FELBE & TELBE

Photon Diagnostics

J. Michael Klopf (FELBE)
Sergey Kovalev (TELBE)

THz@PITZ Workshop
PITZ at DESY in Zeuthen
2023.03.15

ELBE.

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
Mitglied der Helmholtz-Gemeinschaft

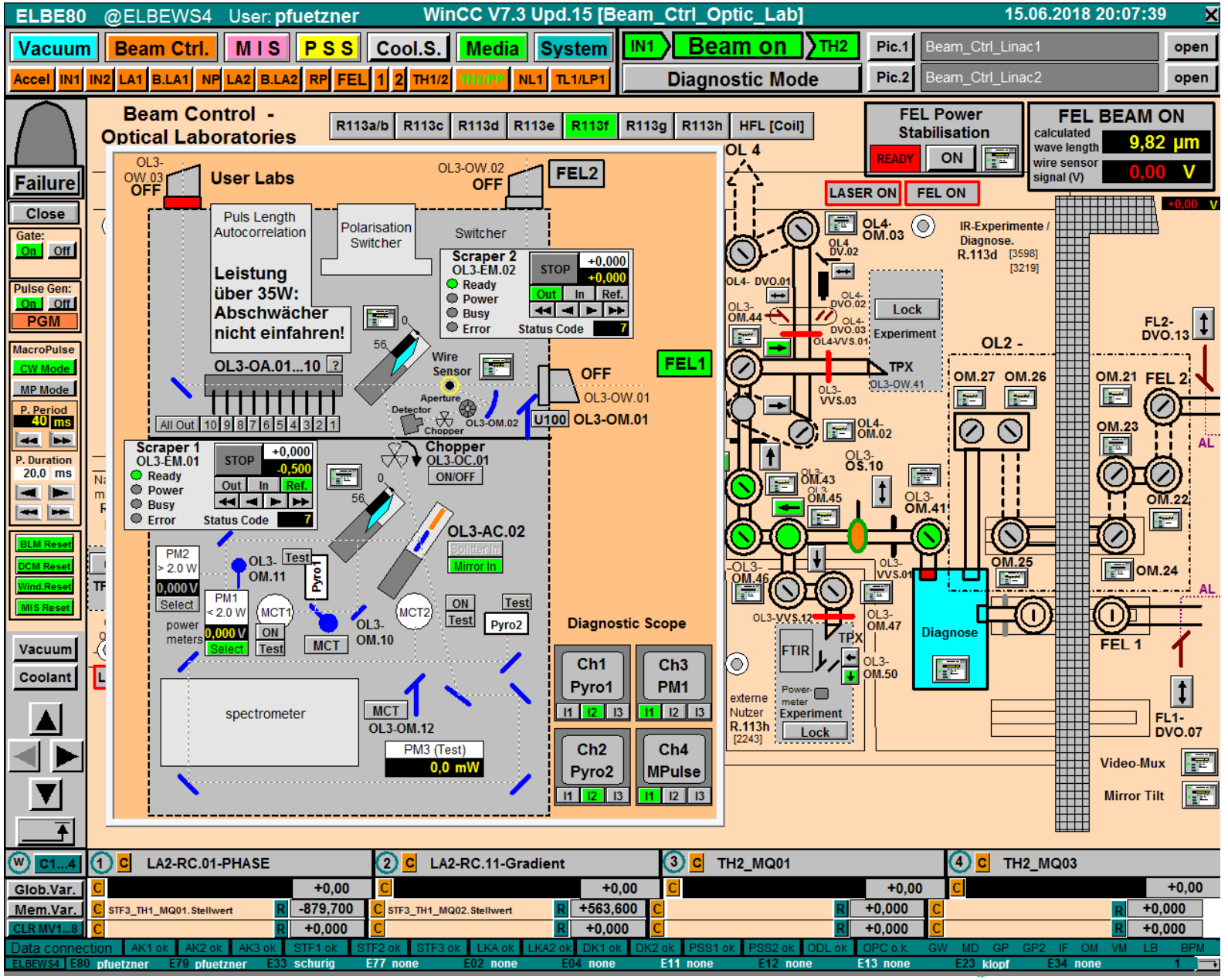
Outline

- FELBE Diagnostics
  - robust, easy to use, remotely operated
  - setup beam for users
  - MD and FEL performance measurements
  - currently limited to power and spectrum (temporal from FT of spectrum)
  - “in situ” diagnostics and more advanced measurements under development
  - phase-resolved measurement of FEL waveform demonstrated

