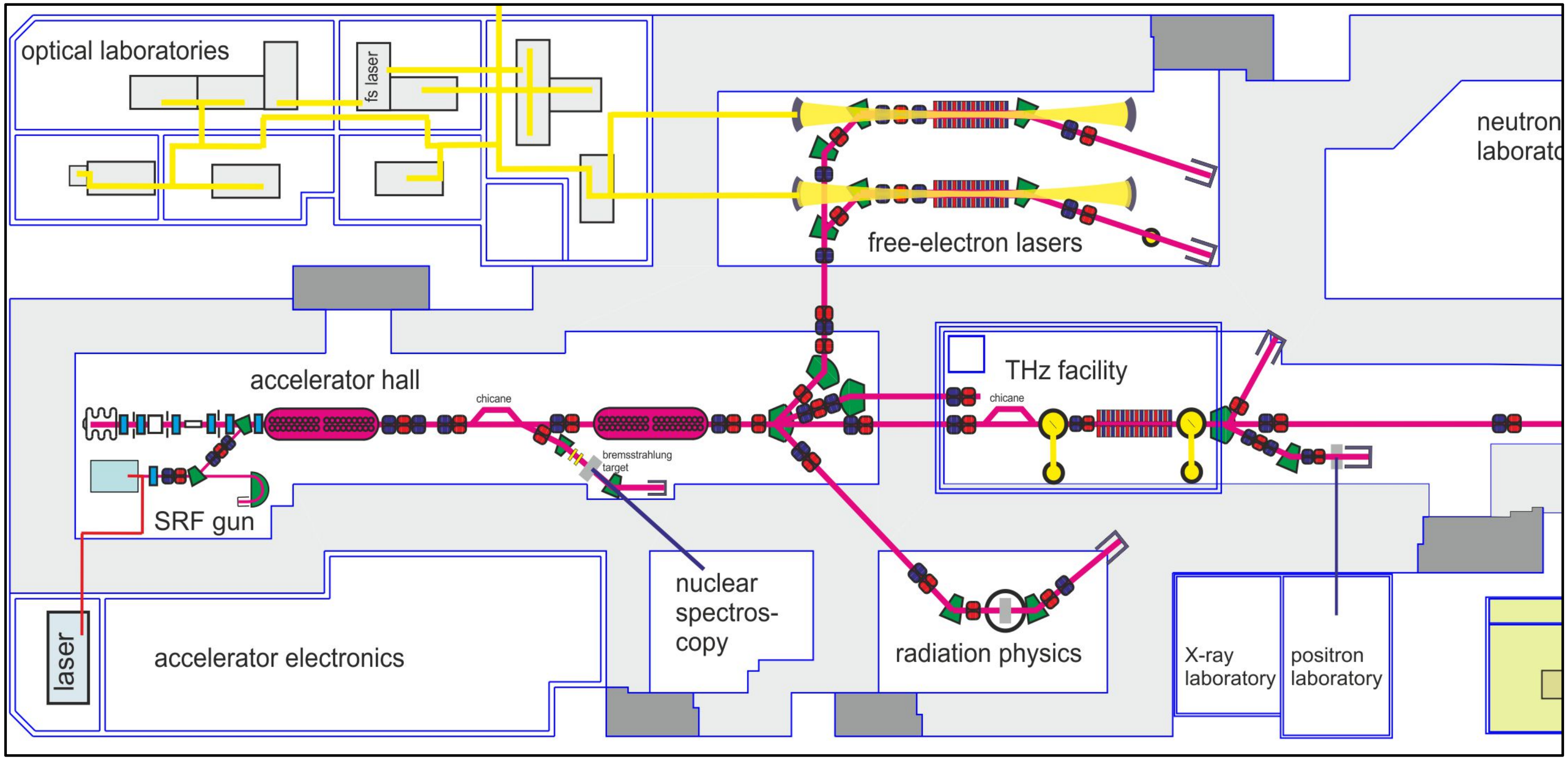
ARD-ST3 at ELBE / HZDR

Klaus Zenker for ELBE and TELBE teams

Outline

- Radiation Source ELBE (reminder)
- THz user operation with SRF gun
- Bunch length measurements
- Digital LLRF
- Synchronization system
- TELBE – even better synchronization / resolution
- 500 kHz stripline kicker (beam separator)

Radiation Source ELBE

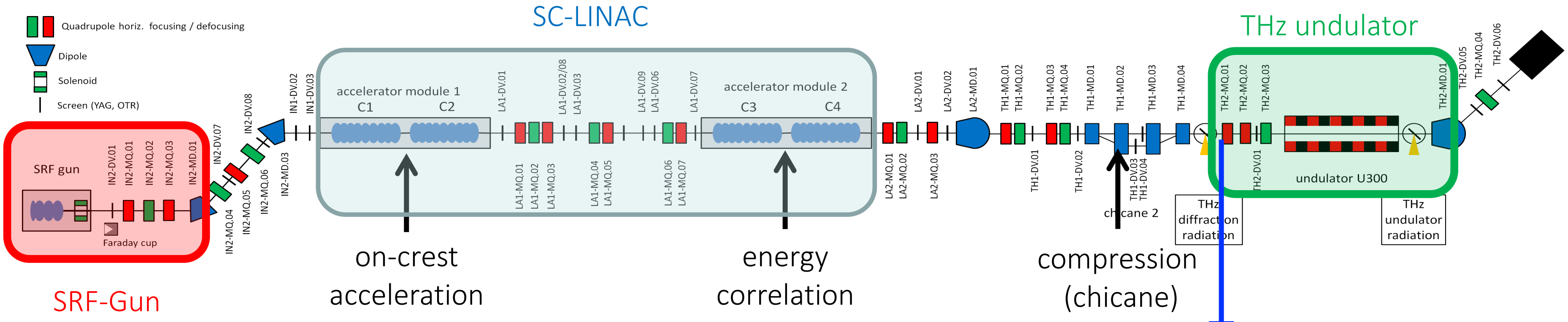


- **User facility:** 24/7 user operations
- **Accelerator:** 1 mA, 40 MeV, CW SRF linac;
- **Two injectors**: 1-DC gun with thermionic cathode; 2-SRF photo injector
- **Applications** demanding short bunches, and/or longitudinal stability:
  2 IR FEL oscillators (13 MHz), super-radiant THz undulator + few-cycle CDR (100 kHz)

