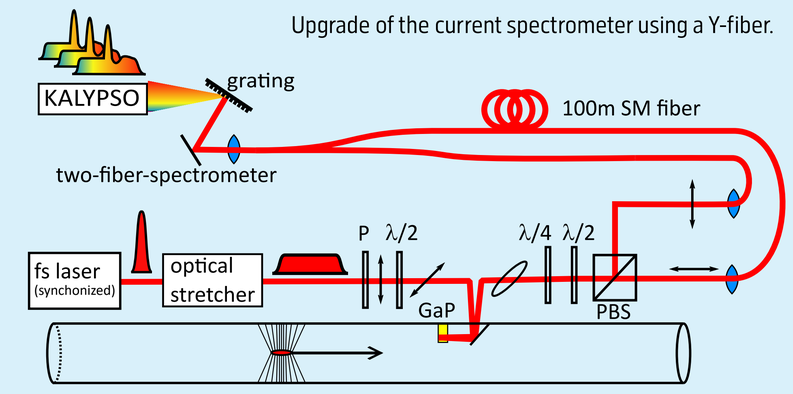
- Laser to RF synchronization in MicroTCA.4 crate with analog and digital boards for synchronization and data readout
- 19" unit with other supporting RF-electronics

- Full control system integration
- Including coarse tuning and auto-locking

- Synchronization to 35 fs (rms)

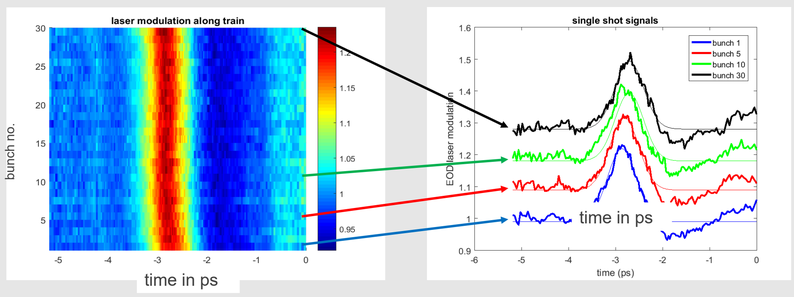


Two channel spectrometer with 1 MHz line rate



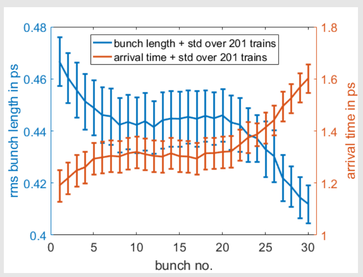
With correct length of the delay fiber, the two spectra of the same laser pulse can be measured with up to 1.3MHz and <0.5% temporal cross-talk.

EOSD-profile measurements



EOD traces of all 30 bunches of a bunch train with 1.13 MHz repetition rate

Single shot EOD traces and fitted Gaussians from the same bunch train



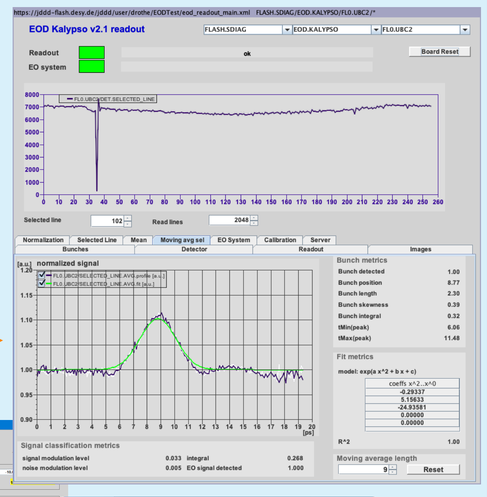
Arrival time and bunch length (rms) along the bunch train

- Matlab expert tools for commissioning serve as 'prototype' for server development

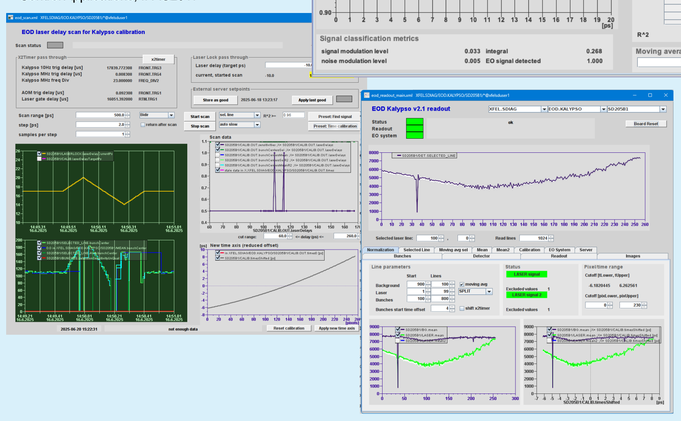
EOD-server

- ChimeraTK based DOOCS control-system interface including:

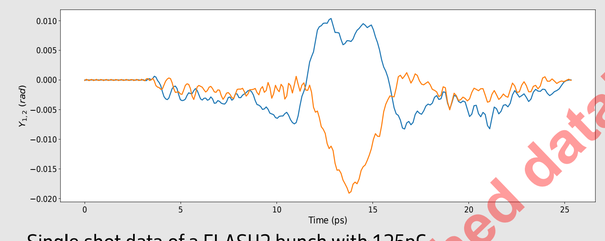
- Signal normalization and background subtraction
- Fault status detection
- Semi-automated operation point search
- Automated time calibration
- Bunch length and arrival time calculation
- Signal based timing feedback
- Prepared for extension to DEOS reconstruction algorithm