- TELBE Diagnostics
  - power measurement in cave for coarse beam setup
  - fine tuning of setup requires “in lab” measurements
  - “in situ” monitoring with fast pyro
  - phase-resolved measurement of THz waveform with 10 fs resolution developed by TELBE group
  - continual improvement of accelerator and timing systems ⇨ real-time measurements

FELBE Diagnostic Table

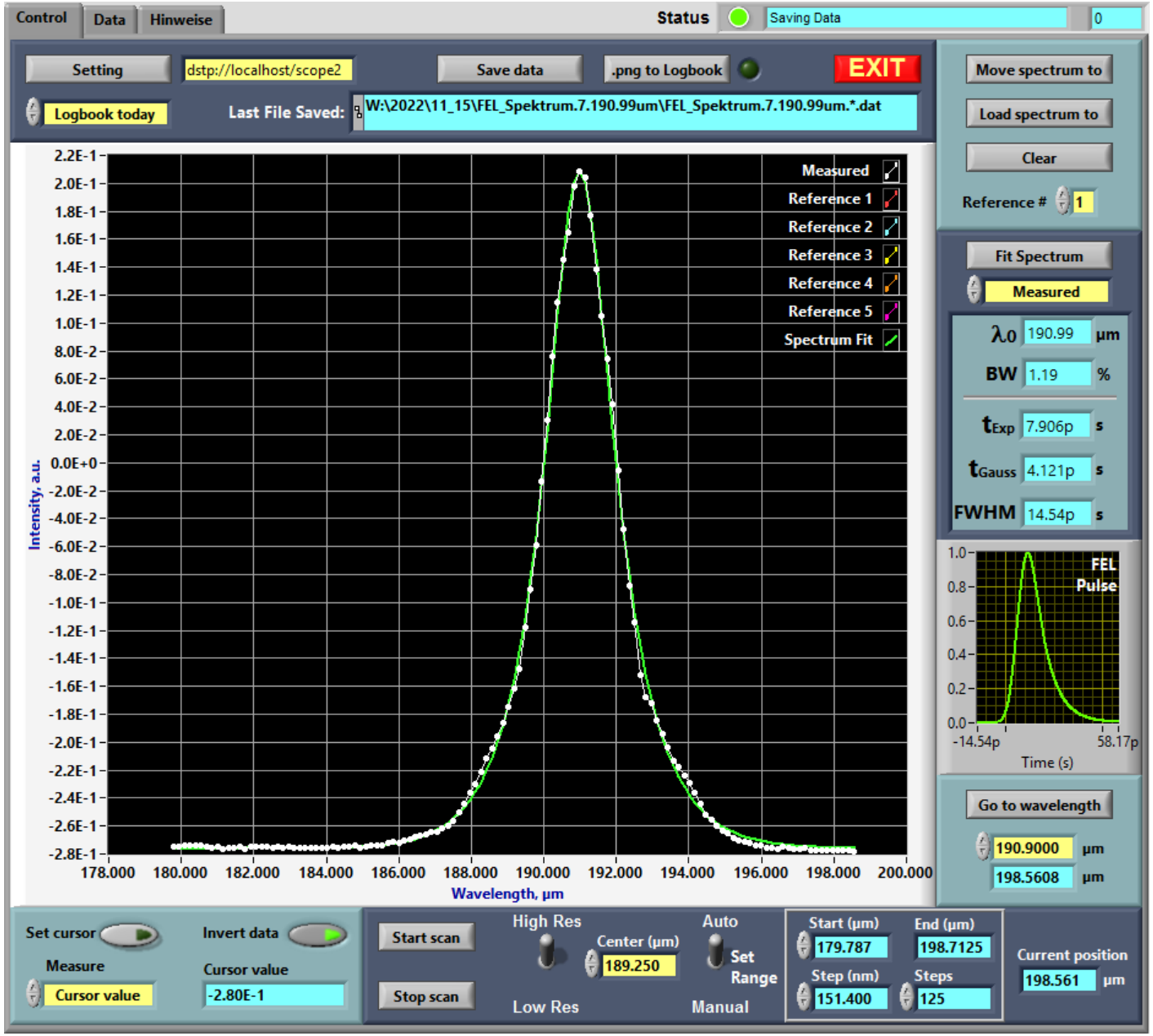
- Diagnostics for both FELs centralized before transport to endstations
- Basic diagnostics for user beam
  - Power
  - Spectrum
- Additional diagnostics available for MD
  - fast detectors for pulse-to-pulse (e.g. gain, noise, etc.)
  - PyroCam for beam profiling
- Step Attenuator for user beam



