HZDR's ARD-ST3 Status and Plans

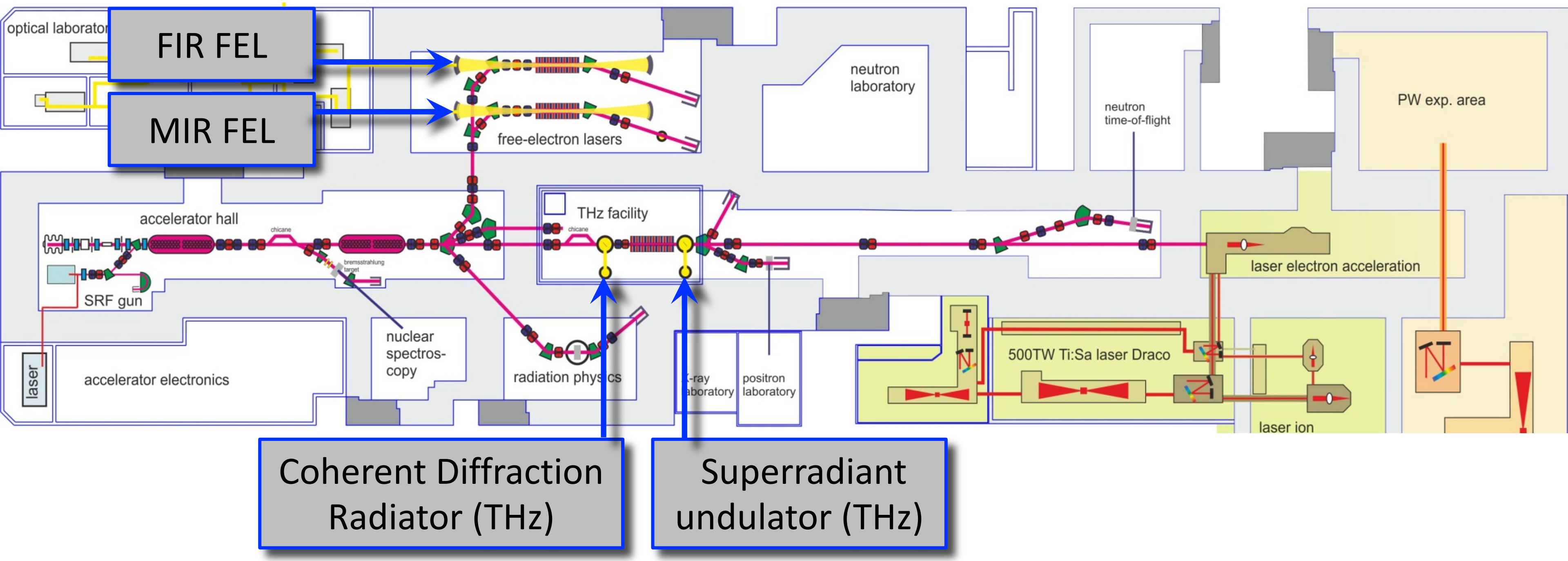
A. Arnold, S. Kovalev, M. Kuntzsch, A. Maalberg, C. Schneider K. Zenker, and P. Evtushenko

OUTLINE

- ELBE - reminder
- Digital LLRF
- High repetition rate stripline kicker
- Towards beam-based feedback
- High Dynamic Range photo-cathode laser measurements
- High Dynamic Range bunch charge measurements
- New metrology at TELBE
- ELBE successor (new facility) concept

HZDR :: ARD-ST3

- Radiation Source ELBE – user facility (CW SRF LINAC, 40 MeV, 1 mA)
- New user facility proposal development (ELBE's possible successor)



