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Studies of the Micro-Bunching Instability in the Presence of a Damping Wiggler

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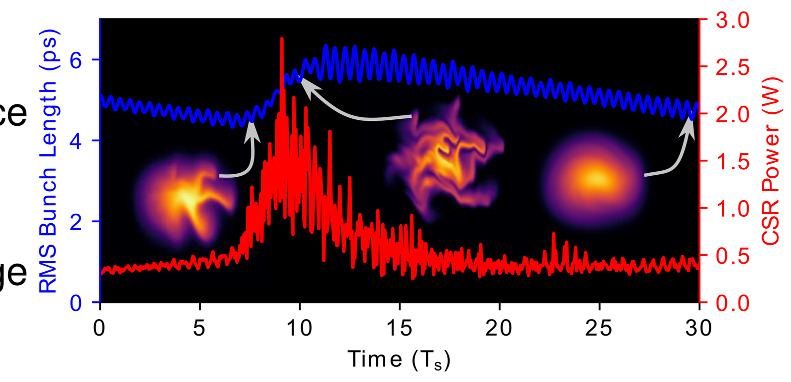
Motivation

Challenge:

- Micro-bunching instability due to Coherent Synchrotron Radiation (CSR) impedance
- CSR acts back on electrons
  → Substructures in longitudinal charge density
  → Bursts of CSR emission in THz frequency range
- Instability depends on machine parameters



Method:

- Damping wiggler changes damping time
- Compensate optic changes due to wiggler
- Fast THz detectors
  → Resolve THz pulses with 2 ns spacing
- Multi-bunch acquisition system
- Precise bunch current measurement

Goals of investigations:

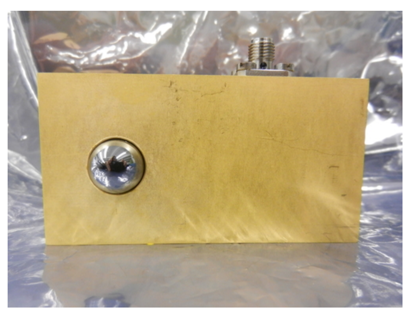
- Answer question: can a wiggler be used to exclusively change the damping time?
- Influence of damping time on the instability
  → Threshold current
  → Dominant fluctuation frequencies
- Crosscheck with Inovesa [1] (Vlasov-Fokker-Planck solver)

Fast THz detectors combined with KAPTURE

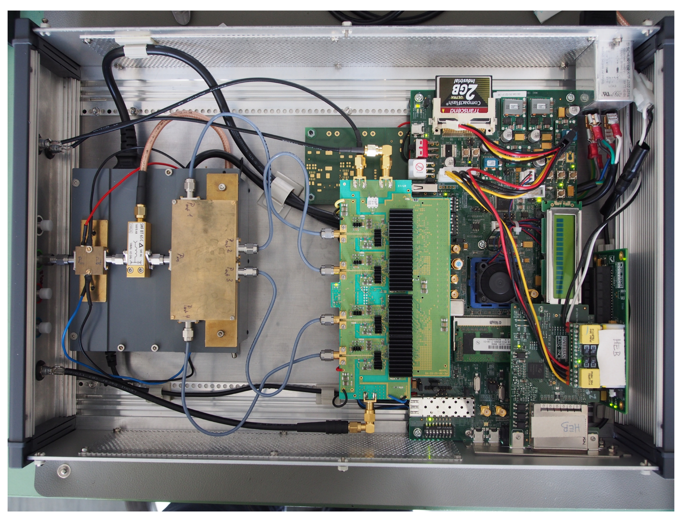
Zero-biased quasi-optical Schottky barrier diode

- Manufacturer: ACST GmbH
- Sensitivity range: 50 GHz - 2 THz
- Typical NEP: 6 pW/Hz$^{1/2}$ @ 100 GHz, 100 pW/Hz$^{1/2}$ @ 1 THz
- 4 GHz analog BW: Pulse FWHM: 130 ps

⇒ Fast enough to resolve bunches with a bunch spacing of 2 ns.



