Longitudinal Bunch Diagnostics in the Terahertz Domain at TELBE using Fast Room Temperature Operable Zero-bias Schottky Diodes

Rahul Yadav [1,2], Michael Kuntzsch[3] , Sascha Preu [2] and Andreas Penirschke [1]

[1] Technische Hochschule Mittelhessen, Friedberg (Hessen), Germany
[2] Technische Universität Darmstadt, Darmstadt, Germany
[3] Helmholtz - Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

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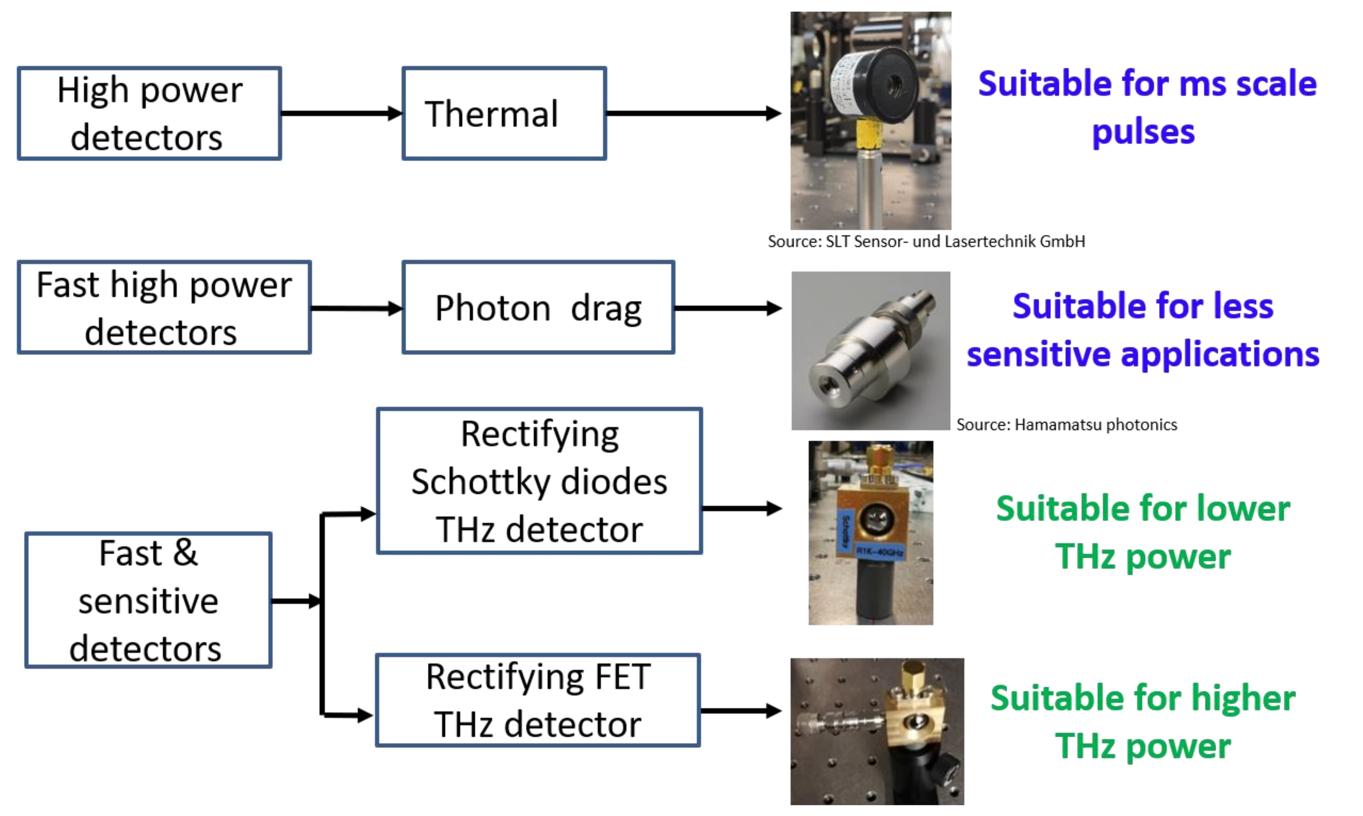
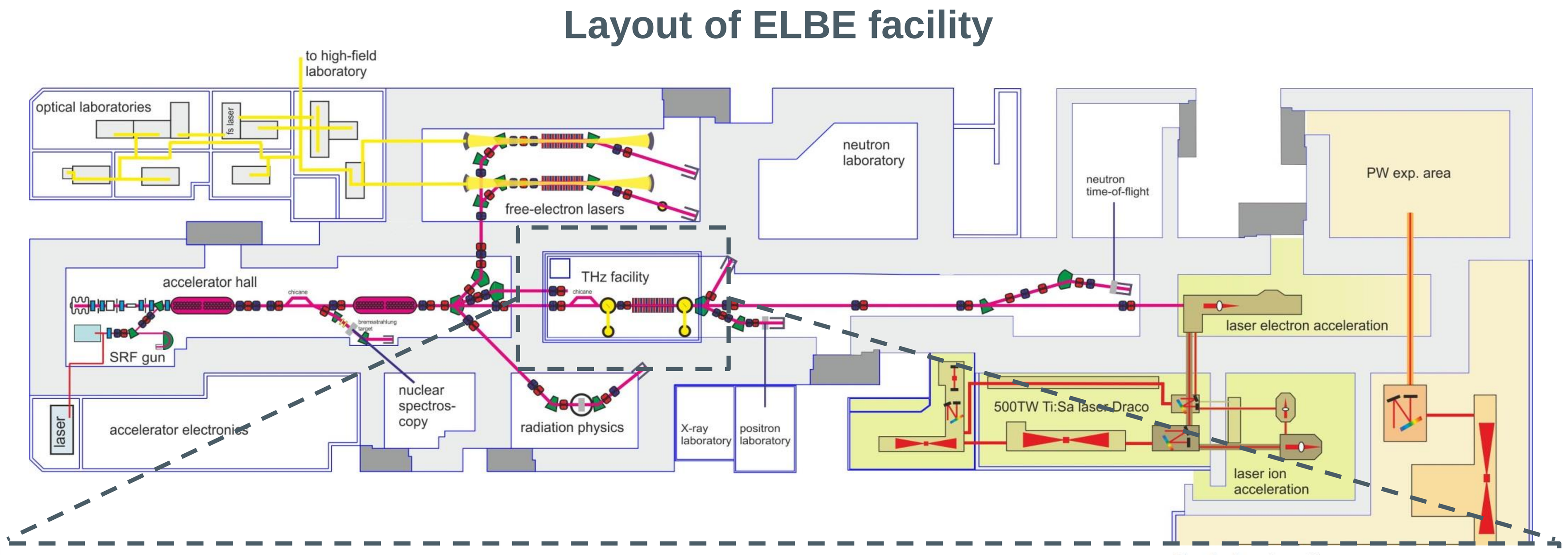
Motivation