DIGITAL LOW LEVEL RF SYSTEM AT ELBE

See talk by Klaus Zenker

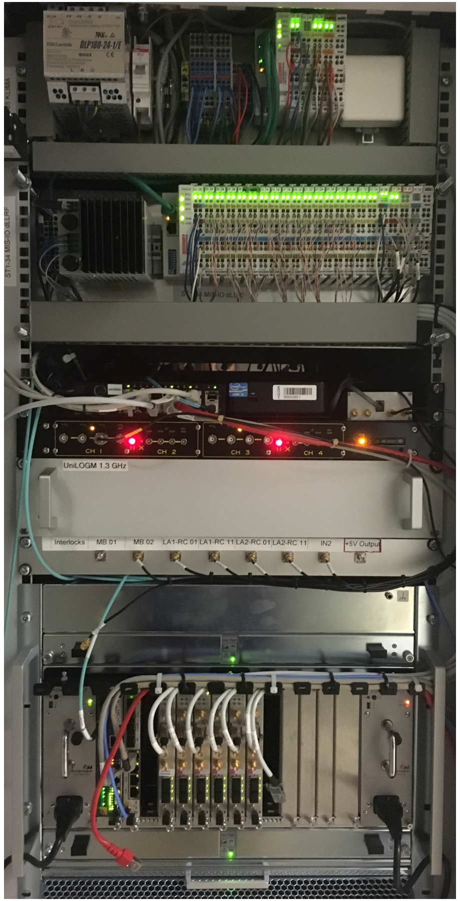
Digital LLRF user operation:
- In user operation since August 2020
- All beam lines were operated without major problems

Issues that have been solved:
- Controller design for all cavities
- Long term drift compensation via reference tracking algorithm
- Communication problems between WinCC and the LLRF application
- Modified/optimized ramp up procedure

Improved machine protection:
- Limiter configuration
- Feedback of the digital LLRF state to the ELBE machine protection system

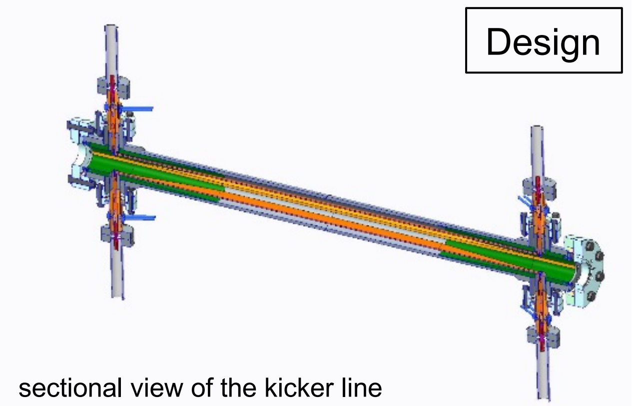
System integration:
- Introduced virtual phase shifters, e.g. shift linac with respect to the buncher cavities
- Adopt existing ELBE feedbacks to work with the digital LLRF (i.e. energy stabilization)

Outlook:
- Dedicated trigger for the digital LLRF once the new timing system is ready
- Beam based feed back implementation

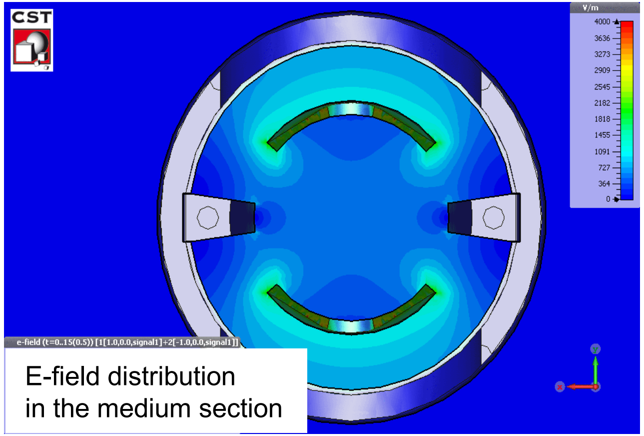


ELBE :: HIGH REPETITION RATE STRIPLINE KICKER

Design



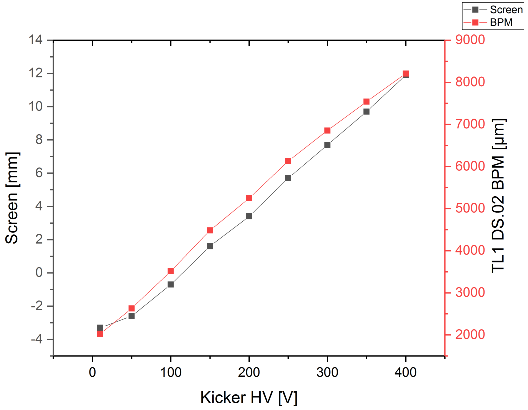
sectional view of the kicker line
with electrodes, taper and ground fender