KAPTURE: KIT readout system [2]



- Simultaneous monitoring of all 184 buckets
- Continuous turn-by-turn read-out of each bucket (500 MHz) -> 32 Gb/s
- Four sampling channels with 12 bit ADC each
- Adjustable delay for each channel in 3 ps steps
- Local sampling rate up to 300 GS/s
- New possibilities in diagnostics

Accelerator (KARA) & Wiggler (CLICDW)

KARA parameters

Parameter	Value
Energy / GeV	1.3
RF voltage / kV	771
Filling pattern	mixed currents
Synchrotron frequency / kHz	7.5, 7.7, 7.95
Horizontal tune	0.7863(1)
Vertical tune	0.7992(1)

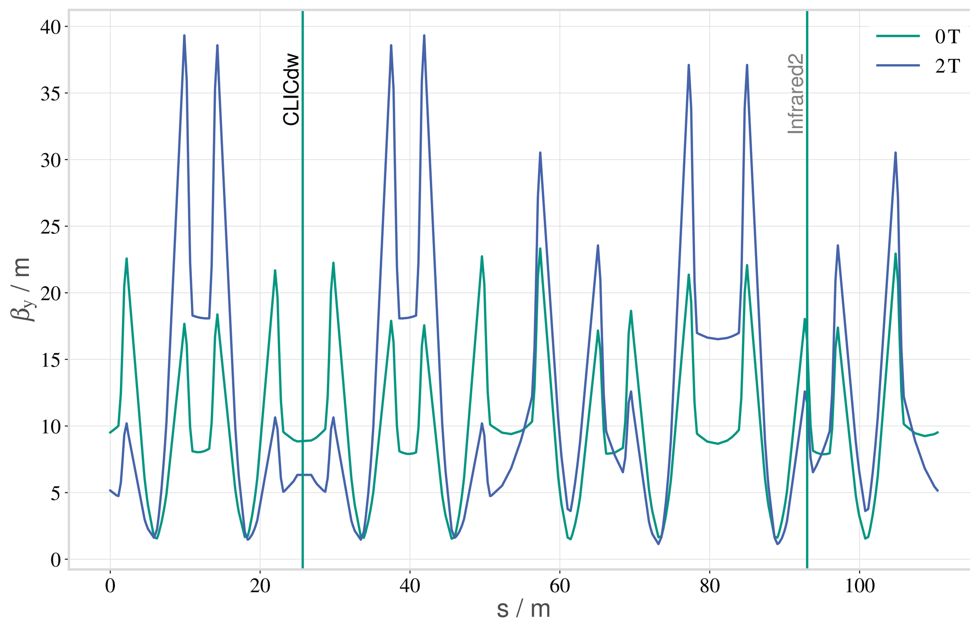
CLICDW

Parameter	Value
Magnetic field / T	2
Period length / mm	51.4
Full periods	36
Undulator parameter K	9.60

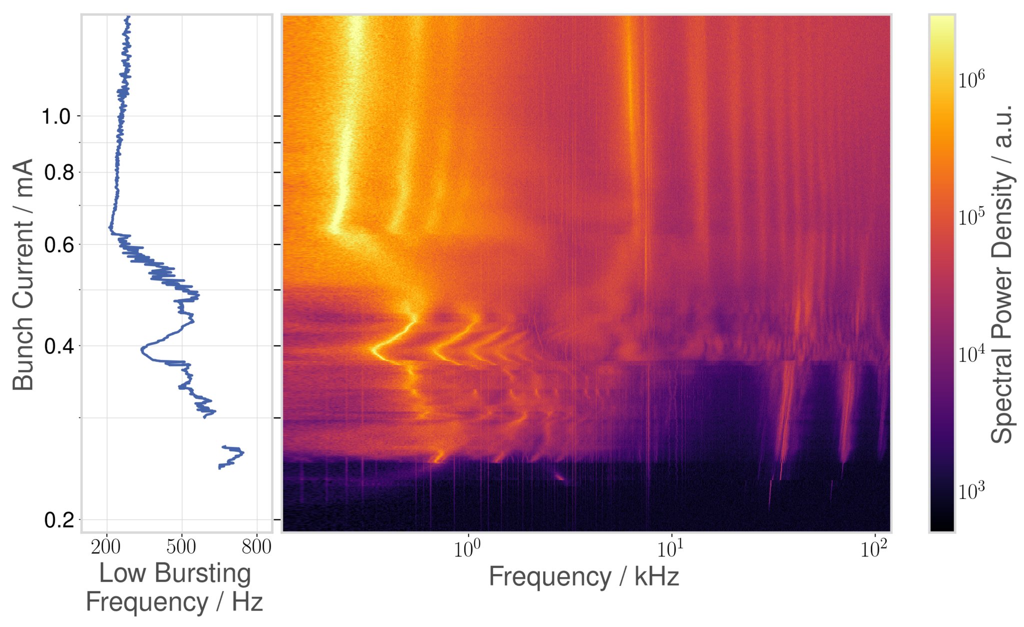
- Superconducting wiggler
- Additional 20 % energy loss
  ⇒ faster damping

Optic adjustments

- 5 quadrupole families
- Beta beat minimized in elegant [3] simulations
- Quadrupole strength adjusted to simulated predictions
- Tunes compensated synchronously to increase of wiggler field B_{wig}
- Final optic measured and feed back into simulations



Measurement Results



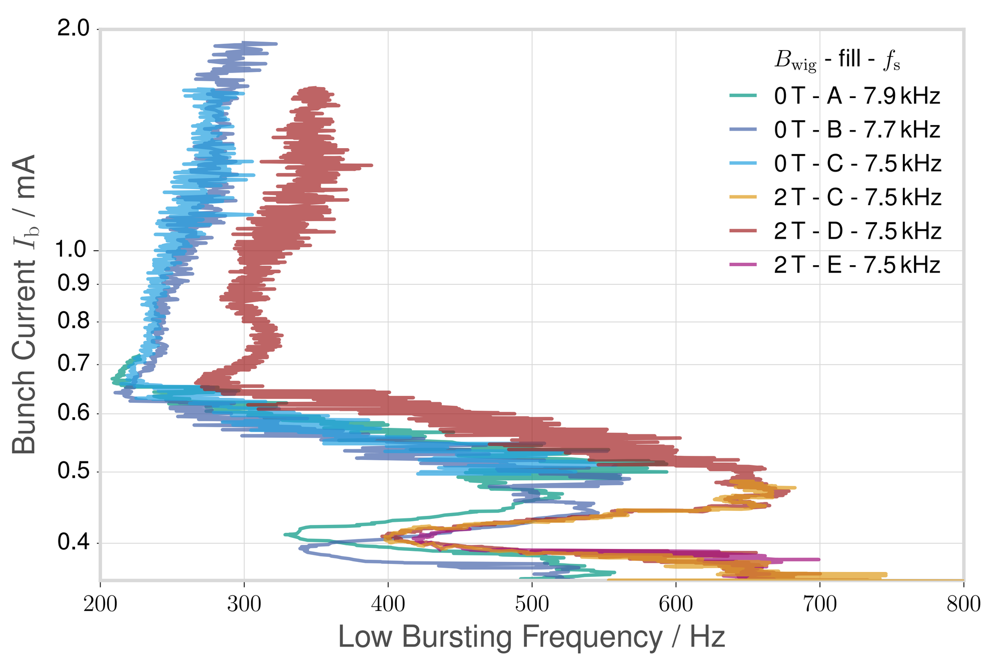
- Fluctuation in THz power due to additional potential
  → convolution of wake function and bunch profile
- Low bursting frequency corresponds to periodicity of radiation outbursts
- During one burst the bunch length is blown-up and damped down again
- The frequency changes with bunch current due to changes in the bunch profile/length and thus in the interaction with the impedance

Bunch current and frequency at instability threshold

- Instability threshold not changed by CLICDW, in agreement with [4]
- Frequency at threshold also not significantly changed by CLICDW

Property	A	B	C	D	E
B_{wig} / T	0	0	0 → 2	2	2
I_{th} / µA	217± 3	213± 3	215±2	-	220± 4
f_{th} / kHz	30.9±0.3	30.1±0.3	29.6±0.3	-	29.7±0.3

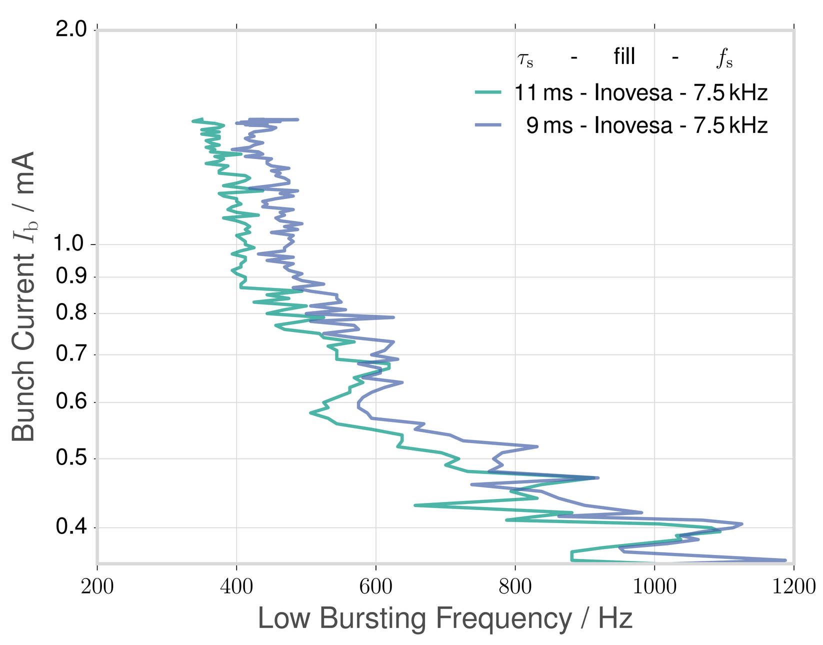
Low bursting frequency / repetition rate of radiation outbursts



- Low bursting frequency as function of bunch current
- Different fills show similar behavior
- Shifted to higher frequencies when CLICDW on
  → faster damping of bunch length after outburst

⇒ Dependent on damping time

Inovesa [1] Simulation Results



- Damping times from optics simulations $\tau_{s,\text{ no wiggler}} = 11\,\text{ms} \to \tau_{s,\text{ wiggler}} = 9\,\text{ms}$ as input for the Vlasov-Fokker-Planck solver
- No change in bunch current and frequency at instability threshold

τ_s / ms	11	9
I_{th} / µA	205±0.5	205±0.5
f_{th} / kHz	29.271±0.05	29.262±0.05

- Shift of low bursting frequencies to higher frequencies for shorter damping times

⇒ Damping time change shows qualitatively similar effect in the simulation

Summary

- Changing damping time with CLIC damping wiggler prototype ($B_{wig} = 2\,\text{T}$) at KARA
- Influence of damping time on key-properties of the micro-bunching instability studied
- No significant influence on bunch current and frequency at instability threshold
- Significant shift of low bursting frequency / periodicity of radiation outbursts

Poster presented at IPAC2018, Vancouver, THPAK029

[1] P. Schönfeldt et al., Phys. Rev. Accel. Beams, 2017, Vol. 20, Nr.3.
[2] M. Caselle et al., IPAC2014, Dresden, THPME113.
[3] M. Borland, elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation
[4] K. L. F. Bane and Y. Cai and G. Stupakov, Phys. Rev. STAB, 2010, Vol. 13, Nr. 10.

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