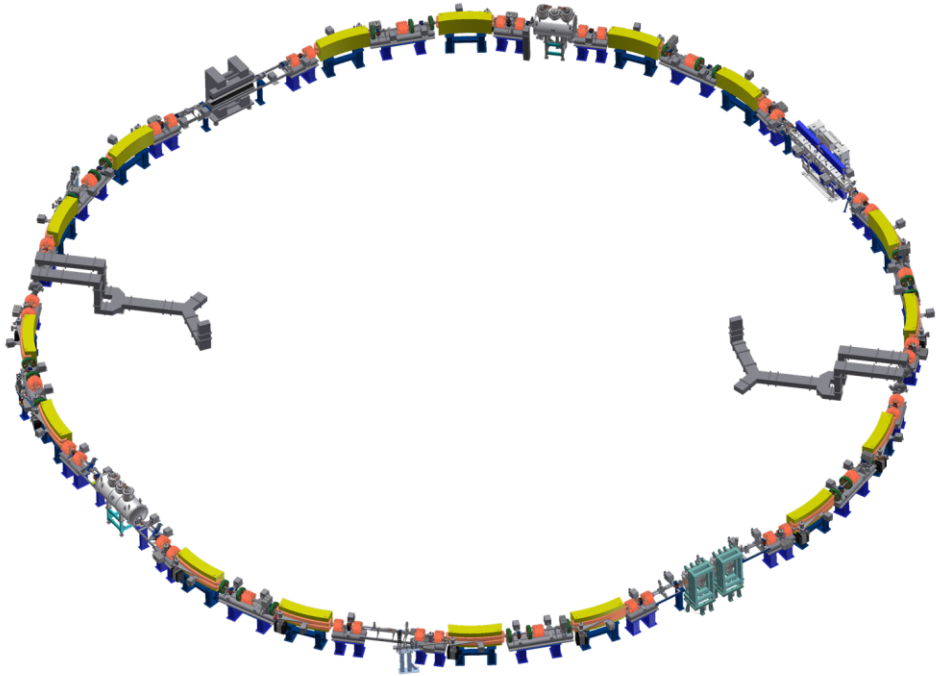
Karlsruhe Institute of Technology

Phase space tomography at MHz-repetition rates at KARA

S. Funkner, G. Niehues, M. J. Nasse, E. Bründermann, M. Caselle, B. Kehrer, L. Rota, P. Schönfeldt, M. Schuh, B. Steffen, J. L. Steinmann, M. Weber, A.-S. Müller

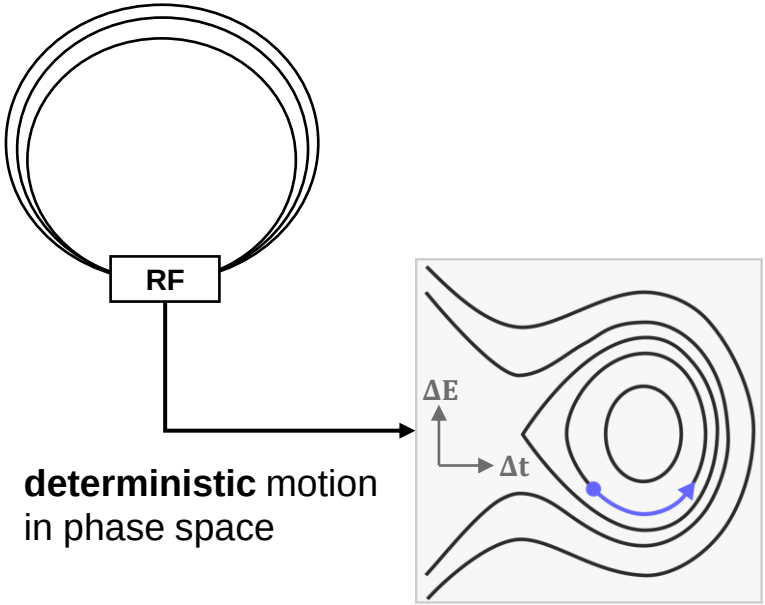
KARA (Karlsruhe Research Accelerator)