E-field distribution
in the medium section

Key Parameters

Parameter	Kicker	HV-Device
Rep. rate	13 MHz	500 MHz
Max. HV	3 kV	2 kV
Amp. Stab.		1%

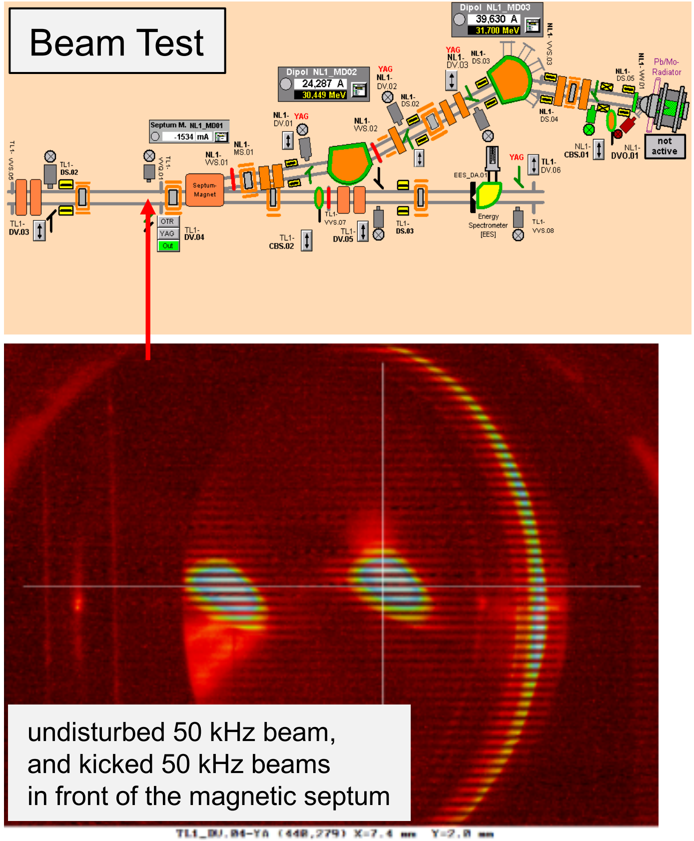


Beam displacement 7 m downstream of the kicker vs. HV source amplitude;
BPM and viewer measurements

A. Arnold, C. Schneider

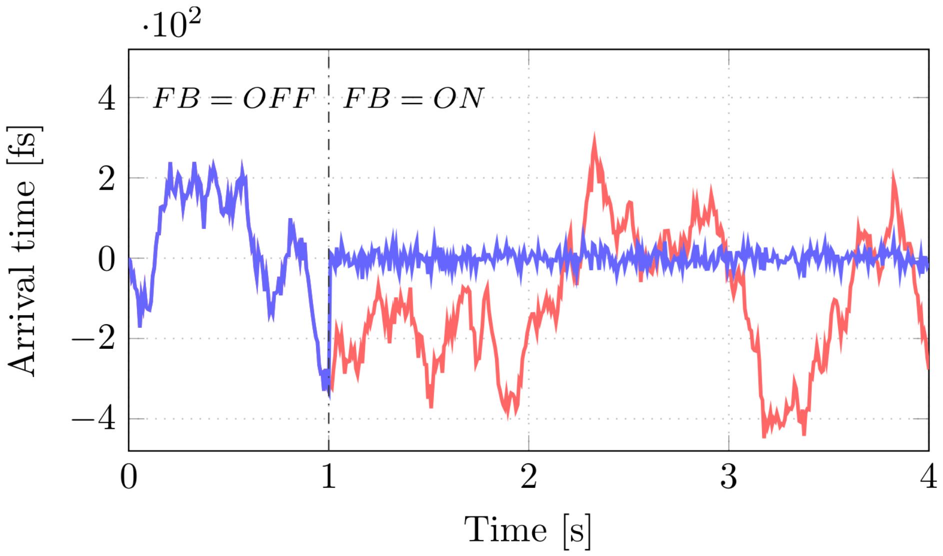
Beamline section used for the kicker's beam test