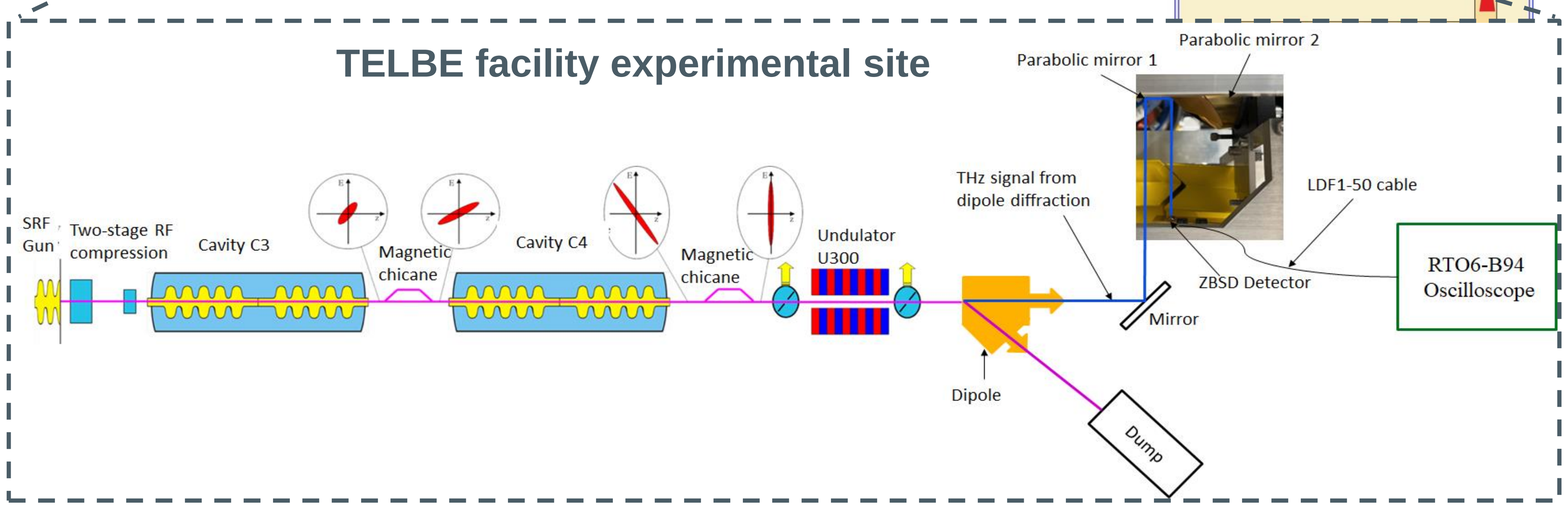
- **Temporal-spatial characterization of ps scale terahertz (THz) pulses at particle accelerators [1-2]**
- Requirement of **robust, fast, sensitive and stable THz detectors**
- Operation at **room temperature, no need of cryogenic condition**
- **Zero bias Schottky diode detectors:** less noise due to absence of shot noise
- **Tens of GHz IF ⟶ Large video bandwidth ⟶ Short THz pulse detection**
- **Broadband detection of ps scale THz pulses: tens of GHz to several THz**

