Femtosecond level diagnostic and control of sub-picosecond electron bunches is an important topic in modern accelerator research. At the same time new quasi-cw linear electron accelerators are the drivers of many future 4th Generation light sources such as X-ray free electron lasers. A high duty cycle, high stability and online pulse to pulse diagnostic of these new accelerators are crucial ingredients to the success of these large scale facilities. A novel THz based online monitor concept is presented that has the potential to give access to pulse to pulse information on bunch form, arrivaltime and energy at high repetition rate and down to sub pC charges.

**Testfacility – TELBE:**

**THz pulse properties:**
- Spectral range: 0.1 – 3 THz
- Repate: up to 500 kHz/13 MHz
- Pulse energy: 100 uJ/1 uJ
- Average power: ~10 W

**Laser systems:**
- Oscillator: 500mW/ 78MHz/ 100fs
- Amplifier: 900mW/ 100kHz/ 100fs
- OPA: 480-700nm / 900-2300nm
- Amplifier: 1W / 1kHz / 130fs

**Super-radiant THz sources**

- Undulator: narrowband THz
- Coherent diffraction radiation (CDR): broadband THz

**Spectral decoding setup:**
- fs laser pulse few 10 fs/100 kHz
  - pulse to pulse
  - linear on THz field.
- low requirements on laser and THz pulse energies.
- operates at high repetition rates.
- time resolution in few fs regime

**Experimental results:**

- time resolution ~ 10 fs
- requ. THz power/pulse energy ~ 50 nJ/0.5 nJ
- requ. laser power/pulse energy ~ 1 mW/10 nJ
- operable at high repreate/low energy

- Fourier analysis of the jitter frequencies
  - allows to quantify the contribution of different jitter sources

- timing jitter CDR to Laser / to undulator
  - much reduced jitter when intrinsically synchronized
  - Data Sorted Undulator Pulse

- intrinsic synchronization between CDR and undulator pulses established

- zoom in - timing jitter CDR to Undulator
  - remaining jitter likely due to electron beam position instabilities

- sensitivity
  - SN ratio sufficient to see 100 fC charges

**Next steps:**

1. **ONLINE determination of bunch form**
   - idea: THz spectra as (indirect) measure of the bunch form
   - electron number / a.u.
   - reconstruction of bunch form
   - ~1150 fs (FWHM)
   - repetition rate

2. **ONLINE determination of bunch energy**
   - idea: Undulator frequency as measure for beam energy
   - intensity / a.u.
   - W_{beam} \sim \frac{1}{f_{THz}}

3. **increase repetition rate**
   - idea: method could operate at MHz repetition rates. bottleneck is CCD (readout and dead time)
   - reprotes:
     - ELBE (13 MHz)
     - X-FEL (4.5 MHz)
     - LCLS II (1 MHz)