Beam Test



undisturbed 50 kHz beam,
and kicked 50 kHz beams
in front of the magnetic septum

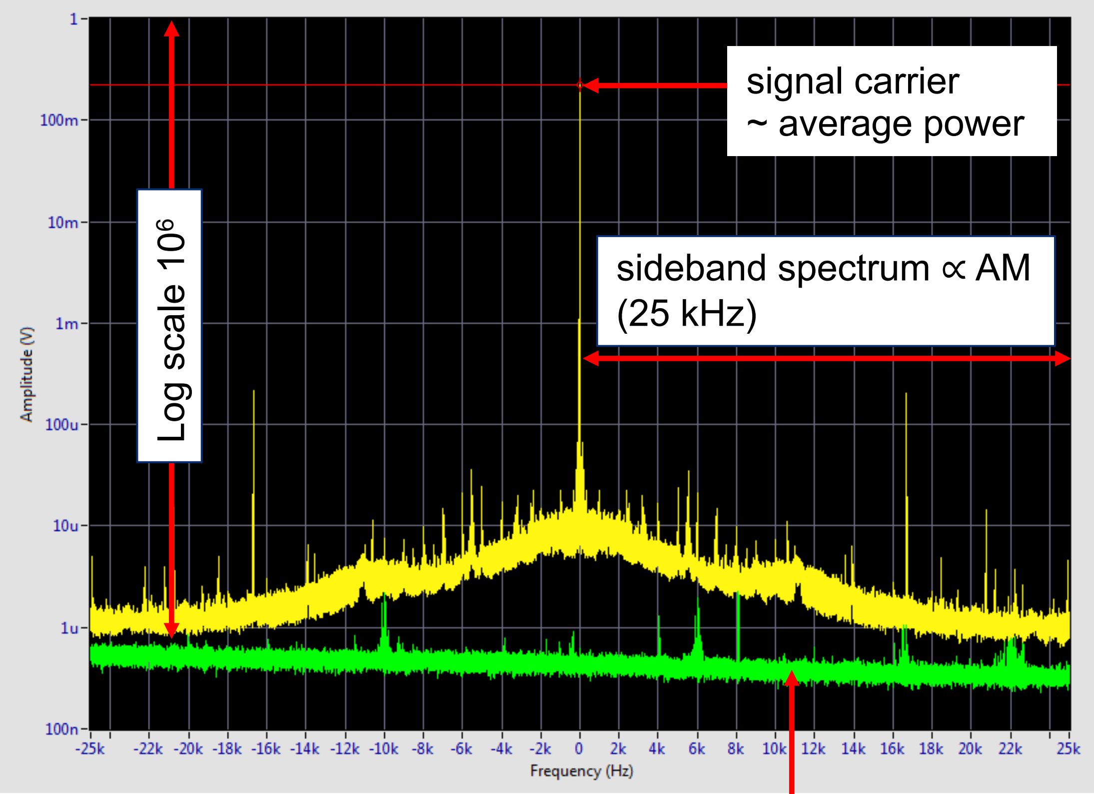
TOWARDS CW BEAM-BASED FEEDBACKS



(See speed talk by Andrei Maalberg for details)

- Continuous improvements of temporal beam stability is needed/expected for user operation of ELBE
- The ELBE successor (new facility) will require sub-100 fs synchronization of multiple photon sources
- Longitudinal beam-based feedbacks are envisioned to be a part of the solution.
- Ongoing numerical modeling of possible feedbacks and controllers.
- Preparation of beam tests at ELBE
- CW is the specific of HZDR machines
- Strong collaboration with DESY