Experimental setup

Layout of ELBE facility

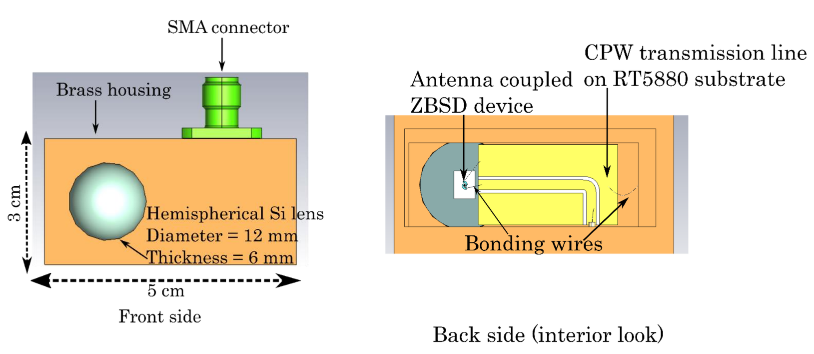


TELBE facility experimental site



- TELBE: Terahertz Electron Linear accelerator with high Brilliance and low Emittance
- SRF gun produce high quality electron beams and high bunch charge
- ZBSD: Zero-bias Schottky diode THz detector with ultra-wide THz bandwidth from 0.05 to 2 THz

Schematic of developed ZBSD detector



Machine parameters	Values
FEL type	Single pass
FEL repetition rate	101.56 kHz
Linac fundamental frequency	1.3 GHz
Electron source	SRF gun
Photocathode	Cs_2Te
Bunch energy	28 MeV
Bunch length	~ 200 fs
Magnetic bunch compressor	< 500 mm
Operation mode	Continuous wave
FEL THz frequency	0.7 THz
Pulse energy	< 8 µJ
# periods	8

Measurement equipment	Specs
Measurement type	Single shot
ZBSD THz detector bandwidth	0.05 – 2 THz
Rdiff of ZBSD	7.14 kOhm
Read-out Oscilloscope (Osci)	R&S RTO6-B94
Osci Sample rate	10 GS/s
Osci resolution bandwidth	40 ps
Osci rise/fall time	104 ps
Record length	1 kpts
Read-out cable	LDF1-50

Results & Discussion

Bunch charge sweep study:

- For TELBE repetition rate range is 10 to 500 kHz, which means detector response time must be 100 to 2 µs
- ZBSD measures time-domain trace with FEL repetition rate of 50 kHz and electron bunch charge of $q_B = 28\,pC$ exemplifies the full width half maximum of 487 ps with rise time of 163 ps
- ZBSD response satisfies the bunch diagnostic requirement in respect to response time
- No post-detection amplifier was used in the presented results
- ZBSDA shows similar response trend as pyroelectric detector