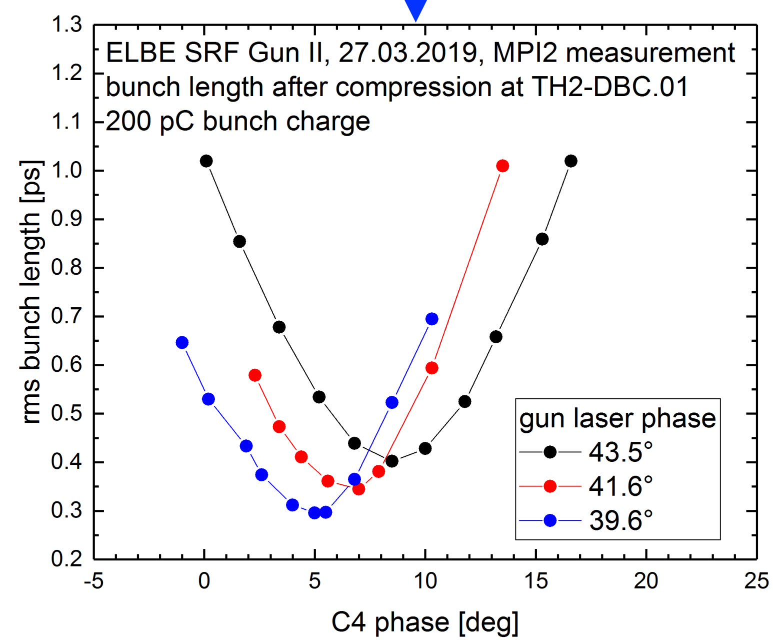
DRESDEN concept

HZDR

SRF Gun Setup for Super-radiant THz Souse

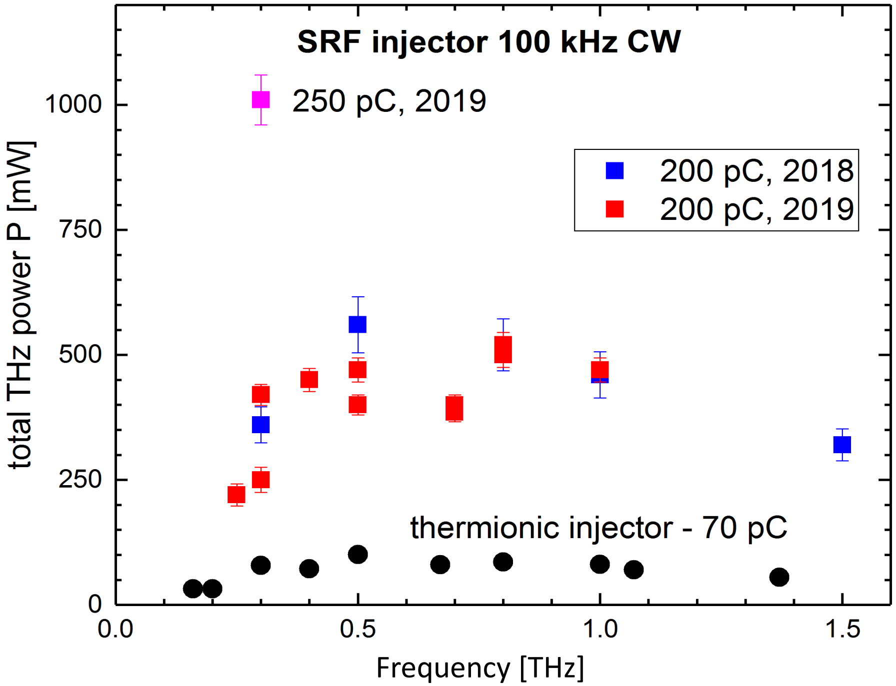


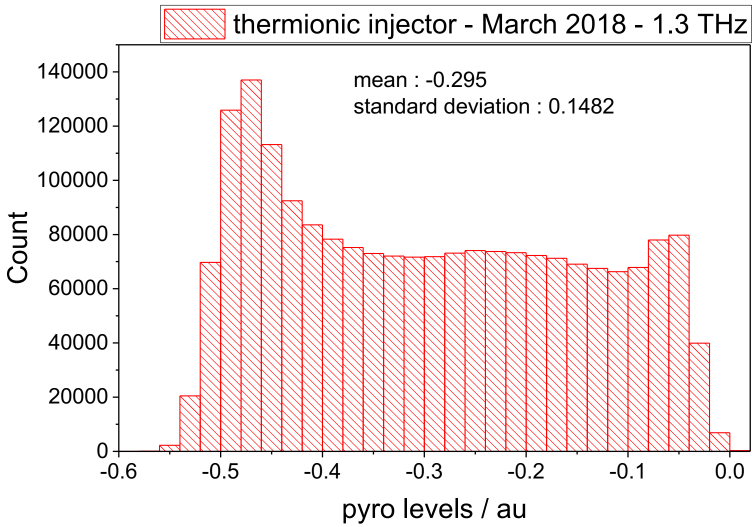
- e-beam: 200 pC @ 100 kHz, 20μA
- E_{gun} = 4 MeV, E_{ELBE} = 26.5 MeV
- Linac 1 (2x Tesla 9-cell) on-crest
- Linac 2 (2x Tesla 9-cell) off-crest
- Compression with magnetic chicane

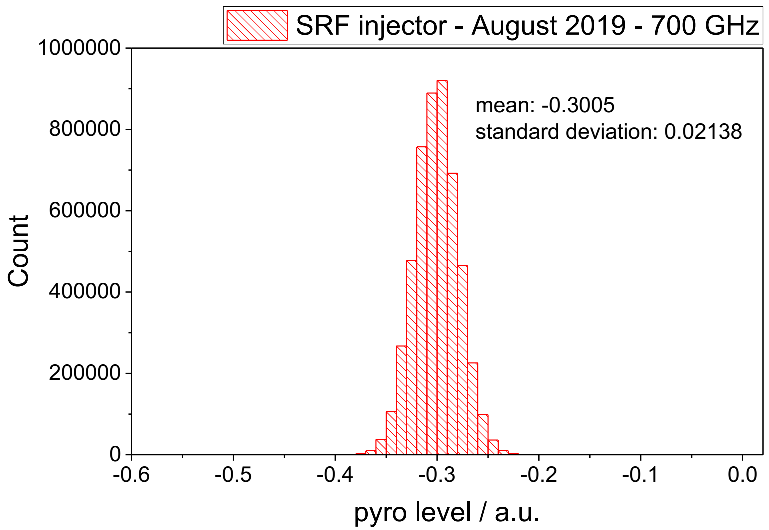


- Measured with with Martin-Puplett Interferometer
- The gun laser phase influences the initial bunch length delivered by the gun.

THz User Operations with SRF Gun Beam





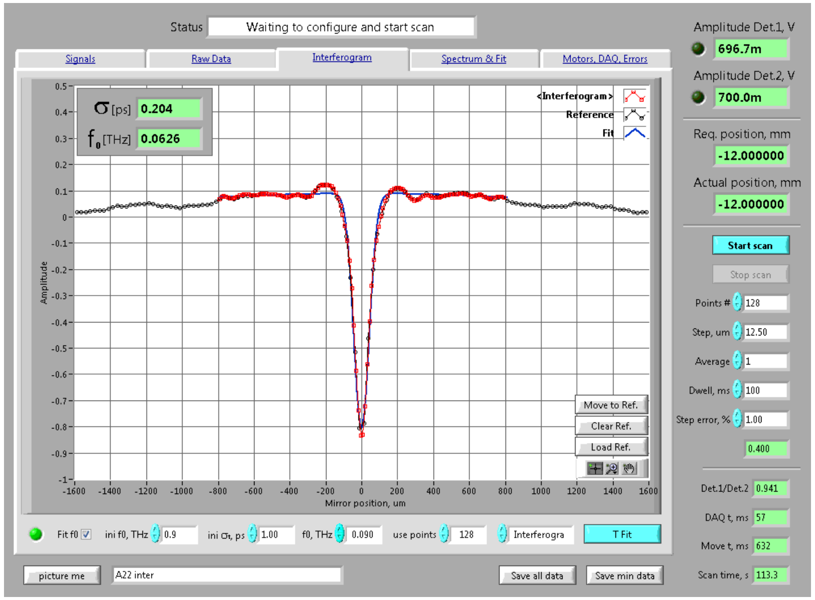


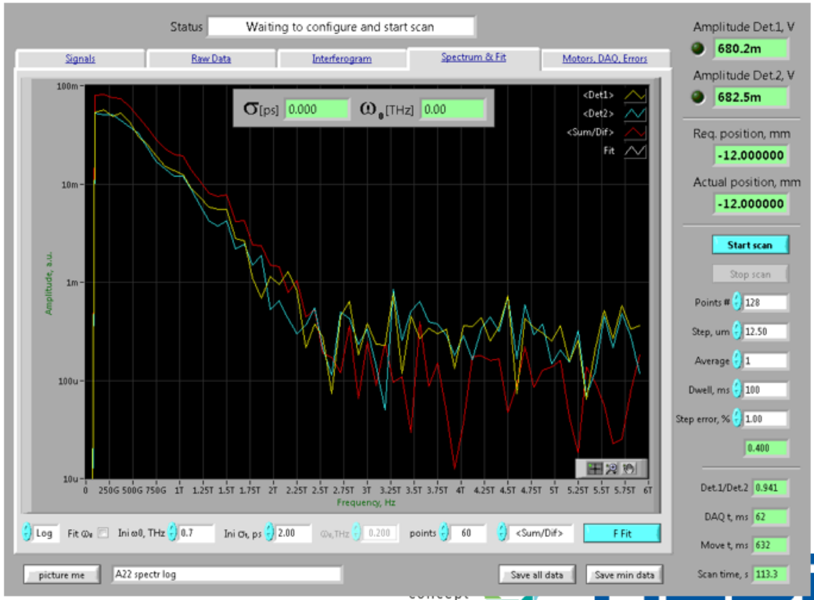
Performance SRF vs. thermionic gun

- higher energy, 10 µJ/pulse @ 100 kHz
- lower timing jitter
- improved overall stability