PHOTOCATHODE LASER PULSE ENERGY STABILITY MEASUREMENTS



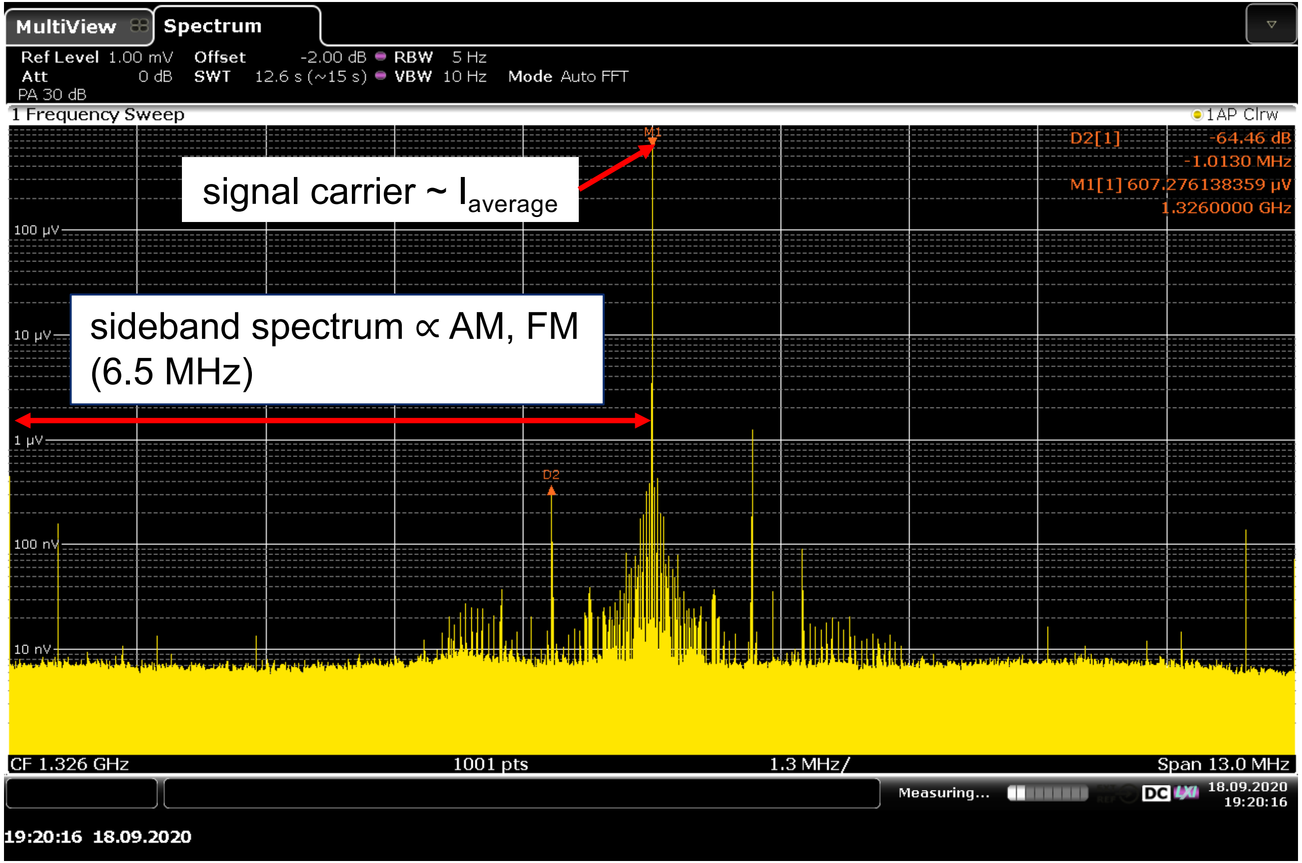
A. Ryzhov, P. Evtushenko

- High energy/pulse stability is required at ELBE's coherent photon sources

$$I_{ch}(\omega) = I_o(\omega) \cdot N_e^2 \cdot |f_\omega(\omega)|^2$$

- Bunch charge (photocathode laser energy) stability is critical (due to ~ N^2)
- **Technique was established to measure the laser energy/pulse stability with dynamic range of >10^5, and frequency resolution of 1 Hz**
- Largest perturbation at ~ 16.6 kHz was identified (initially at few % level) and reduced ~ 10 times
- THz source pulse energy stability of last few runs ~ 0.3 % RSM