J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

FELBE Diagnostics

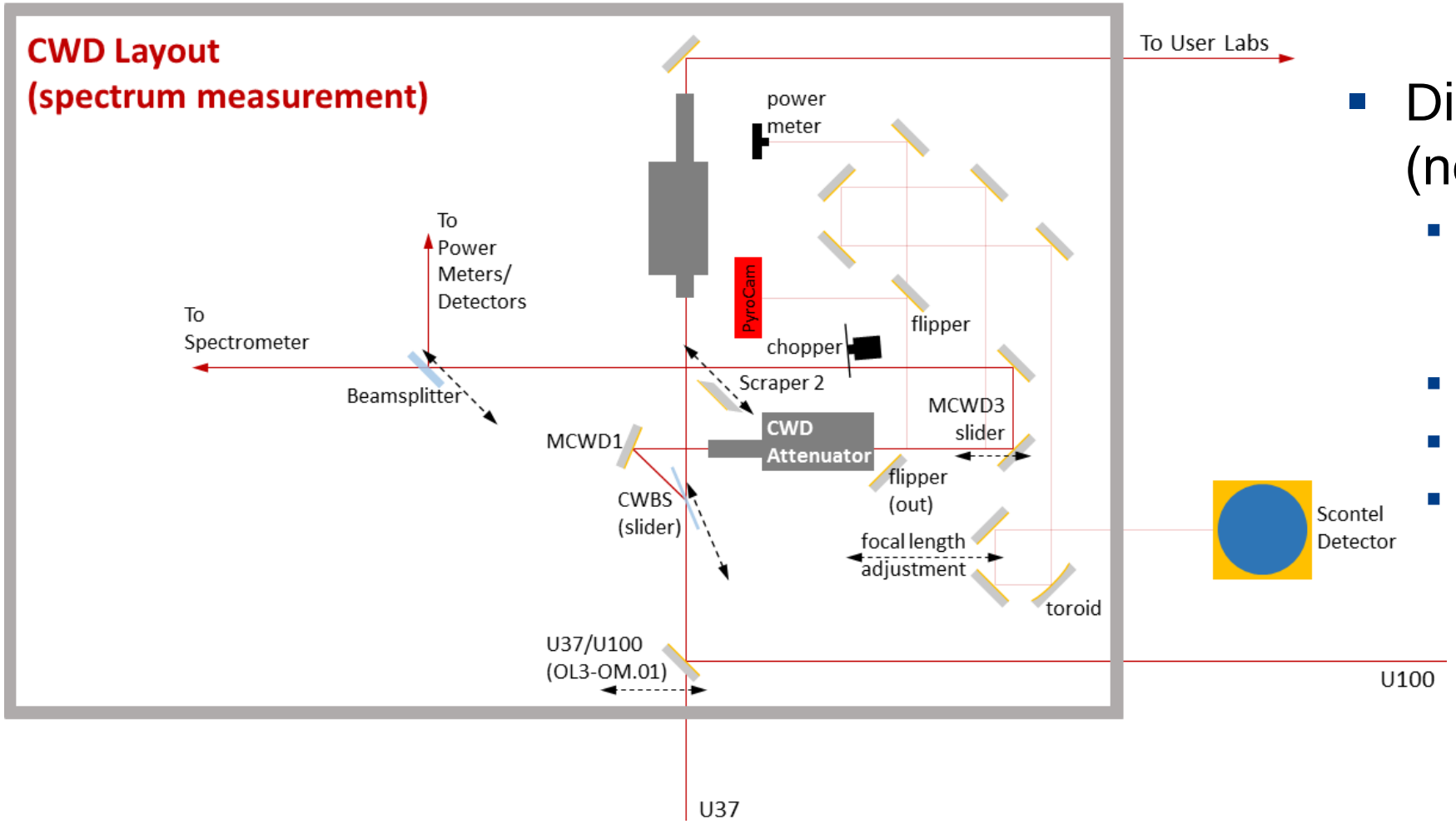
- FEL spectrum measurement
  - grating monochromator
  - stepwise scan
  - single measurement *takes* ~1 minute
  - temporal distribution from FT [1]



[1] S. Regensburger, et al., IEEE Transactions on Terahertz Science and Technology **9**, 262-271 (2019).