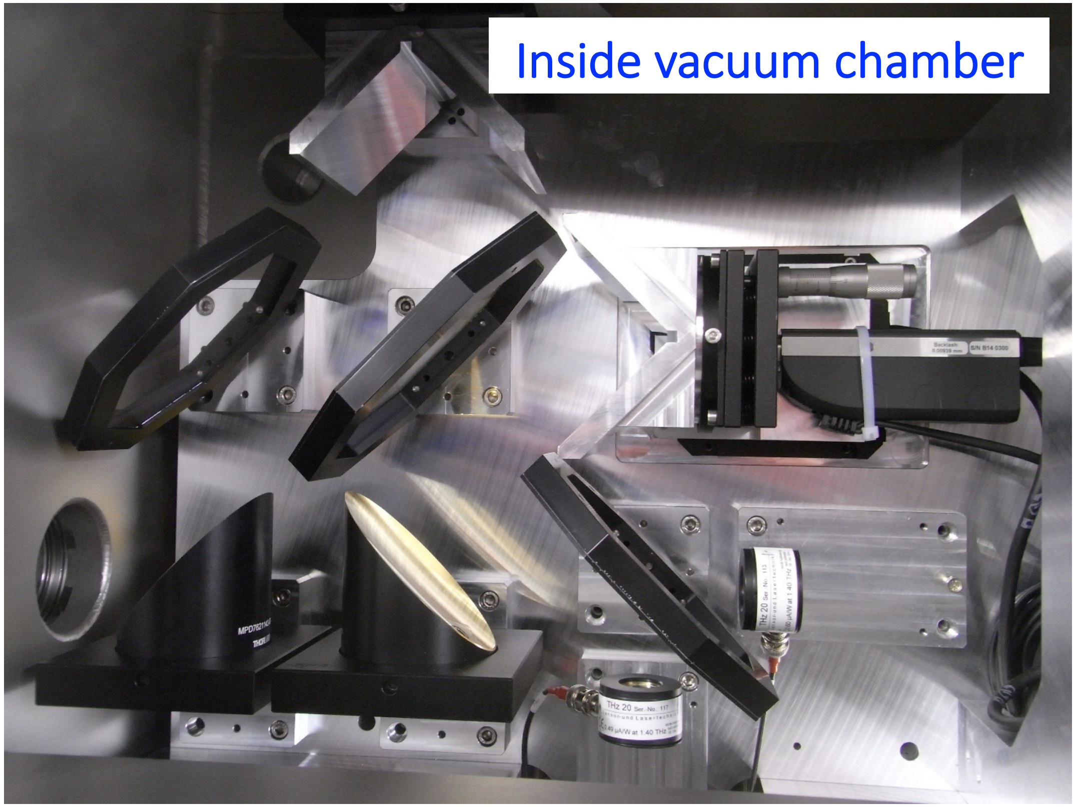
Bunch Length Measurements at ELBE

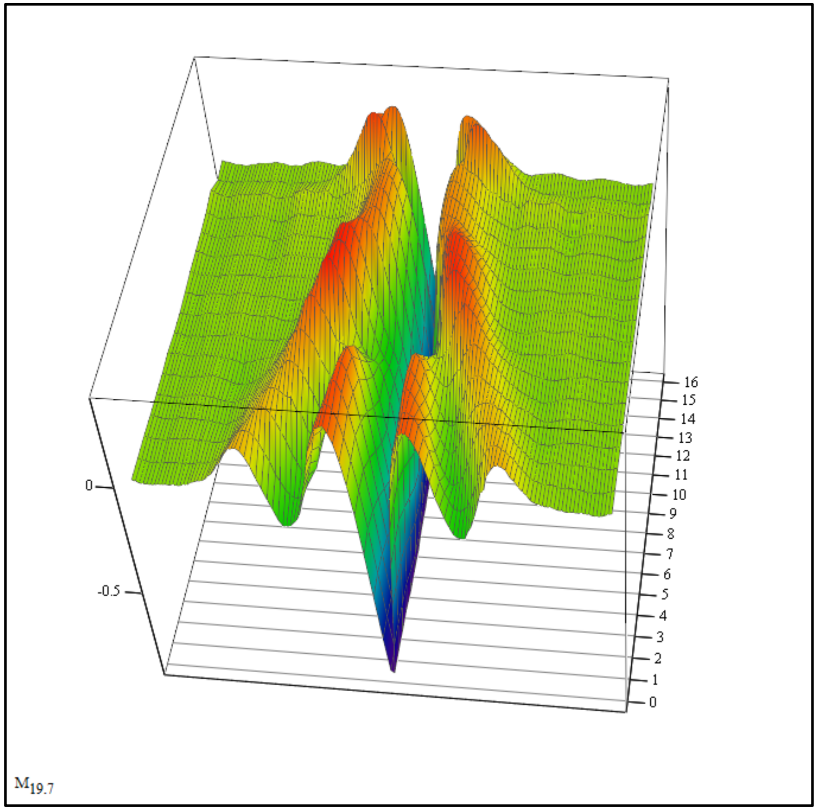
- For few-ps to sub-ps bunch length measurements polarizing Michelson interferometer is used
- First order field autocorrelation is measured
- Fourie Transform ⇒ Power Spectrum
- Data evaluation in time domain with NLSF
- In vacuum – no air absorption
- Two detectors remove intensity fluctuations
- At ELBE measured down to ~ 200 fs RMS
- Instrument reproducibility < 0.5 %
- No phase measurements:
  not a problem for FEL (peak current sufficient) and super-radiant undulator (bunching factor is measured directly)
- Next improvements:
  - bunch-by-bunch measurements with fast detectors
  - cont. scanning: 5-10 sec. per measurement





Bunch Length Measurements at ELBE





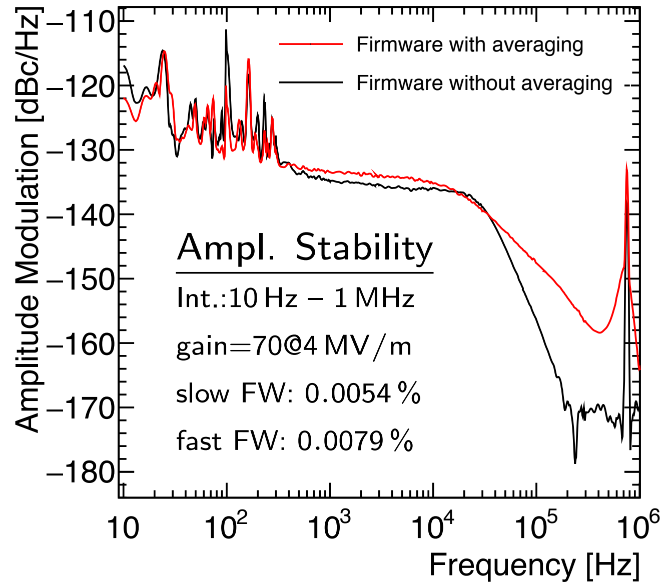
data set – vs. linac phase

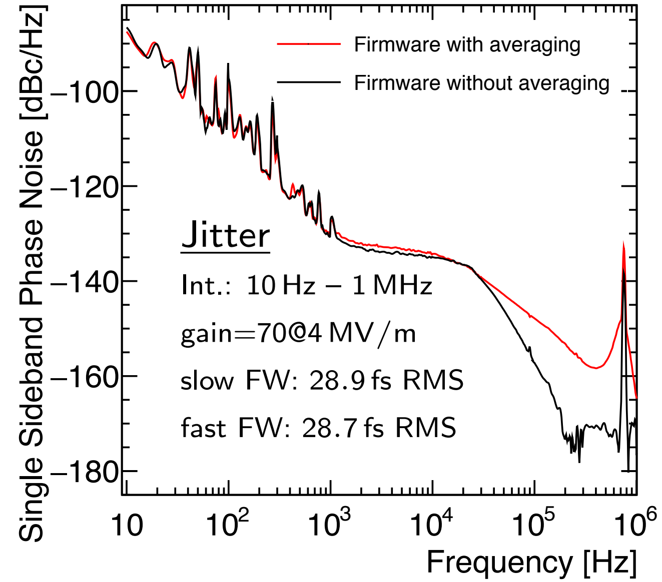
Digital Low Level RF System

- NC RF buncher (260 MHz/1.3 GHz) cavities are controlled digital since beginning of 2019
- Controller design finished for all SRF cavities
  - Issue with digital filters operated at the bandwidth limit was solved by implementing the filter in the MIMO
  - Different firmware versions were tested and evaluated using noise measurement
- Digital SRF cavity control will start in the upcoming month

Open issues

- One open server application bug that sometimes requires an application restart after an interlock was fired
- We observed wrong attenuator settings on the analog RTM board after a MTC4 crate reboot
- Possible explanations:
  - Communication between the AMC and the RTM failed
  - Server application failed to set attenuation values from persist file

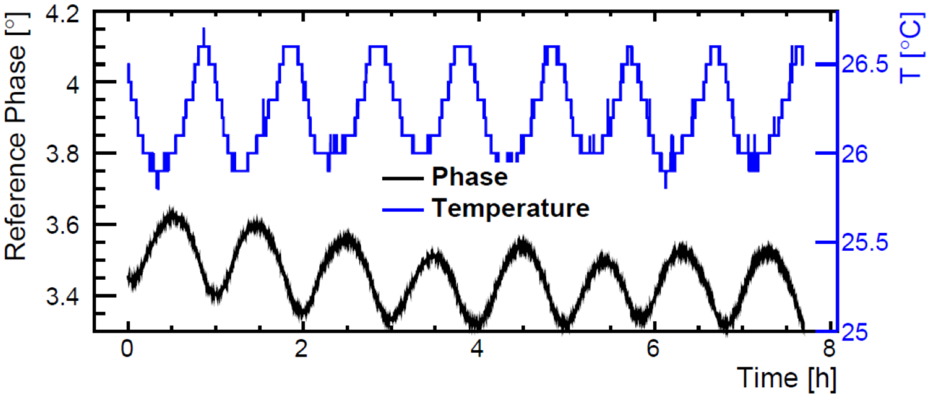




Reference Based Phase Correction

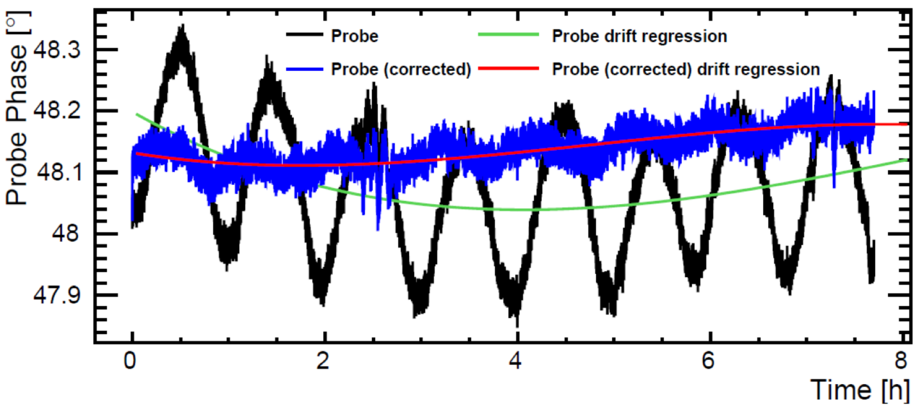
Ideas

- Measure the reference phase from the master oscillator
- Fluctuations seen by the digital LLRF system are induced e.g. by temperature fluctuations
- These fluctuations are similar for all channels
- Correct Probe phase based on the reference phase



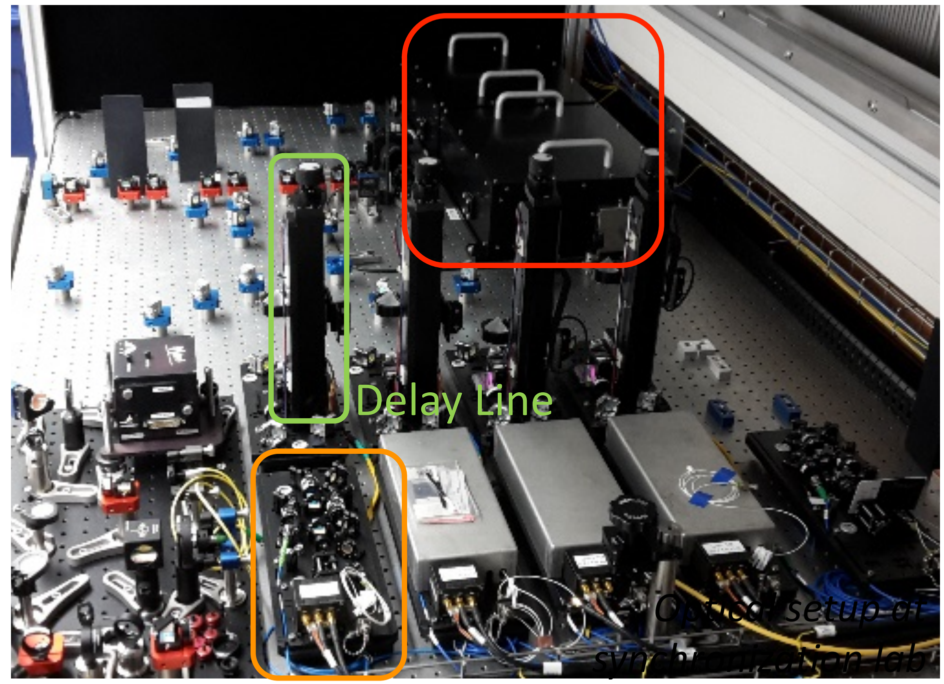
Result

- Offline analysis showed reduced fluctuations
- Reduction from 0.1° RMS to 0.02° RMS (after subtracting phase drift)

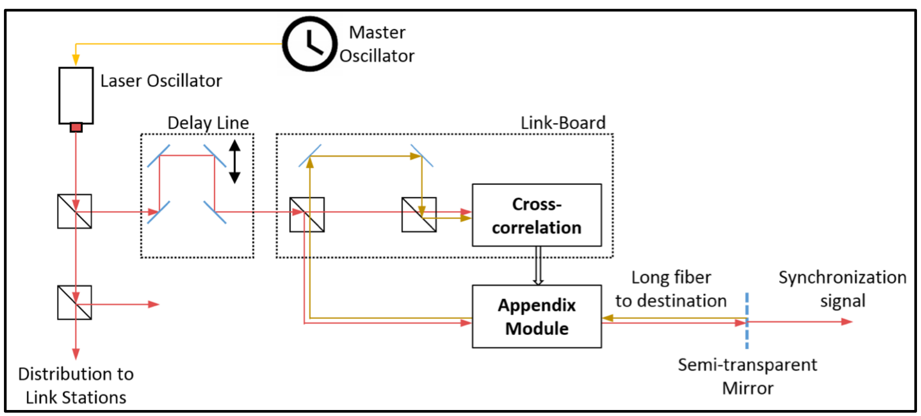


Status of femtocecond synchronization system

- Synchronization System got upgraded in the last years, now using polarization maintaining fibers
- Initial design provided by DESY, adapted at HZDR
- Two Stabilized Fiber Links in regular operation since 2018 (used by high power laser facility / laser acceleration)
- Three more in commissioning: for BAMs and new HP Laser
- System characterization in 2019: 130 fs phase noise (integrated from 1 Hz through 1 MHz, entire system)

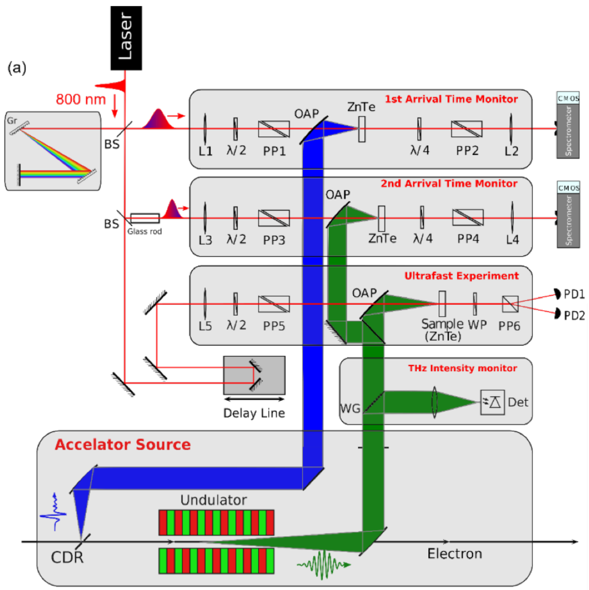


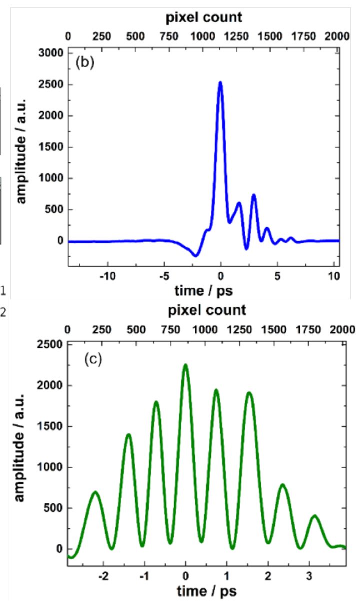
ELBE synchronization system scheme

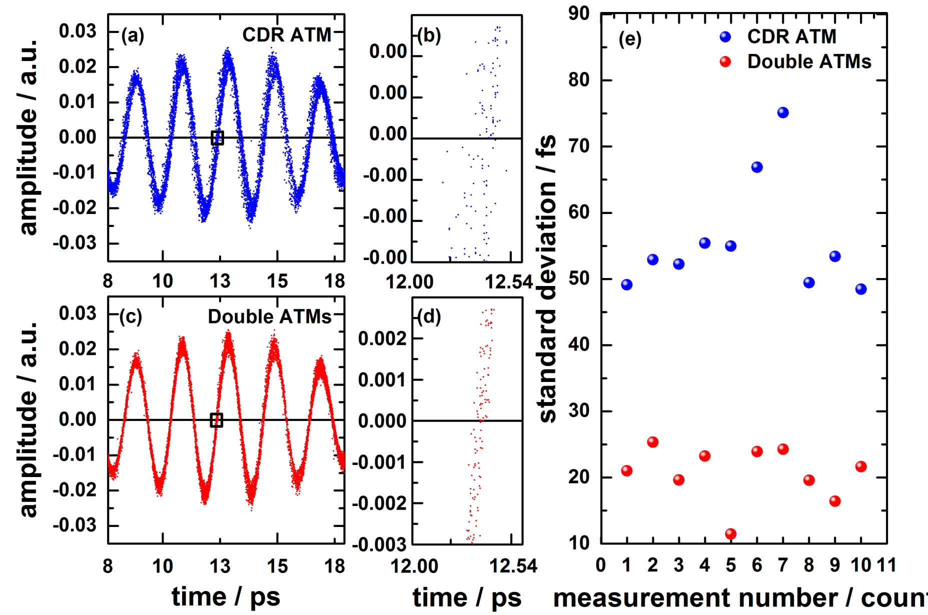


Dual Arrival Time Monitor

Sequential arrival time monitors to –
improve temporal resolution of pulse-resolved detection



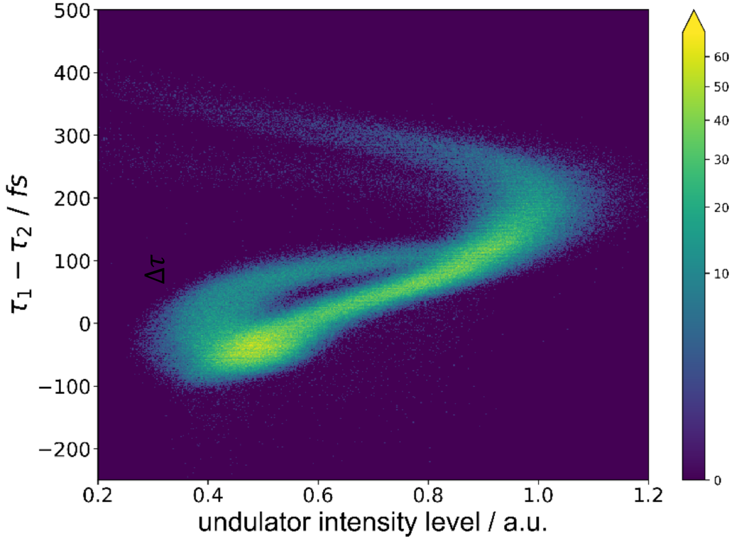




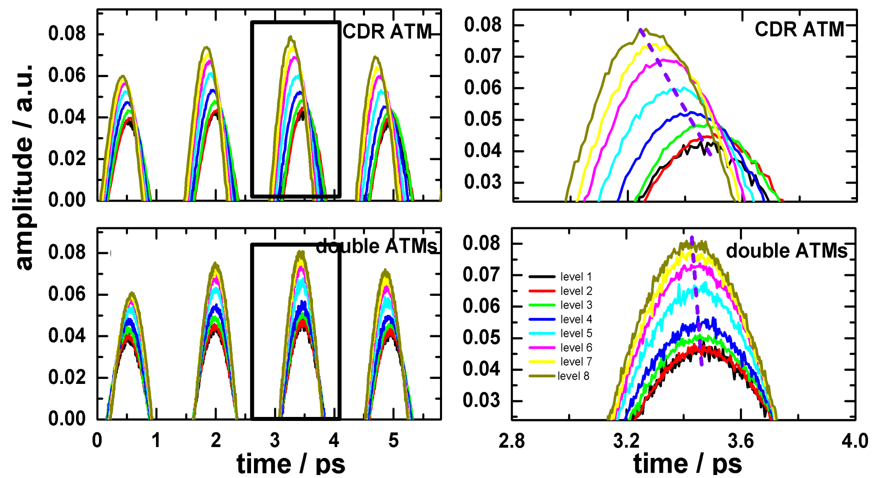
- Temporal resolution increase from 55 to 20 fs (RMS)
- Short -term jitter compensation
- Avoid CDR-undulator jitter

Correlated Pulse Energy and Arrival Time

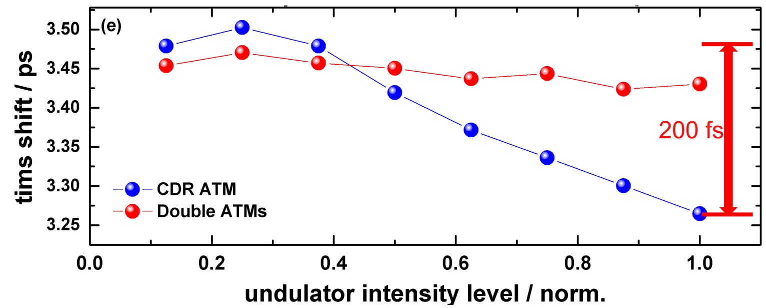
Sequential arrival time monitors to –
understand complex dynamics of the electron bunch



EOS trace binned with different undulator intensity level



- Δτ – arrival time difference between CDR and undulator pulse
- Undulator intensity level – read out from undulator ATM



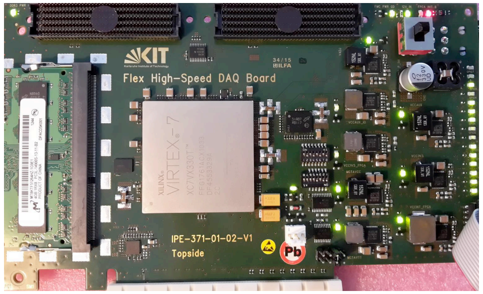
- ✓ Increased timing accuracy by decreasing pulse intensity correlated arrival time shift
- ✓ !!!Could be a new diagnostic tool investigating electron energy charge dispersion between undulator and CDR source !!!

Other on-going TELBE Projects

Online FPGA-based data acquisition and data processing

poster by M. Bawatna

"High-Speed Data Acquisition System and Real-time Data Processing using FPGA Architecture"



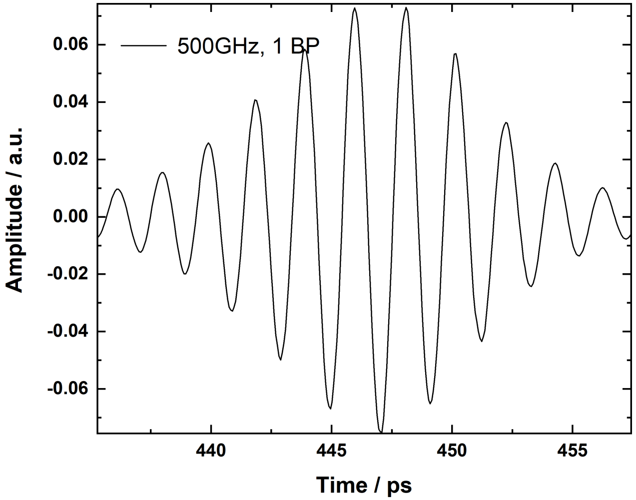
Work in progress

- To bring current pulse-resolved detection technique from 100 kHz towards few MHz repetition rates
- Uses new camera and FPGA technique
- All hardware assembled/installed, under tests now

All-optical, passive, jitter-free, intrinsic CDR – table top laser synchronization

talk by Min Chen (next session)

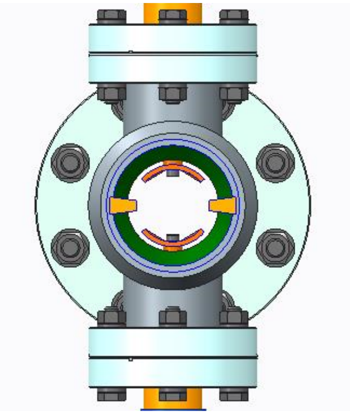
"Pulse- and Field-resolved THz diagnostics at TELBE"



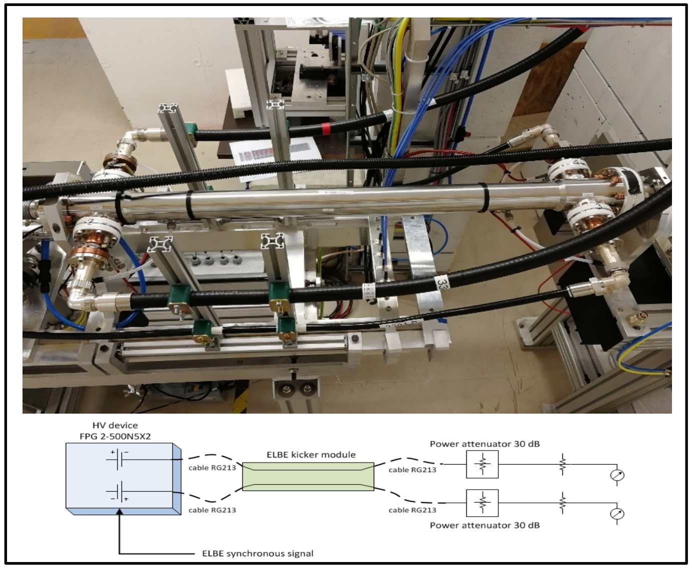
First results of THz slicing at TELBE

- Multi-shot, conventional EOS measurement
- Probe laser is gated by CDR pulse

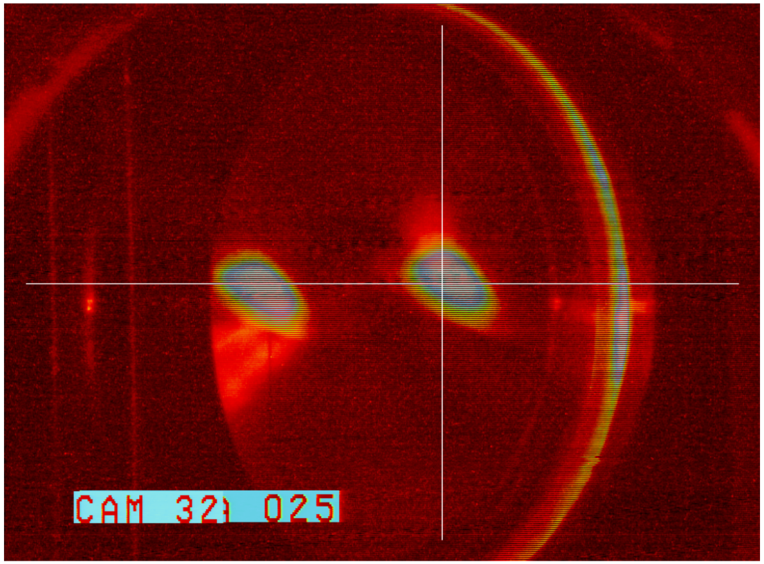
500 kHz Stripline Kicker



Stripline kicker – beam view

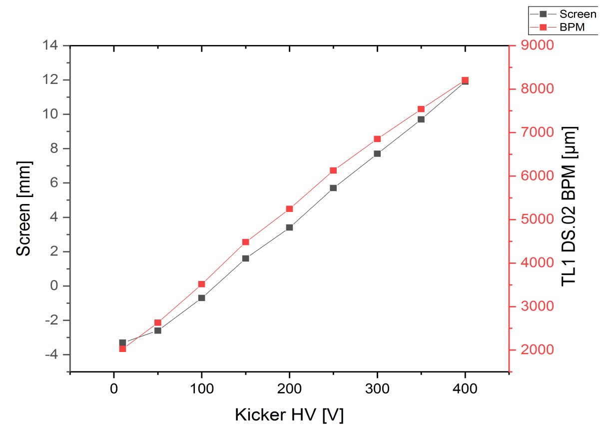


- Installation the ELBE beamline 2018
- Shown: the interconnection to the HV power device (FID), the power dampers at the end of the circuit
- The HV device max.: 2kV at 500 kHz
- The kicker commissioned Feb 2019 (see on the right)
- For beam separation the kicker works together wit a magnetic septum in 7 m distance from the kicker.



TL1_DV.04-YA (440,279) X=7.4 mm Y=2.0 mm

- Kicked and not-kicked beams seen by beam viewer downstream of the kicker
- Beam repetition rate – 100 kHz
- Kicker rate – 50 kHz (50/50)



This is it folks

Backups

- aaa
- bbb
- ccc