- Circumference: 110.4 m
- Energy range: 0.5 - 2.5 GeV
- Revolution frequency: 2.715 MHz
- RMS bunch length: 45 ps (for 2.5 GeV) down to a few ps (for 1.3 GeV)

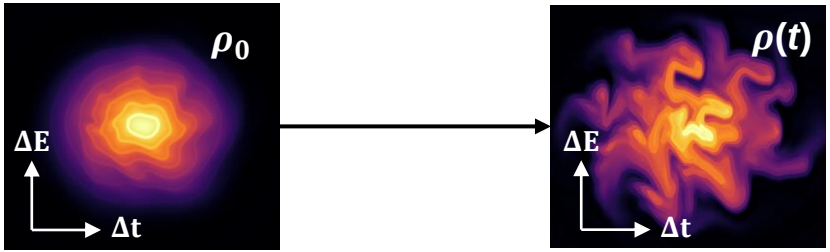
Longitudinal Phase Space

single electron (phase focusing)

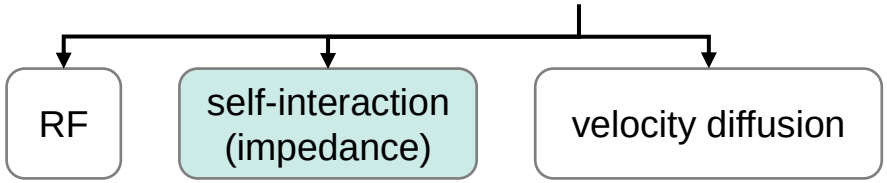


deterministic motion in phase space

electron bunch



ρ_0 ***determines*** $\rho(t)$ via Vlasov-Fokker Planck Equation



Microbunching Instability

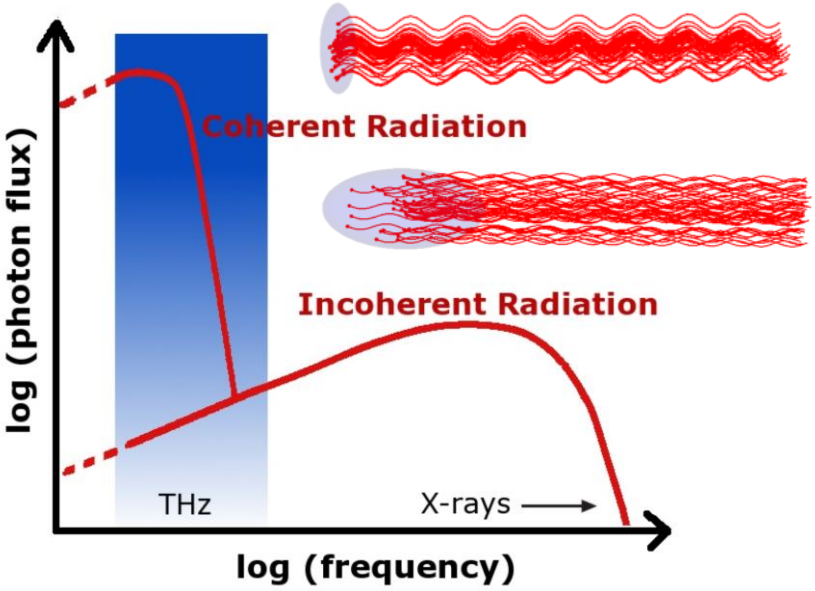
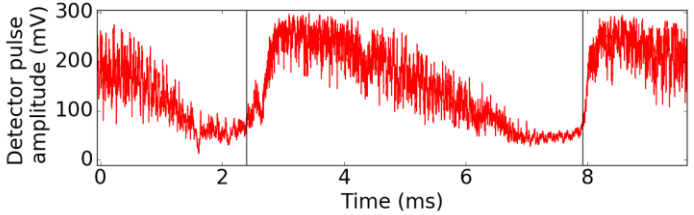