J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

FELBE Diagnostics



- "in situ" diagnostics are under development for FELBE
- Diamond window pickoff (near Brewster's angle)
  - ultrafast transition-edge superconducting bolometer for pulse-to-pulse measurements
  - FEL spectrum on demand
  - monitor mode distribution / pointing
  - monitor power of full beam

J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

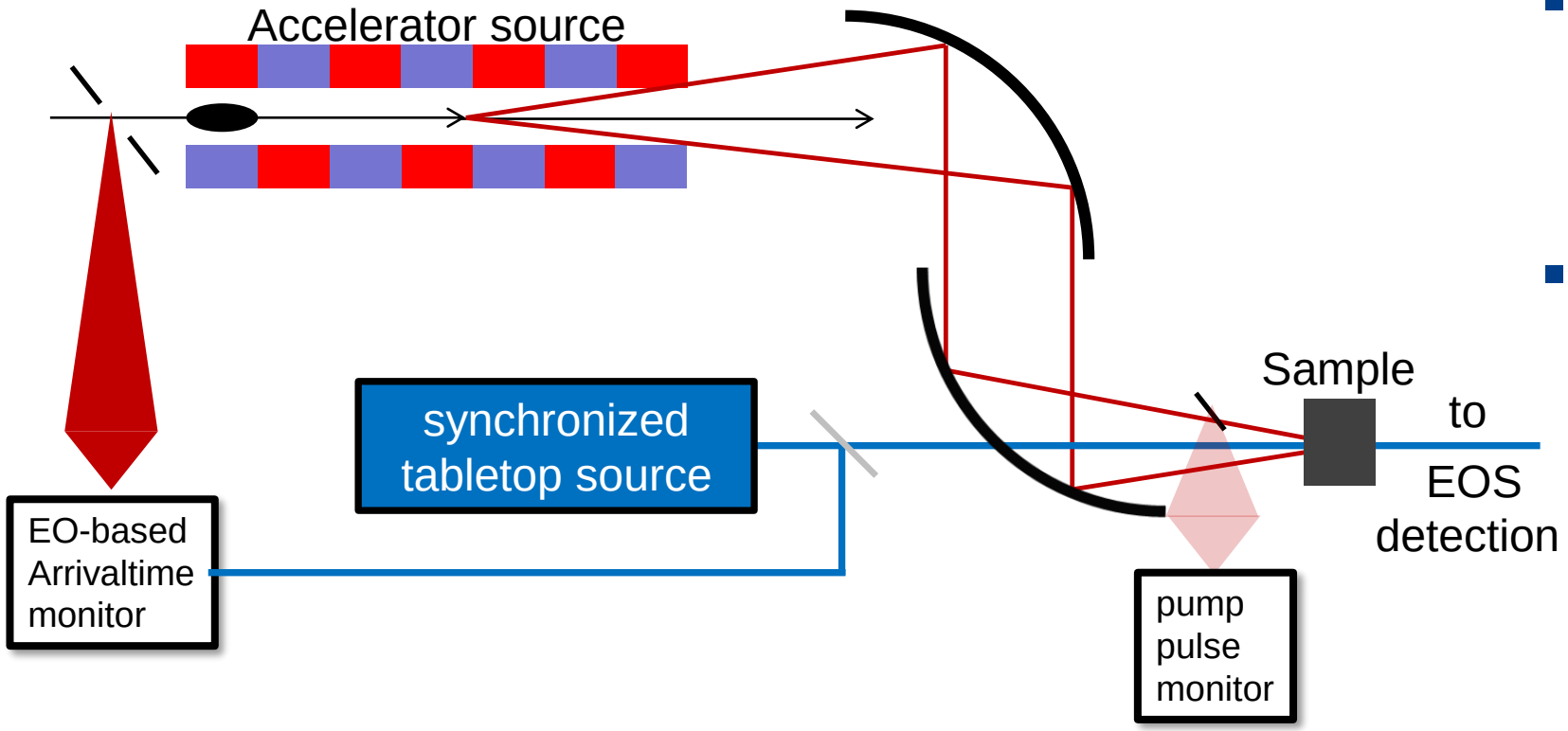
Outline

- FELBE Diagnostics
  - robust, easy to use, remotely operated
  - setup beam for users
  - MD and FEL performance measurements
  - currently limited to power and spectrum (temporal from FT of spectrum)
  - “in situ” diagnostics and more advanced measurements under development
  - phase-resolved measurement of FEL waveform demonstrated