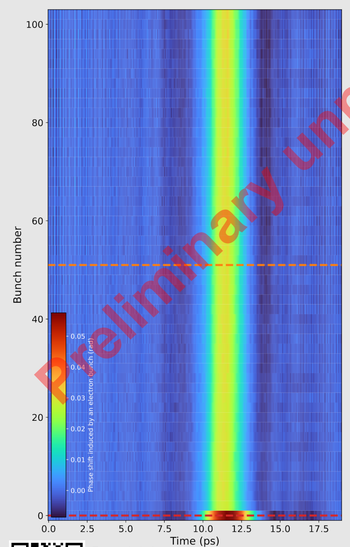
G. Varghese *et al.*
ChimeraTK - A Software Tool Kit for Control Applications, IPAC2017



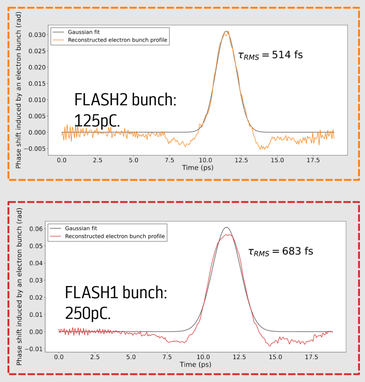
DiversityEOS@FLASH with the two-channel spectrometer



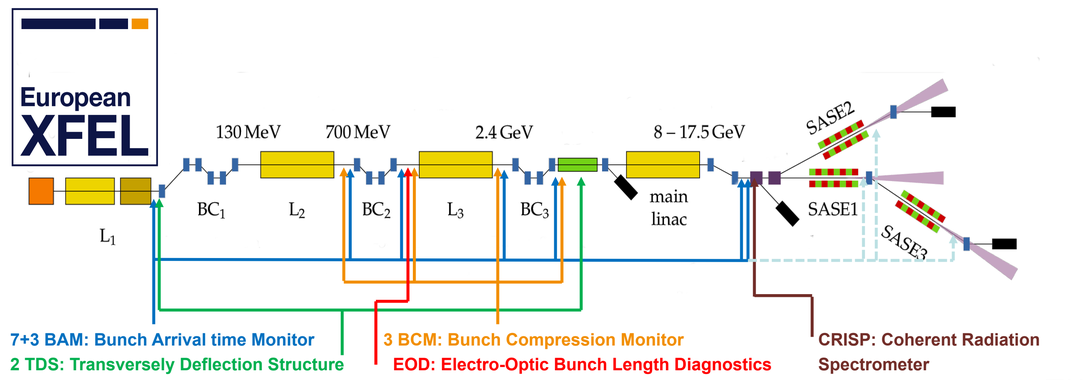
Single shot data of a FLASH2 bunch with 125pC.



Electron bunch profiles of a FLASH bunch train, reconstructed with a maximum-ratio combining (MRC) algorithmus.



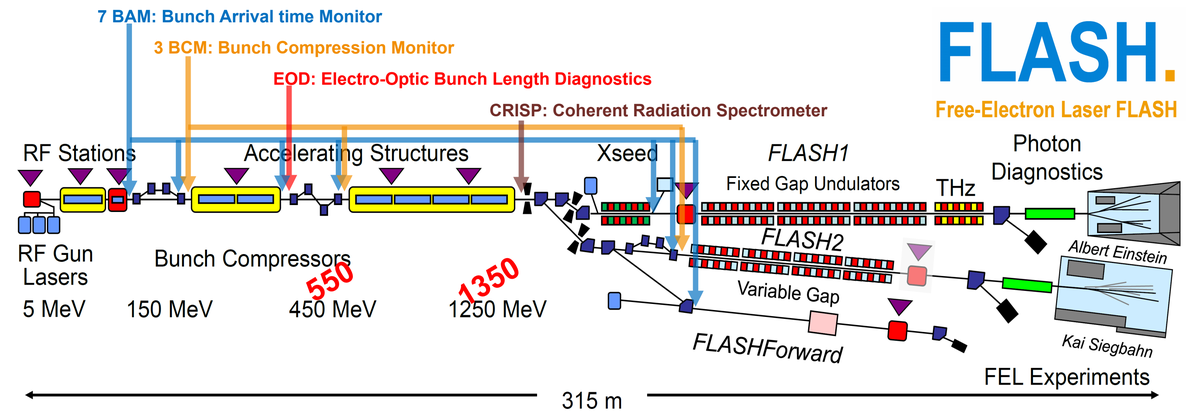
Roussel et al.
Phase Diversity Electro-optic Sampling:
A new approach to single-shot terahertz waveform recording
Light: Science & Applications (2022) 11:14



Accelerator
- Superconducting RF, up to 17.5 GeV
- 10 Hz pulsed operation
- Bursts of up to 2.7k bunches at 4.5 MHz
- Bunch length: 6 ps (at gun) to <10 fs at undulators

Photon Beamlines
- 3 beamlines (room for extension)
- 6 instruments (more in preparation)
- 0.26keV (4.7nm) to 20keV (0.6nm)

W. Decking *et al.*
A MHz-repetition-rate hard X-ray free-electron laser driven by a superconducting linear accelerator.
Nat. Photonics **14**, 391–397 (2020)



Accelerator
- Superconducting RF, up to 1350 MeV
- 10 Hz pulsed operation
- Bursts of up to 800 bunches a 1 MHz
- Bunch length: 6 ps (at gun) to 30 fs at undulators

Beamlines
- Since 2014 two beamlines with parallel SASE delivery
- Demonstrated wavelength range: 90 nm to 4 nm (from XUV to soft X-rays)
- integrated powerful THz source

bernd.steffen@desy.de 13th MT ARD ST3 Meeting, Zeuthen, June 2025

HELMHOLTZ

Bundesministerium für Bildung und Forschung