image credit: A.-S. Müller

tail to head interaction

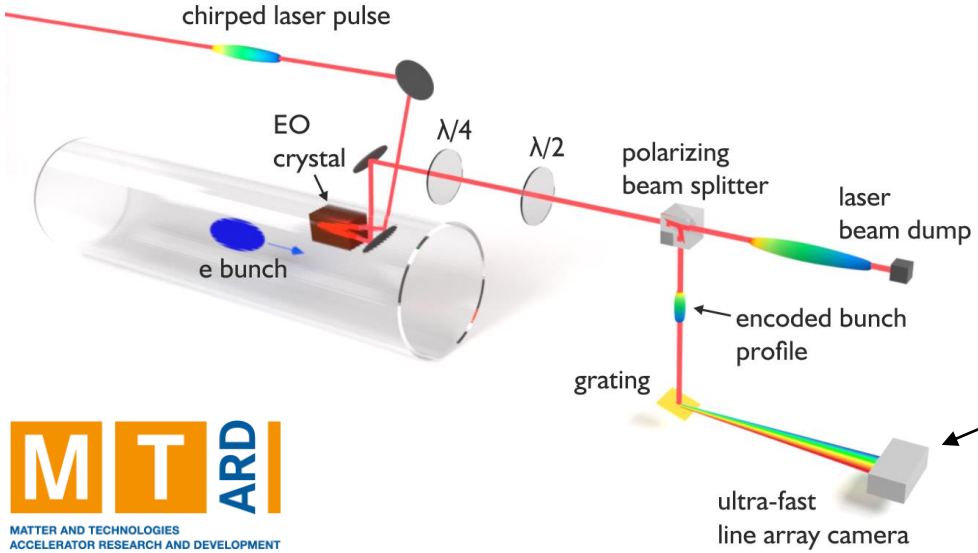
head to tail interaction

sawtooth bursting

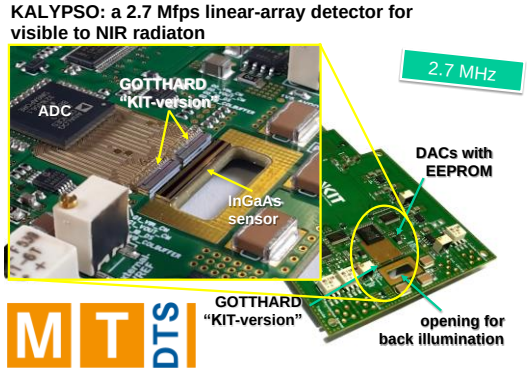


E. Roussel "Spatio-temporal dynamics of relativistic electron bunches during the microbunching instability: study of the Synchrotron SOLEIL and UVSOR storage rings", Thesis, 2015
B. Kehrer et al., "Simultaneous Detection of Longitudinal and Transverse Bunch Signals at ANKA," IPAC 2016, MOPMB014