- TELBE Diagnostics
  - power measurement in cave for coarse beam setup
  - fine tuning of setup requires “in lab” measurements
  - “in situ” monitoring with fast pyro
  - phase-resolved measurement of THz waveform with 10 fs resolution developed by TELBE group
  - full waveform in time-domain, FFT gives spectral distribution
  - continual improvement of accelerator and timing systems ⇨ real-time measurements

J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

TELBE Diagnostics



- single-cycle CDR source
  - primarily used for arrival time monitor
- multi-cycle undulator source
  - CEP stable
  - phase-resolved detection reveals coherent dynamics
  - 10 fs temporal resolution

sources of instability

- pump phase noise
- probe phase noise.
- detector noise.
- probe intensity noise.
- pump pulse noise

solution @ TELBE

- **arrival time monitor**
- **monitor pulse-to-pulse amplitude**
- **sort and bin every measurement**

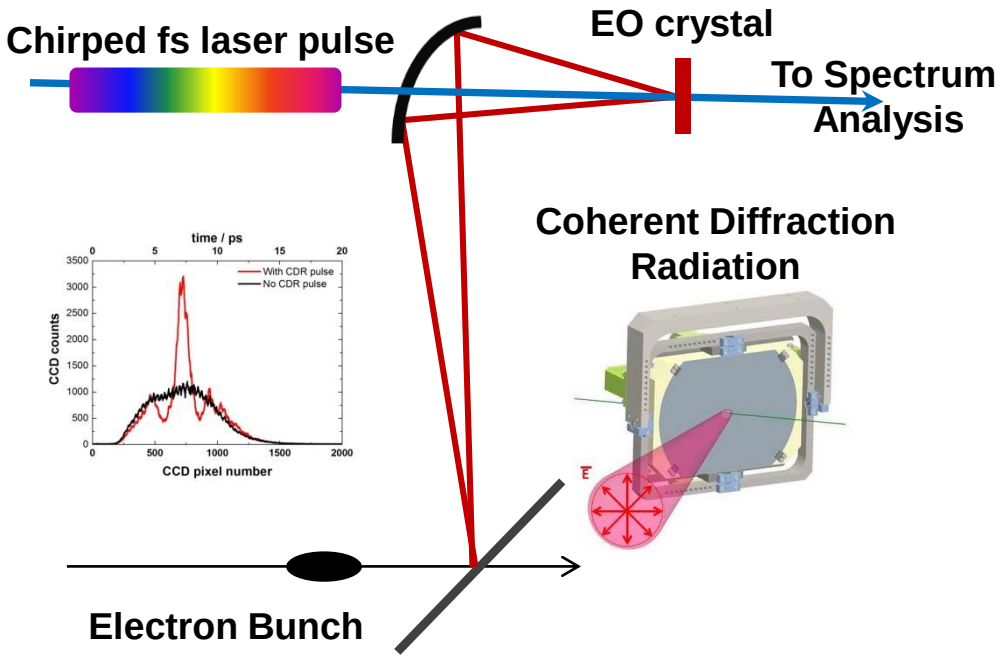
@ few 100 kHz rep rate!