Bunch compression study:

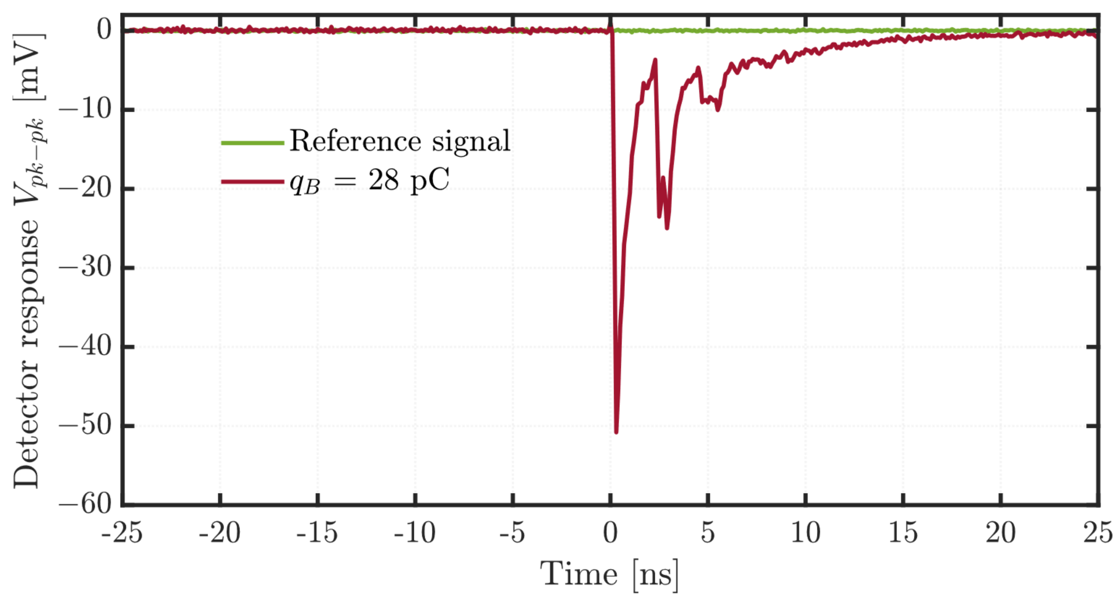
- Bunch compression measurements performed at $q_B = 45\,pC$
- Phase stability of single compression stage is given by [3]:

$$\Delta\emptyset \leq \left|\frac{\emptyset_0}{C_0}\frac{\Delta I_{pk}}{I_{pk}}\right|$$

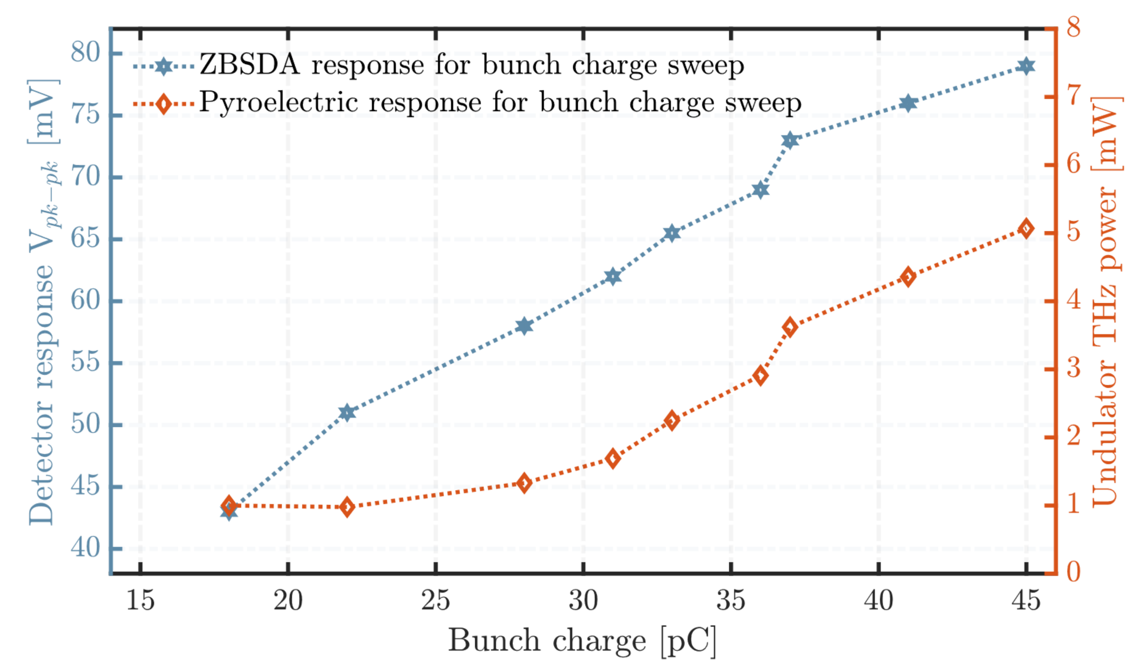
where, C_0 is compression factor, $\left|\frac{\Delta I_{pk}}{I_{pk}}\right|$ is tolerable relative peak current jitter and $\emptyset_0$ is nominal RF chirp phase