Measurements of Electron Bunch Profiles



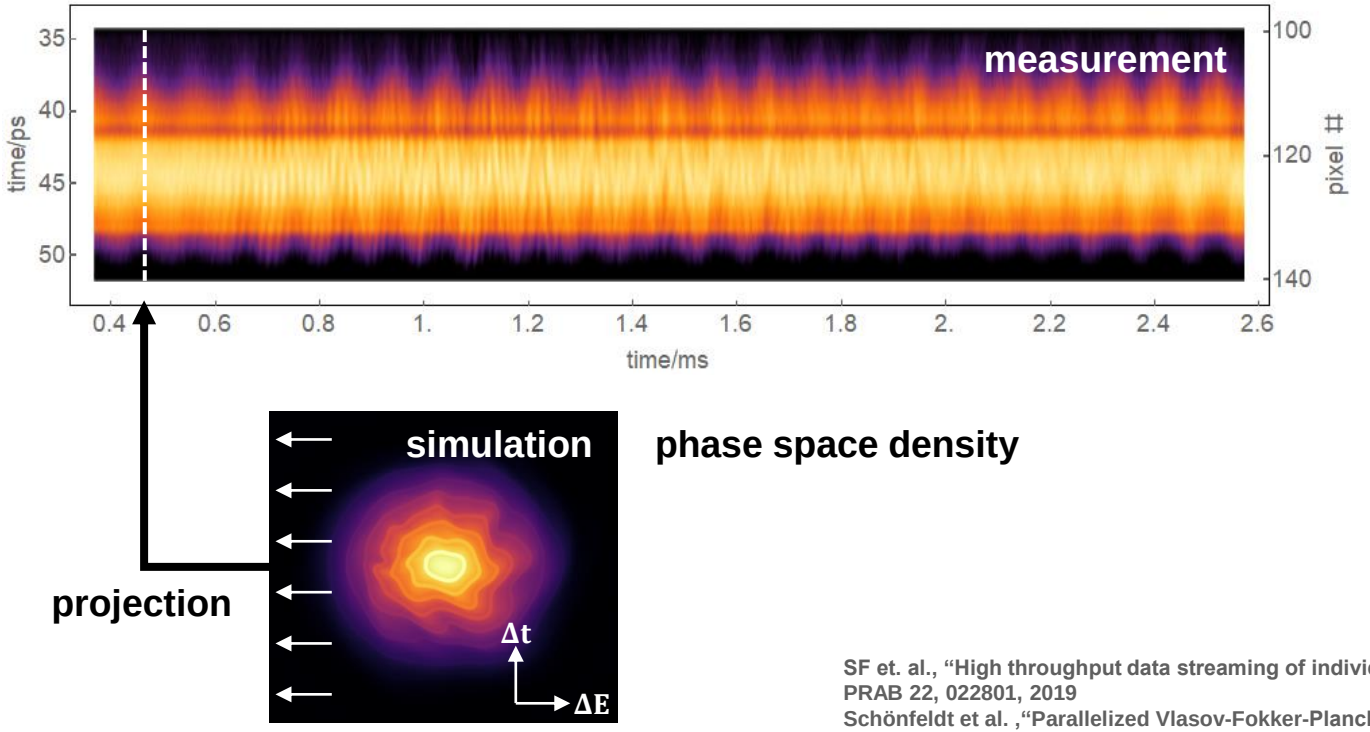
MATTER AND TECHNOLOGIES
ACCELERATOR RESEARCH AND DEVELOPMENT



SF et. al., "High throughput data streaming of individual longitudinal electron bunch profiles" , PRAB 22, 022801, 2019
SF et. al., "Revealing the dynamics of ultrarelativistic non-equilibrium many-electron systems with phase space tomography", preprint arXiv:1912.01323

Rota et al. ,"KALYPSO: Linear array detector for high-repetition rate and real-time beam diagnostics", Nucl. Instrum. Methods Phys. Res. A, 936, pp. 10-13, 2019

Phase Space Interpretation of Bunch Profile Measurements



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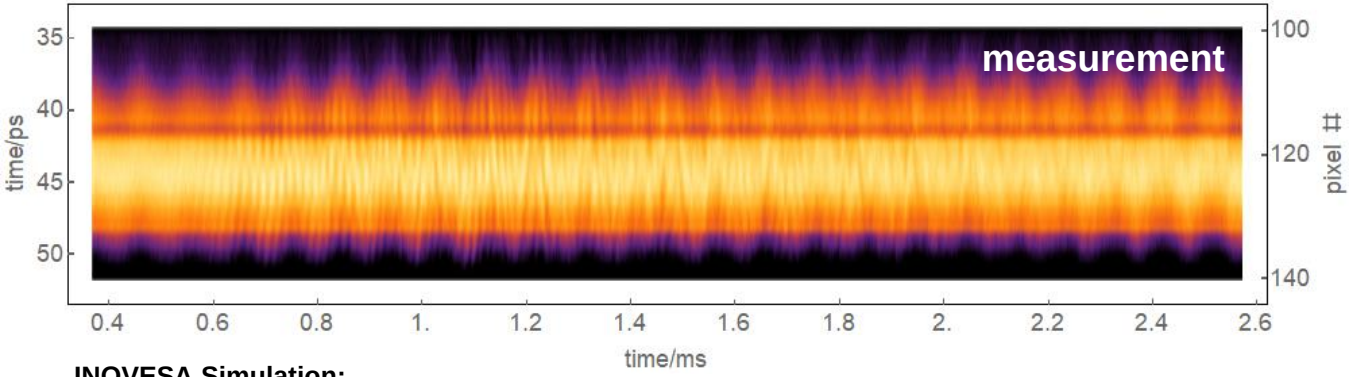
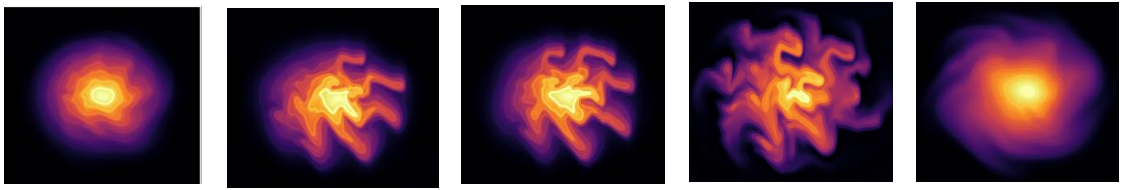


INOVESA Simulation:



short unstructured bunch

micro-structures appear + increase of bunch size

micro-structures disappear

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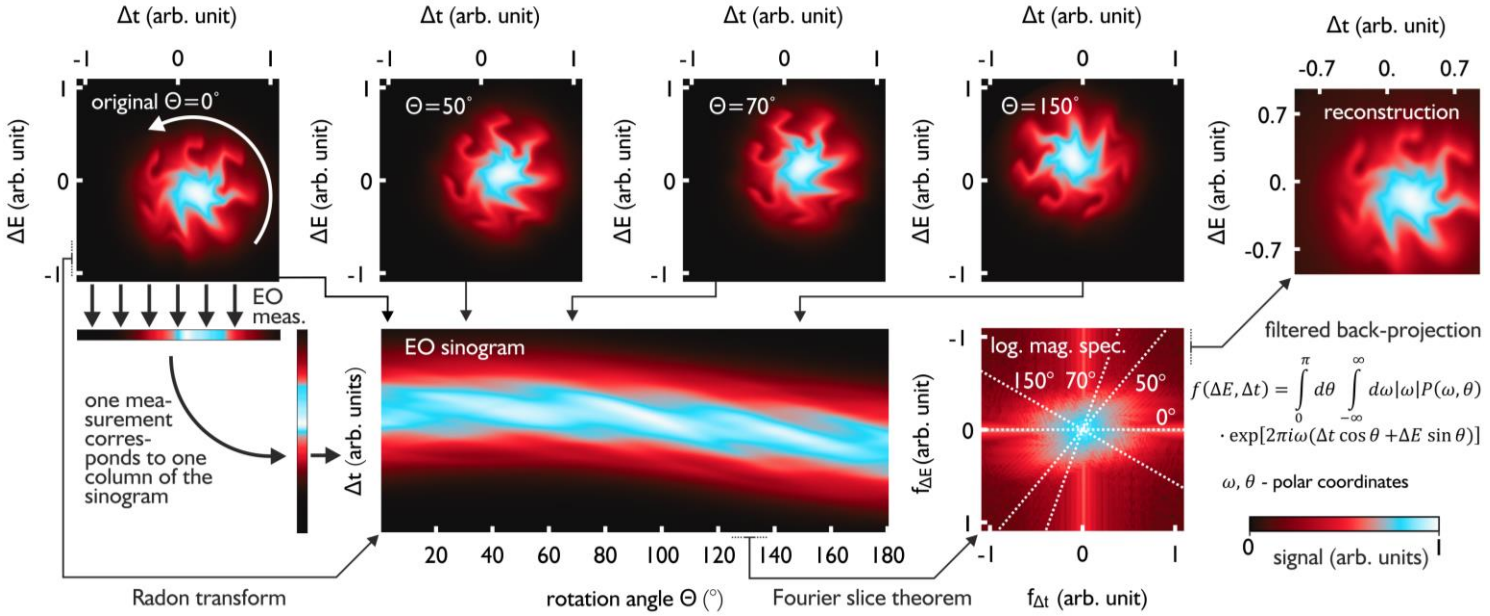
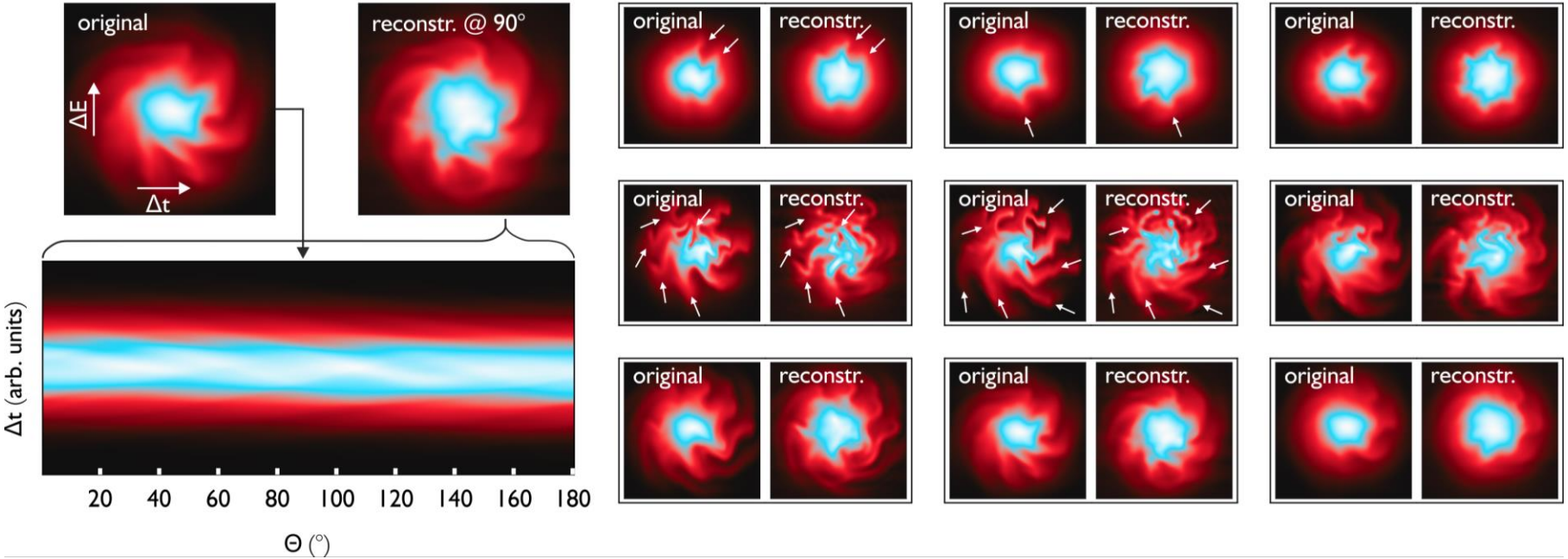
Phase Space Reconstructions



SF et. al., "Revealing the dynamics of ultrarelativistic non-equilibrium many-electron systems with phase space tomography", preprint arXiv:1912.01323

Validation with Simulations



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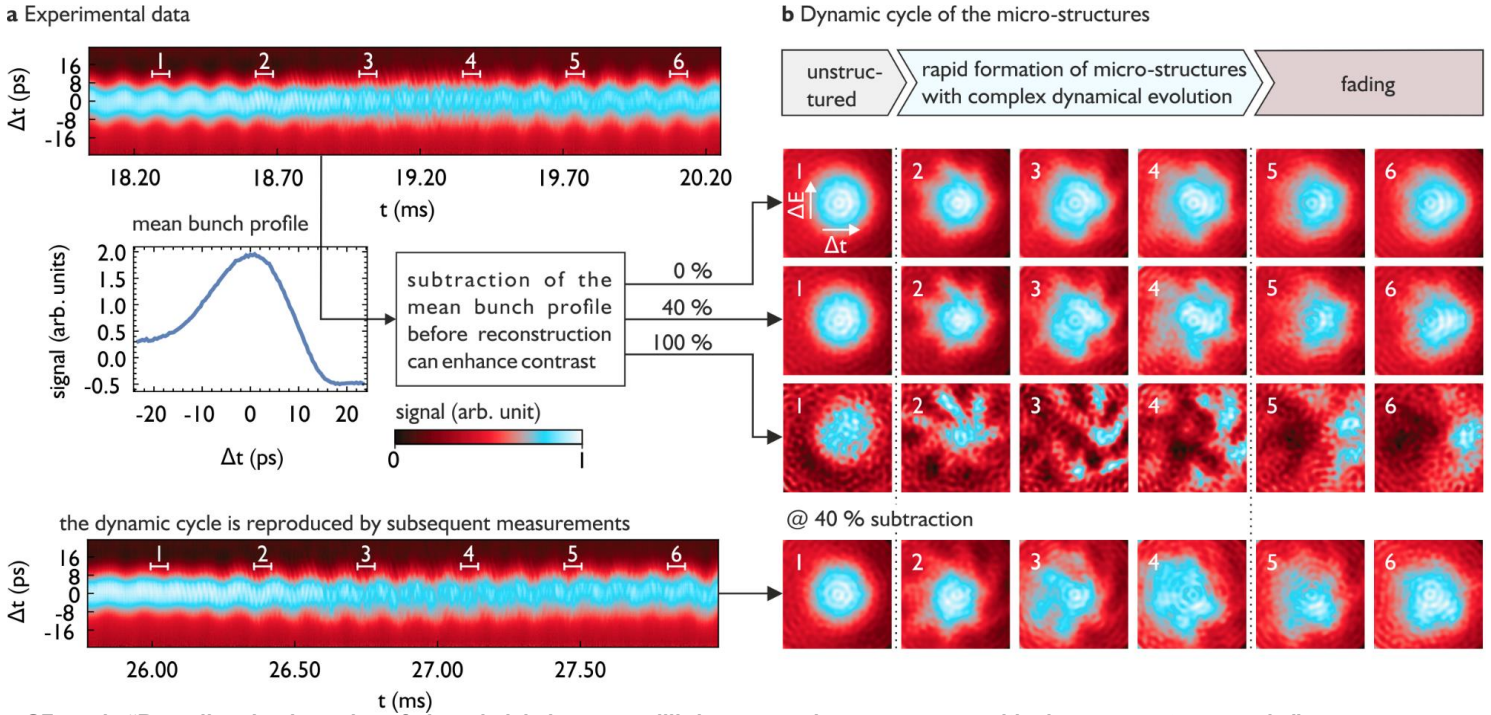
Phase Space Measurements



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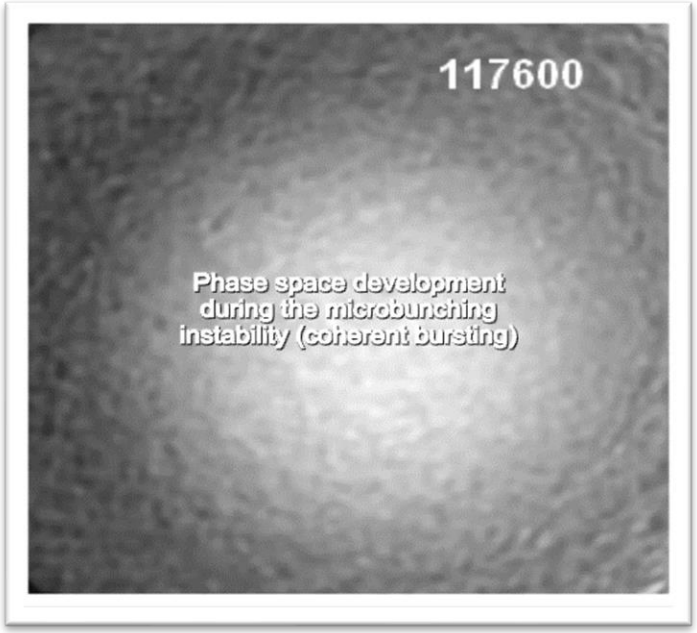
Turn-by-Turn Dynamics

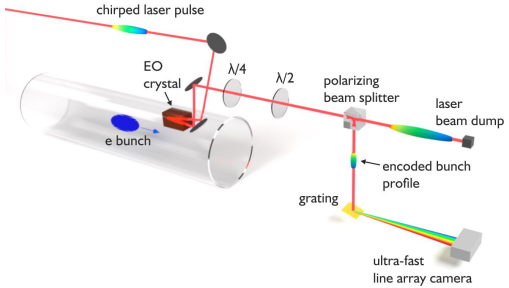


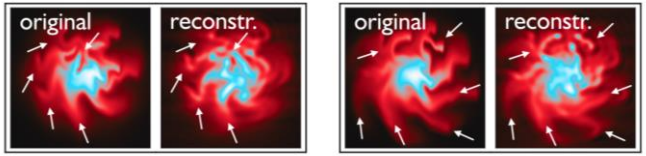
- reconstruction time for complete phase space image: 61 µs
- „Randon morphing“ between independent measurement

SF et. al., “Revealing the dynamics of ultrarelativistic non-equilibrium many-electron systems with phase space tomography”, preprint arXiv:1912.01323

Conclusion

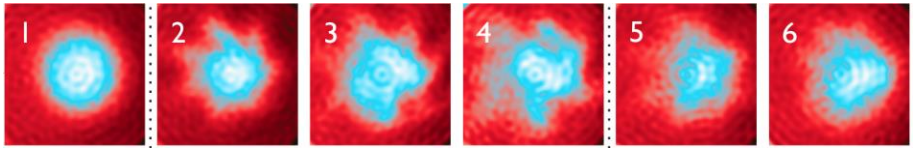
EOSD → electron bunch profile measurements with 2.71 MHz repetition rate implemented





phase space reconstruction method with simulated data validated

phase space dynamics from experimental data (sawtooth bursting) reconstructed



Acknowledgements

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- Laboratory for Applications of Synchrotron Radiation (LAS)
- Institute of Experimental Particle Physics (ETP)
- Institute for Beam Physics and Technology (IBPT)
- Institute for Data Processing and Electronics (IPE)

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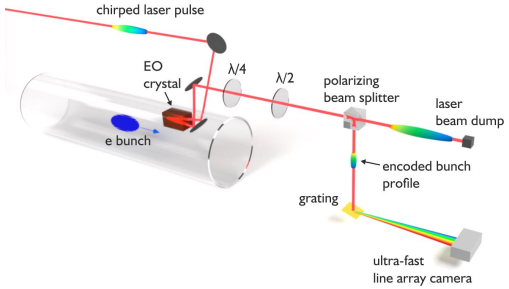

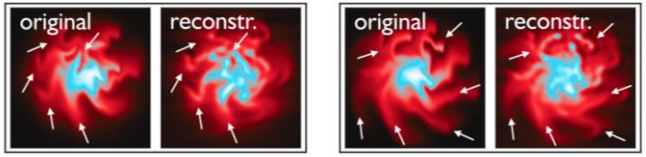

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