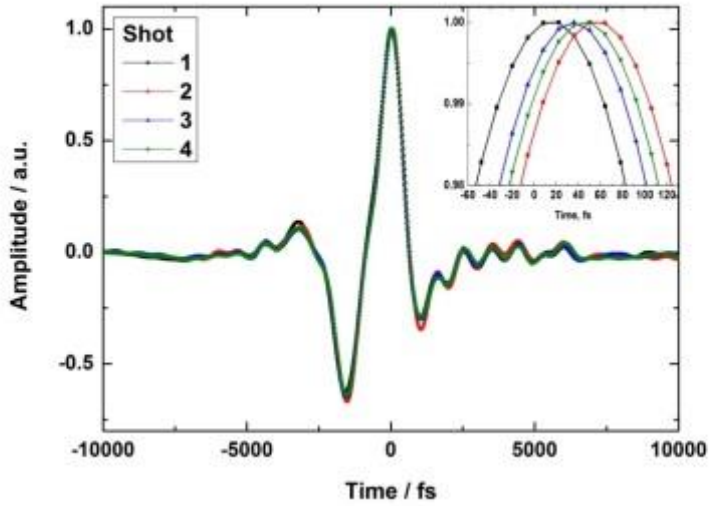
J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

TELBE Diagnostics

spectral decoding[1,2] based single shot EO monitor of the CDR THz pulse

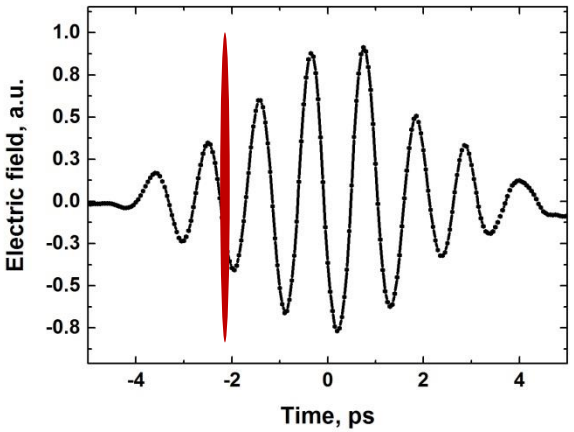
1. high resolution
2. high sensitivity
3. high rep. rate.



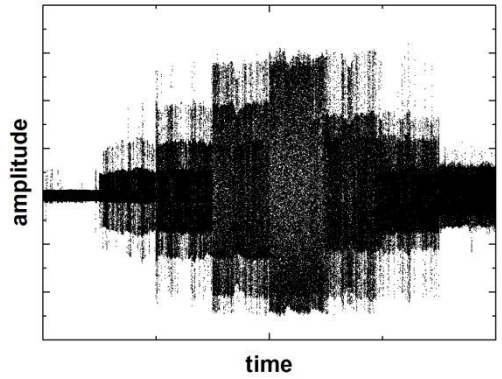


1.Z. Jiang, X. C. Zhang, *IEEE Journal of Quantum Electronics*, **36**, 1214, 2000.
2.I. Wilke et al., *Phys. Rev. Lett.*, **88**, 124801, 2002.

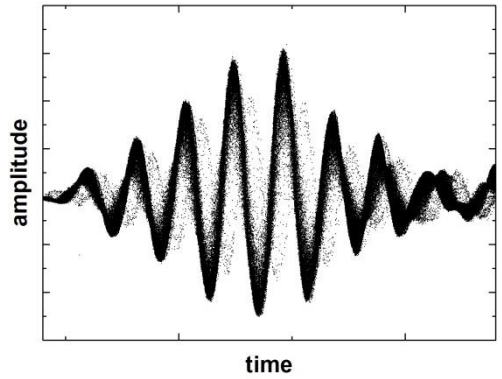
TELBE Diagnostics



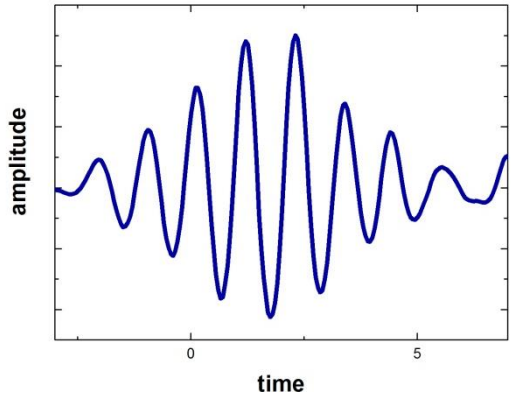
fs-laser pulse
(800 nm, 100 fs)