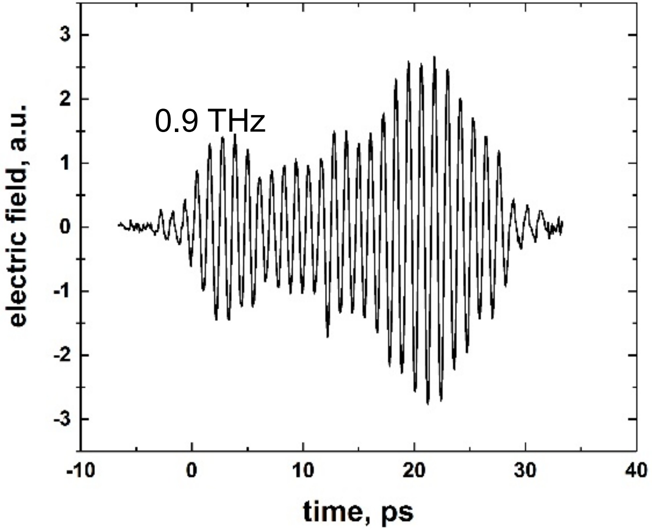
BUNCH CHARGE STABILITY MEASUREMENTS



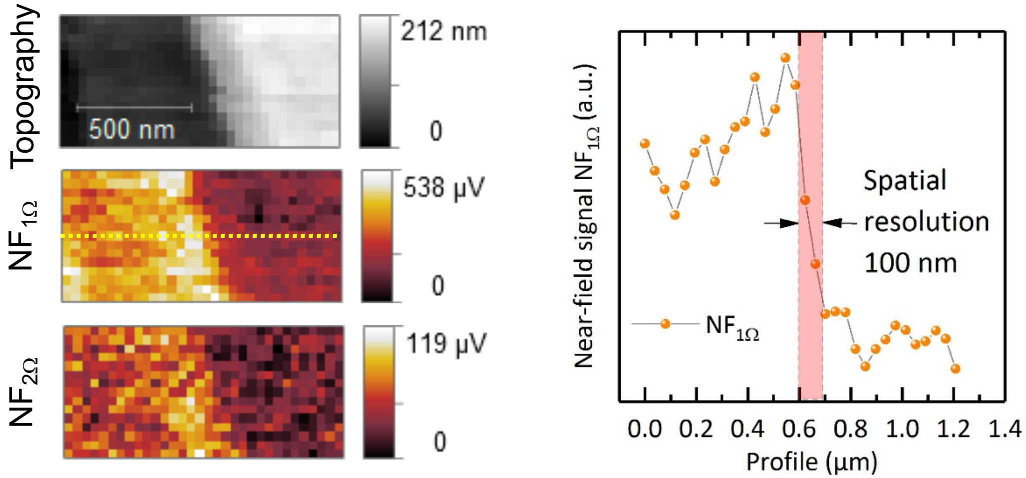
- Setup: ¼-λ stripline BPM + spectrum analyzer
- Test with thermionic electron gun (50 pC × 13 MHz)
- SNR > 2×10^5
- Largest intensity modulations ~ 1×10^{-3}
- Due to CW nature of the facility – this is the data formal of ELBE users.
- The necessary format of beam measurements: Q_b, σ_t, φ_{beam}, beam position

TELBE: ENABLING TIME-RESOLVED THz NANOSCOPY

- Conceptually new all-optical passive jitter-free synchronization scheme is successfully implemented at TELBE
- Passive synchronization allowed suppressing the initial timing jitter between accelerator and external laser system to few tens of fs that enable ultrafast time-resolved spectroscopy without implementation of post-processing jitter correction
- Using the developed synchronization technique we successfully demonstrated operation of time-resolved nanoscopy using accelerator-based light source.



THz time-resolved near field signal on gold film directly demodulated with a lock-in amplifier



THz-tr-SNOM image channels of Au-pattern on Si substrate, including topography (left) and near-field images at fundamental (1Ω) and second harmonic (2Ω) of the cantilever frequency. Spatial resolution of ~100nm is obtained beating the Abbè diffraction limit by a factor of >1665.

S. Kovalev, TELBE team

IR-THZ USER COMMUNITY REQUIREMENTS

※ Present IR-THz sources operate with pulse energy of a **few μJ** (at 13 MHz or 100 kHz)

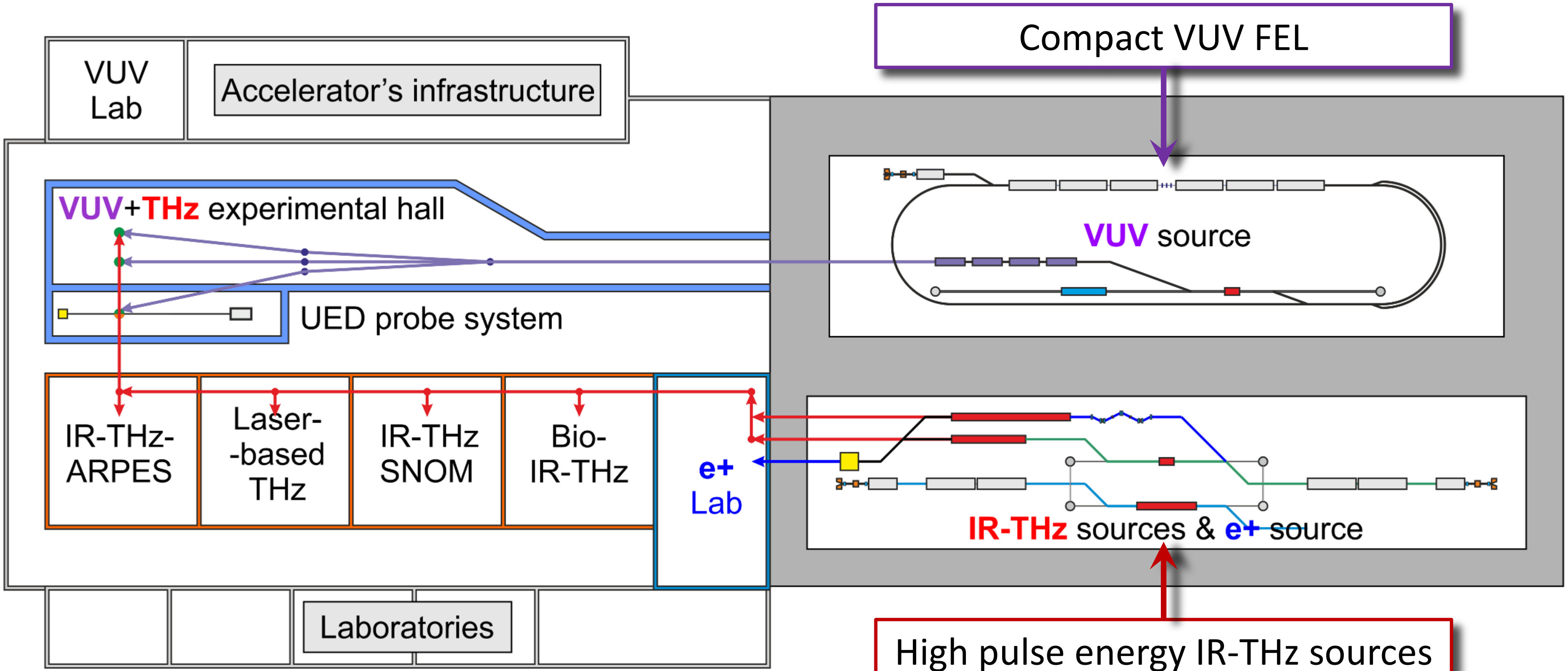
※ **New facility IR-THz parameters**

- pulse energy: 100 μJ ... 1 mJ *(as high as possible)*
- frequency range: 0.1 THz … 30 THz
- repetition rate: 100 kHz … 1 MHz *(high flexibility)*
- narrowband (~1 %) - multi-cycle pulses
- simultaneous operation of broadband (~100 %) few-cycle pulses

※ **New facility VUV parameters**

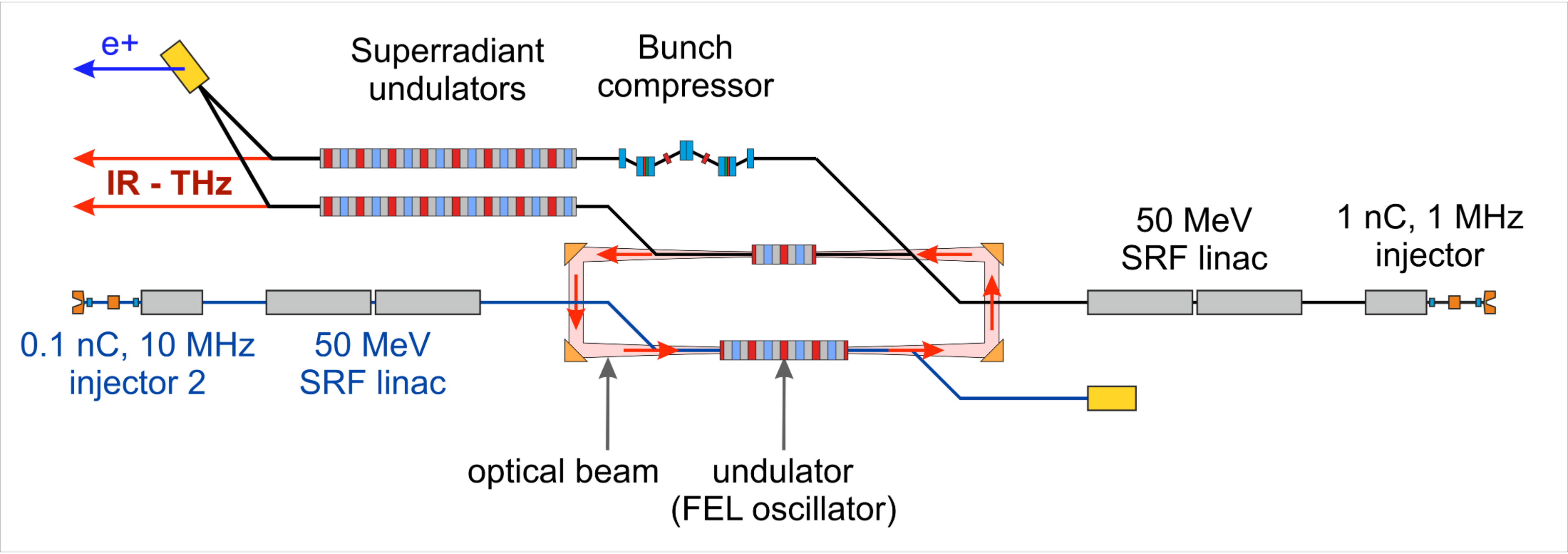
- wavelength range: 50 nm … 250 nm (at fundamental)
- pulse energy: ≥ 30 μJ in the entire wavelength range
- repetition rate: up to 5 MHz
- pulse length: 100 … 200 fs range

DALI – ELBE SUCCESSOR CONCEPT



Thank you

NEW IR-THZ SOURCE ARCHITECTURE



VUV SOURCE ARCHITECTURE

- ※ 50…250 nm needs ~300 MeV beam energy, but
- ※ High current capability of ELBE linac allows 2-pass acceleration in the same linac
- ※ Required transvers emittance ≤ 2 mm-mrad
- ※ Undulator length required for saturation ~ 8 m