- LA2 phase is an offset phase used as a reference for bunch compression
- Practically expected agreement observed between ZBSD and pyroelectric response

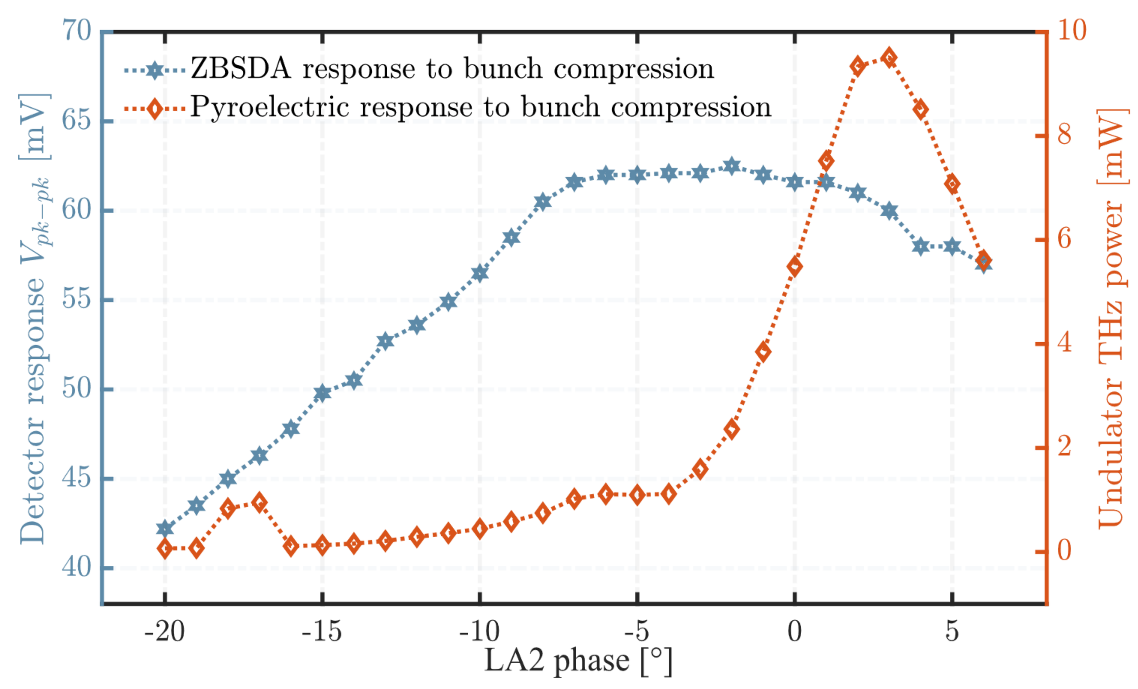
Trace of electron bunches



Electron bunch charge sweep



Bunch compression monitoring



Conclusions & Outlook

- ZBSD THz detector application as beam compression monitor (BCM) and beam diagnostics
- Better response time (FWHM of 487 ps and rise time of 163 ps) compared to similar old literature [4]
- Planned rigorous test with ZBSD THz detector in September and October 2024
- Commissioning of the detectors at accelerator facilities after successful tests

References

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Own related work

IBIC 2021 | IPAC 2022 | IEEE MMS 2022 | MDPI SENSORS 2023 | IBIC 2023 | IBIC 2023

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Rahul Yadav, M.Sc
rahul.yadav@iem.thm.de
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