unsorted



sorted

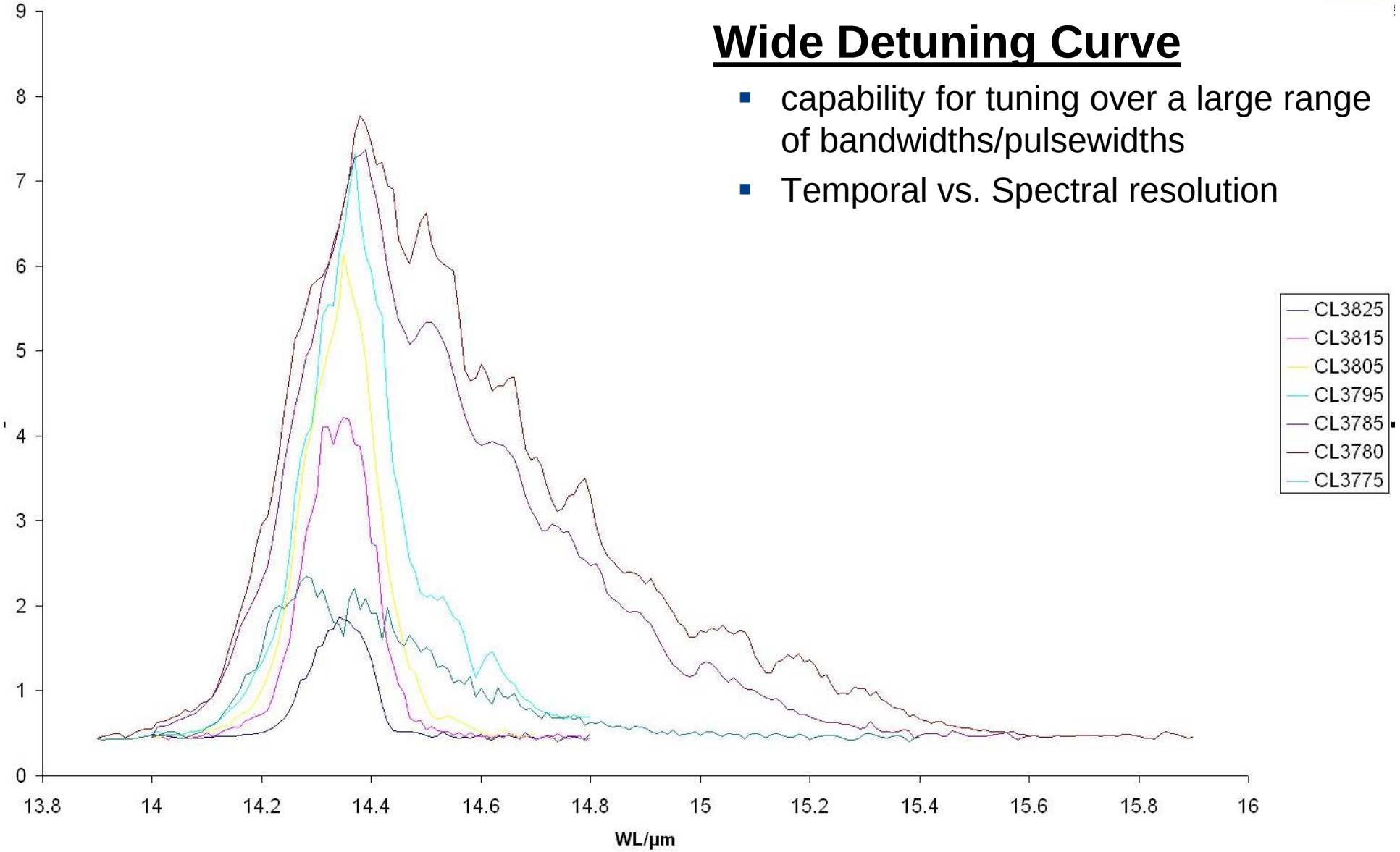


binned

- **Problem:** timing jitter between TELBE source and tabletop laser sources
- Data sorting and binning
  - measure arrival time of every pulse using CDR source
  - **sort** each EOS measurement of undulator source
  - bin or average intensity of every pulse (fast pyro)
  - step EOS laser pulse across full multi-cycle waveform
- **New method of THz-slicing eliminates need for sorting [1]**

[1] M. Chen, et al., Optics Express **30**, 26955 (2022).

Characteristics of an Oscillator FEL



Wide Detuning Curve

- capability for tuning over a large range of bandwidths/pulsewidths
- Temporal vs. Spectral resolution

J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR