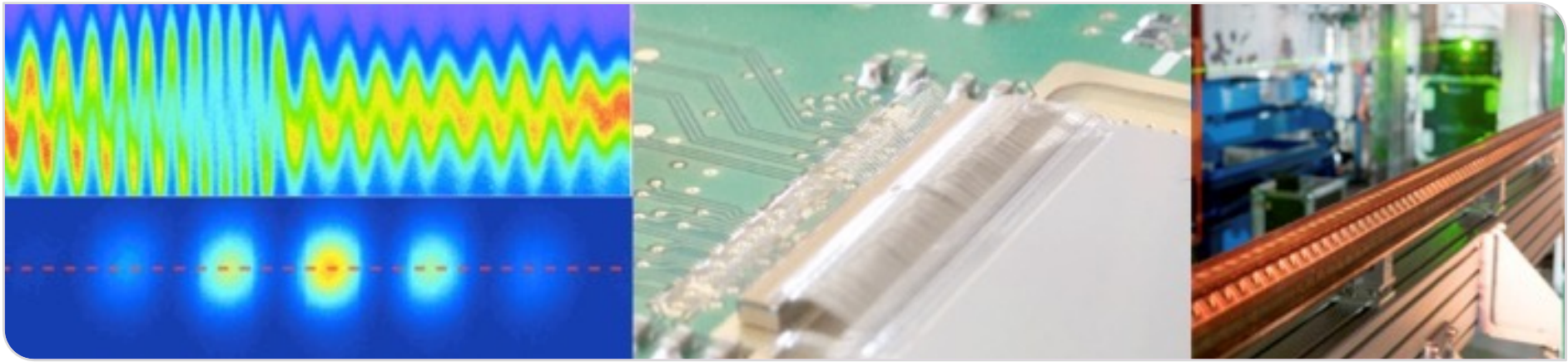
Karlsruhe Institute of Technology

Status of the KIT test facilities KARA & FLUTE

29th European Synchrotron Light Source Workshop 2021

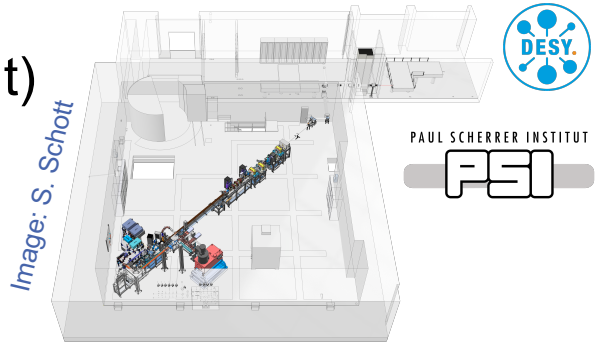
ESRF – by Zoom Video conference

Marcel Schuh for the KIT team



FLUTE: Accelerator Test Facility at KIT

- FLUTE (Ferninfrarot Linac- Und Test-Experiment)
  - Test facility for accelerator physics within ARD
  - Experiments with THz radiation
- R&D topics
  - Serve as a test bench for new beam diagnostic methods and tools
  - Systematic bunch compression and THz generation studies
  - Develop single shot fs diagnostics
  - Synchronization on a femtosecond level



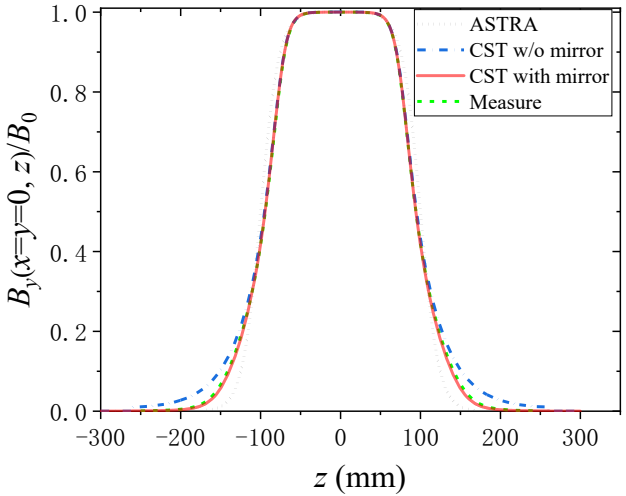
Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 3	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m

www.ibpt.kit.edu/flute

FLUTE Status

- Full operation permission
- Gun operation
  - Ramped gun power up to 18 MW (100 MV/m) and repetition rate to 5 Hz
  - Dark current decreased by a factor 2
  - Additional feedback loop to compensate temperature fluctuations
- RF conditioning of the linac finished, preparing installation
- Stabilized the jitter down to 120 fs
- Full characterization of the bunch-compressor dipoles
- Assembly of bunch compressor in preparation

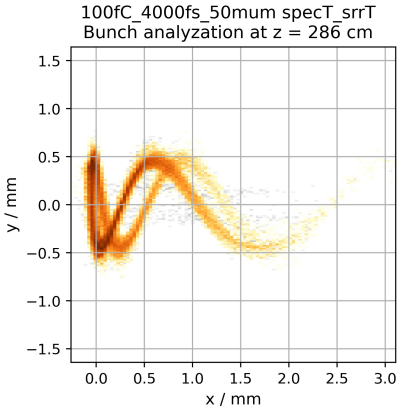
M.-D. Noll, Master thesis, https://publikationen.bibliothek.kit.edu/1000135903



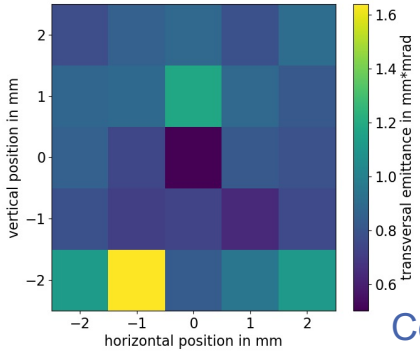
Y. Nie et al.,
DOI: 10.18429/JACoW-IPAC2021-TUPAB087

FLUTE Simulation and Beam Characterisation

- Simulation
  - Matching simulation, machine settings and measurements
  - Prediction of optimal machine settings for split ring resonator experiment
- Beam characterisation
  - First Energy and Spread measurements
  - First Emittance measurements



Courtesy: J. Schäfer



Courtesy: T. Schmelzer

J. Schäfer et al., DOI: 10.18429/JACoW-IPAC2021-MOPAB280
S. Schmelzer et al., DOI: 10.18429/JACoW-IPAC2021-WEPAB103

Karlsruhe Research Accelerator (KARA)

- KIT synchrotron light-source & accelerator test facility
- Key parameters
  - Circumference: 110.4 m
  - Energy range: 0.5 - 2.5 GeV
  - RF frequency: 500 MHz
  - Revolution frequency: 2.715 MHz
  - Beam current up to 200 mA
  - RMS bunch length:
    - 45 ps (for 2.5 GeV)
    - down to a few ps (for 1.3 GeV)

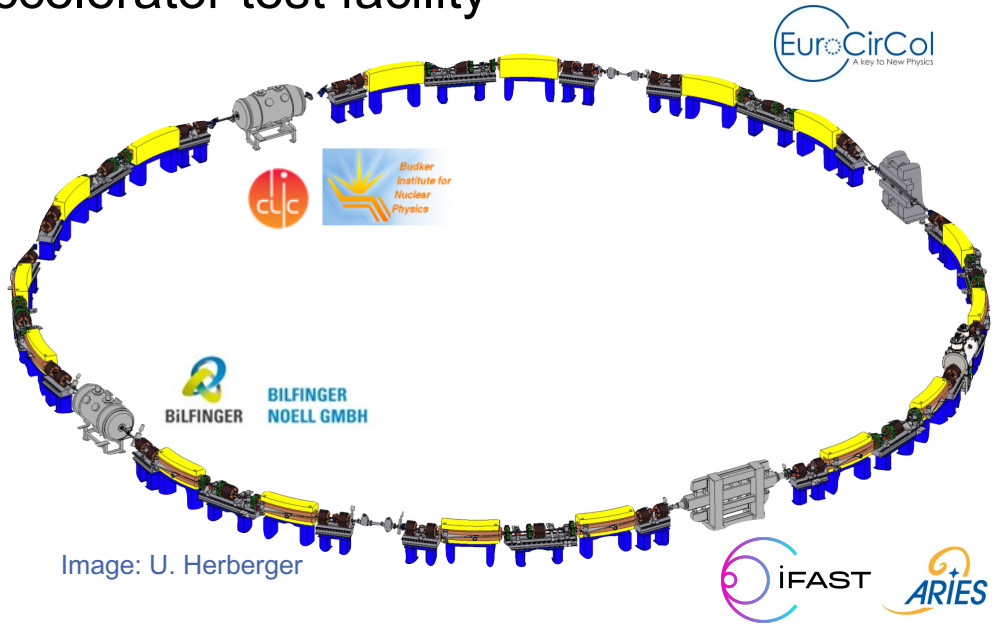
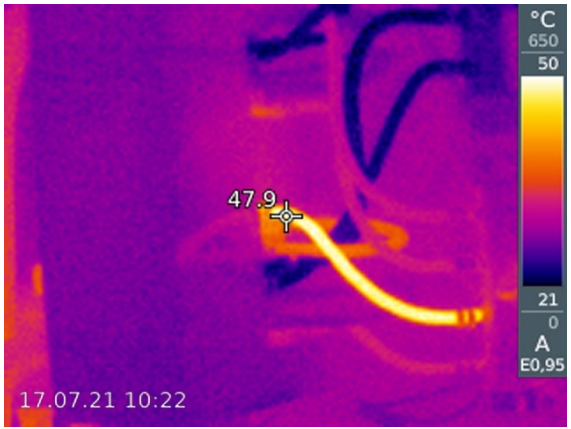


Image: U. Herberger

www.ibpt.kit.edu/kara

KARA Operation Issues 2021

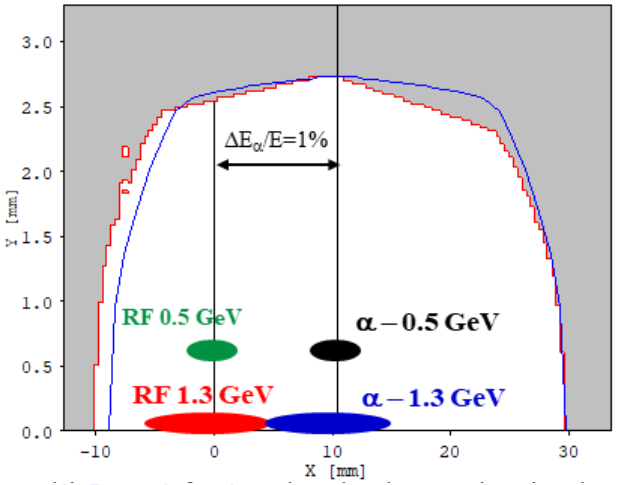
- No major failure up to now in 2021
- Issues with Sigma Phi power supplies used at the SC Wigglers
  - 5 out of 10 units failed in the past year
  - JEMA took over Sigma Phi power supplies
  - New units have a delivery time of 52 weeks
- Increase in the failure rate of Delta Electronica power supplies
- Some issues with magnet water flow - established monitoring with IR camera
- First issue with a pressure gauge power supply during operation



Courtesy: S. Pfeifer

General KARA Operation Status

- No downtime due to COVID19 – delivered 2020 326 Ah @ 2.5GeV (30% more than 2019)
- New virtualisation cluster dedicated for controls within the machine network
- Implemented different optics with low and/or negative momentum compaction factor
- Finished renew of 500MHz and trigger distribution
- Started commissioning of booster diagnostic

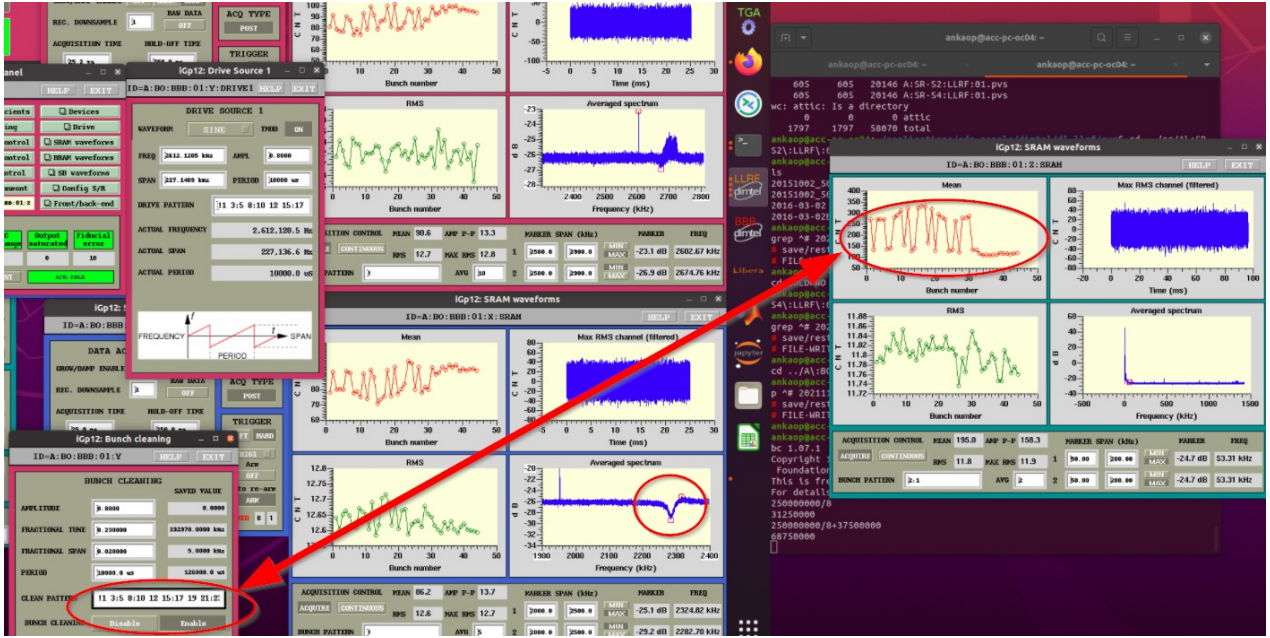


A. Papash et al.,
DOI: 10.18429/JACoW-IPAC2021-MOPAB037

A. Papash et al., DOI: 10.18429/JACoW-IPAC2021-MOPAB036
A. Papash et al., DOI: 10.33140/ATCP.04.02.08

Booster Bunch by Bunch Feedback System

- Commissioned System with D. Teytelman Nov. 2021
- Established active feedback
- Cleaning of individual buckets
- Tune measurement on the ramp now possible



Courtesy: E. Blomley

Renew of all Kicker and Septum Power Supplies

- Contract to replace
  - All the control units – new ones have a safety PLC
  - All power supplies - FUG HCK/HCE Series
  - Pulser circuits for booster septa and injection kicker
  - Control system integration (EPICS/CSS)
- Installation delayed by 6 month due to COVID19
- Serious issues during commissioning in April/May 2021
  - Several bugs in the PLC code caused a delay of one week during the start up
  - FUG HCK 200-350 MOD
    - Fuses blown / trip → too high start up current
    - FUG implemented a current choke on these units, since then no issue anymore
  - Short circuit in the storage ring septum due to wrong operation settings
- Since a service visit end of October most of open minor issues are solved

Courtesy: M. Schuh

Replacement of the Main Power Supplies

- Replacement planned of
  - Booster bend, quadrupole PS
  - Storage ring bend and 3x sextupole PS (split 2 families into 3)
- Contract was placed end of 2020
- TDR approval 2021-08
- FAT shifted from Q3 2021 to Q1 in 2022 due to COVID19
- Installation planned 2022:
  - April: storage ring bend and sextupole
  - June / July: booster bend and quadrupole
- Next project: Replacement of storage ring quadrupole power supplies

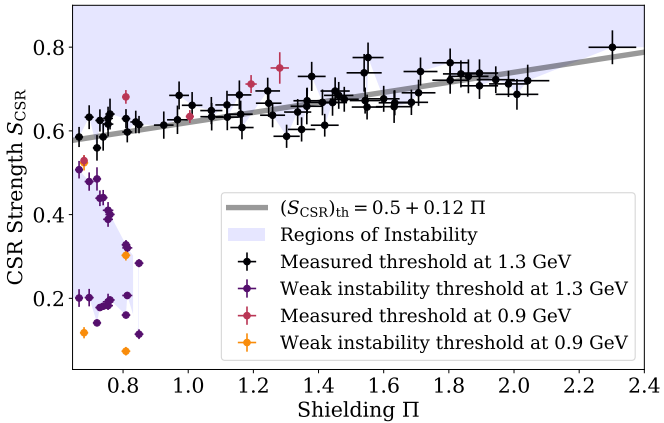
Longitudinal Beam Dynamics
Micro-bunching Instability - Measurements

M. Brosi: Overview of the Micro-bunching Instability in Electron Storage Rings and Evolving Diagnostics, Invited IPAC21 Contribution DOI: 10.18429/JACoW-IPAC2021-THXA02

Helmholtz Doctoral Prize
M. Brosi

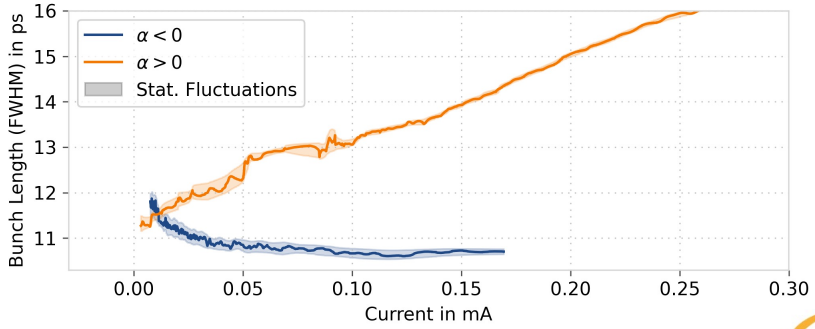
https://www.youtube.com/watch?v=6TUFDovtBws

- Influence of different beam energies on the Micro-bunching instability



M. Brosi et al. DOI: 10.18429/JACoW-IPAC2021-WEPAB246

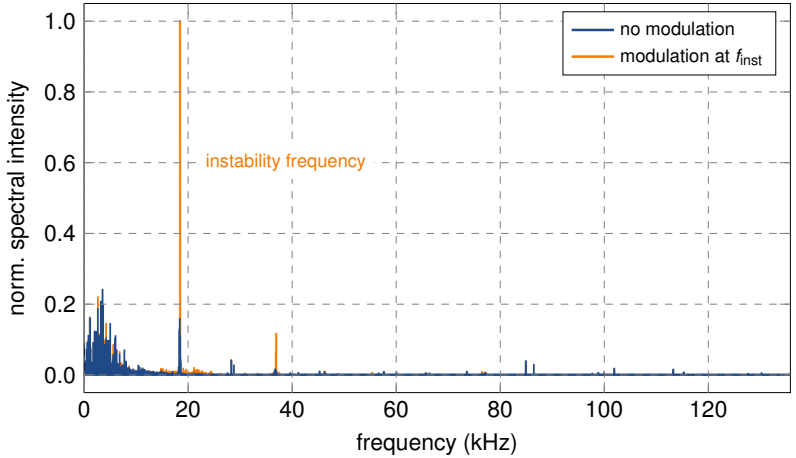
- Effect of negative momentum compaction operation on the current-dependent bunch length



P. Schreiber et al. DOI: 10.18429/JACoW-IPAC2021-WEPAB083

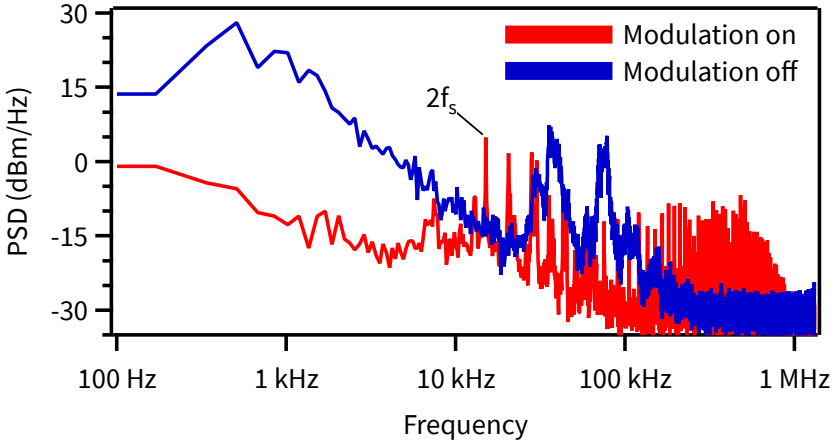
Longitudinal Beam Dynamics
Micro-bunching Instability - Manipulation

- Excitation of Micro-bunching in short electron bunches using RF amplitude modulation



T. Boltz et al., DOI: 10.18429/JACoW-IPAC2021-WEPAB233

- Increasing the single-bunch instability threshold by bunch splitting due to RF phase modulation

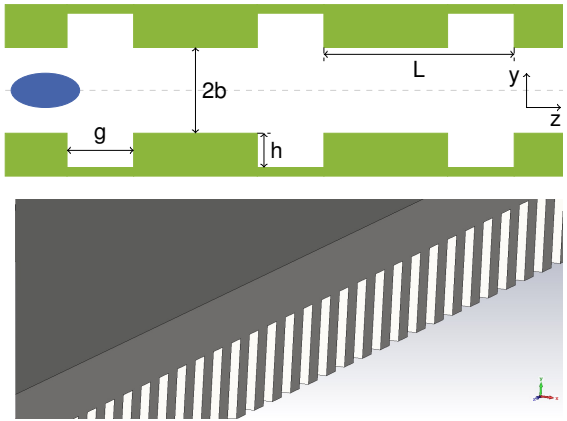


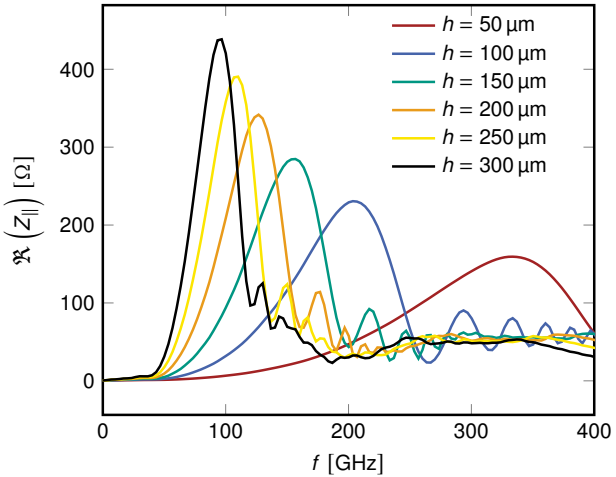
J.L. Steinmann et al., DOI: 10.18429/JACoW-IPAC2021-WEPAB240

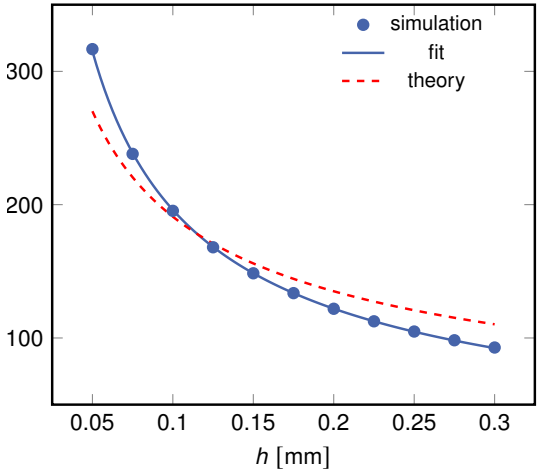
Impedance Manipulation Chamber

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation
MU 4033/4-1

Karlsruhe Institute of Technology





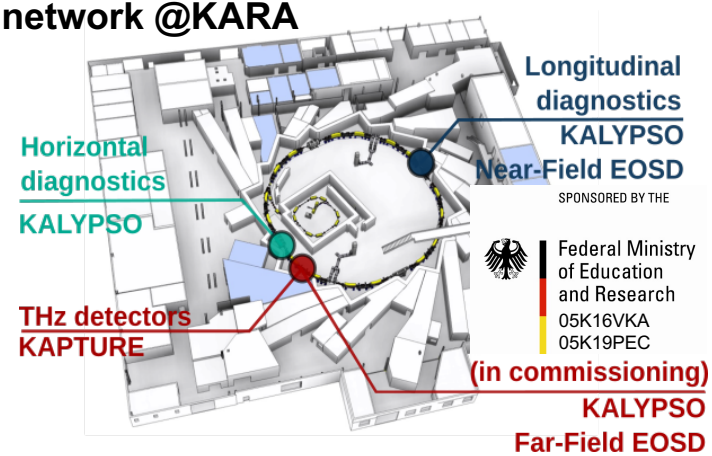


S. Maier et al., DOI: 10.18429/JACoW-IPAC2021-TUPAB251

- Controlling of microbunching instability for short bunches and intense THz radiation
- Designing of a chamber with vertically moveable plates

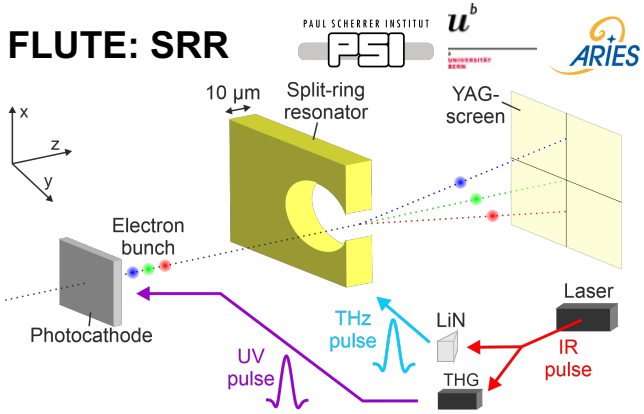
Diagnostics @ IBPT

Diagnostic detector distribution network @KARA

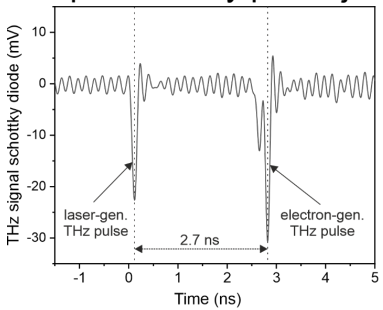


S. Funkner et al. arXiv preprint, arXiv:1912.01323
S. Funkner et al., PRAB 22(2), 022801 (2019).
M. Brosi et. Al., Phys. Rev. Accel. Beams 19, 110701 (2016)
M. Brosi et al., Proc. IPAC, WEPTS015 (2019).
B. Kehrer et al., PRAB 21(19), 102803 (2018)
J. L. Steinmann et al., PRAB 21(11), 110705 (2018

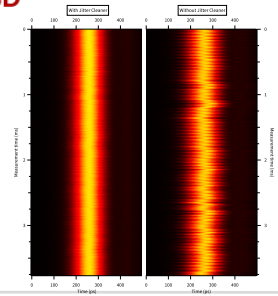
FLUTE: SRR



Temporal overlap experimentally pre-adjusted!



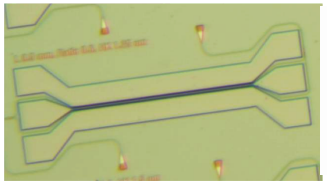
M. Nabinger et al., DOI: 10.18429/JACoW-IPAC2021-THPAB251



Single-Shot analysis of short radiation pulses with fast detector & oscilloscope

Courtesy:
J. L. Steinmann

EO Modulators for Low Charge Bunch Arrival Monitors



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05K19VKB

S. Ummethala et al., Optica, 8(4):511–519, 2021.

EO Diagnostics @ IBPT

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05K16VKA
05K19PEC

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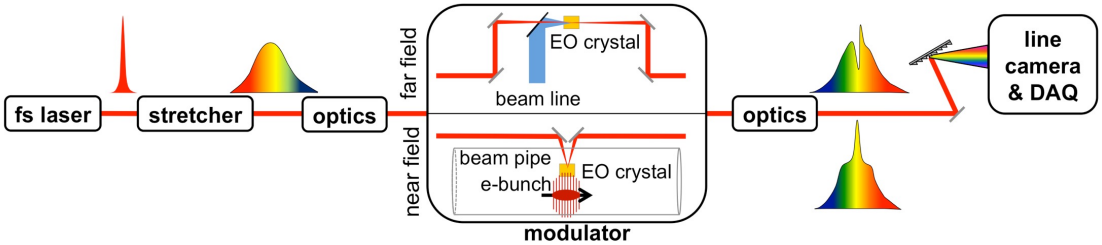
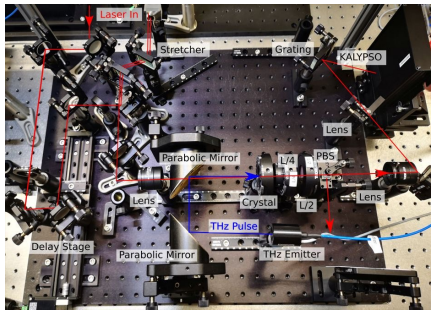
Far-field

- Experiment under commission, current status: off-line demonstrator tests
- Measuring the complete THz pulse in single-shot



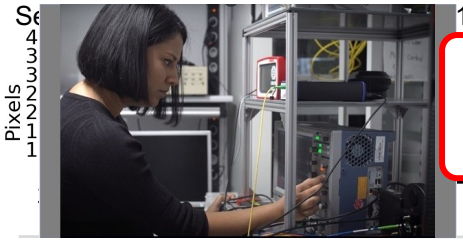
G. Niehues et al., DOI: 10.18429/JACoW-IPAC2021-THPAB251

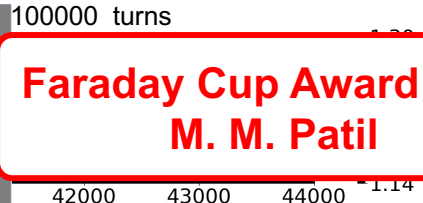


C. Widmann et al.,
DOI: 10.18429/JACoW-IPAC2021-MOPAB294

Near-field:

- Resollving electron bunch profile in every turn @ 2.7 MHz
- Capable of uninterrupted data acquisition for up to several millions of turns



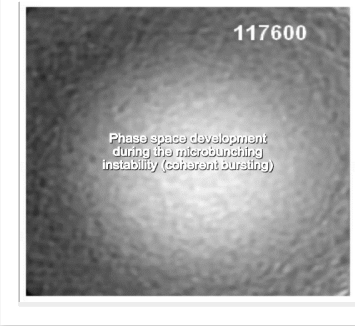


Faraday Cup Award 2021
M. M. Patil

M. M. Patil et al., FRXC03 and WEPAB33 , IPAC 2021.

Phase space tomography

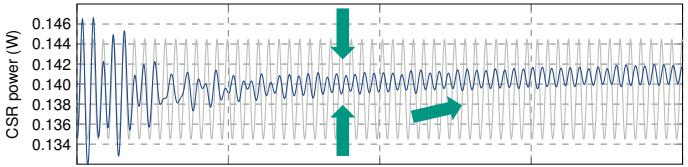
- Complete phase space image reconstructed from time interval of 61 µs
- “Random morphing“ between independent measurement

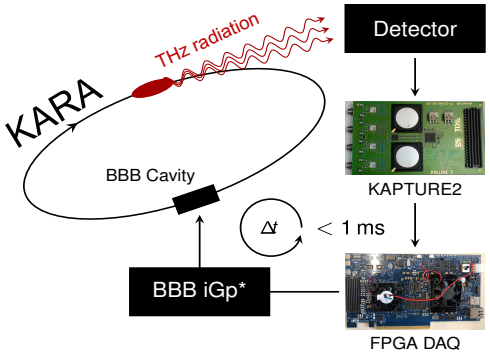


S. Funkner et al. arXiv preprint, arXiv:1912.01323.

Machine Learning Activities

First steps at real-time control of physical processes with Reinforcement Learning





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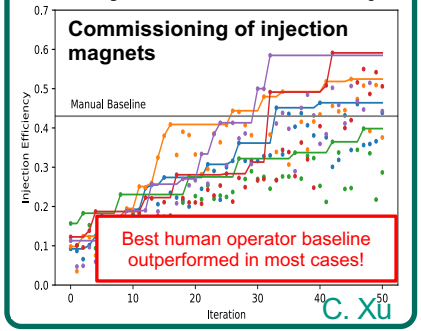
05K19VKC (TiMo)

In house framework for ML deployment on hardware

T. Boltz

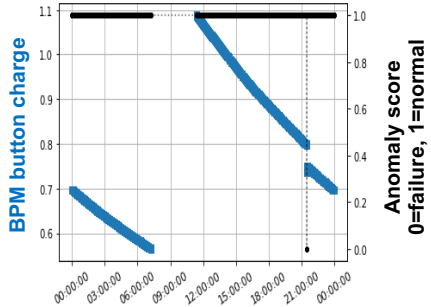
"Accelerated Deep Reinforcement Learning for Fast Feedback of Beam Dynamics at KARA" (IEEE 10.1109/TNS.2021.3084515)

Bayesian Optimization of injection efficiency



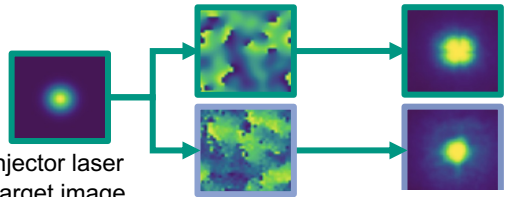
C. Xu

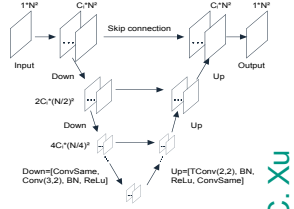
BPM anomaly detection with autoencoders



N. Bruchon

First steps at beam shape control





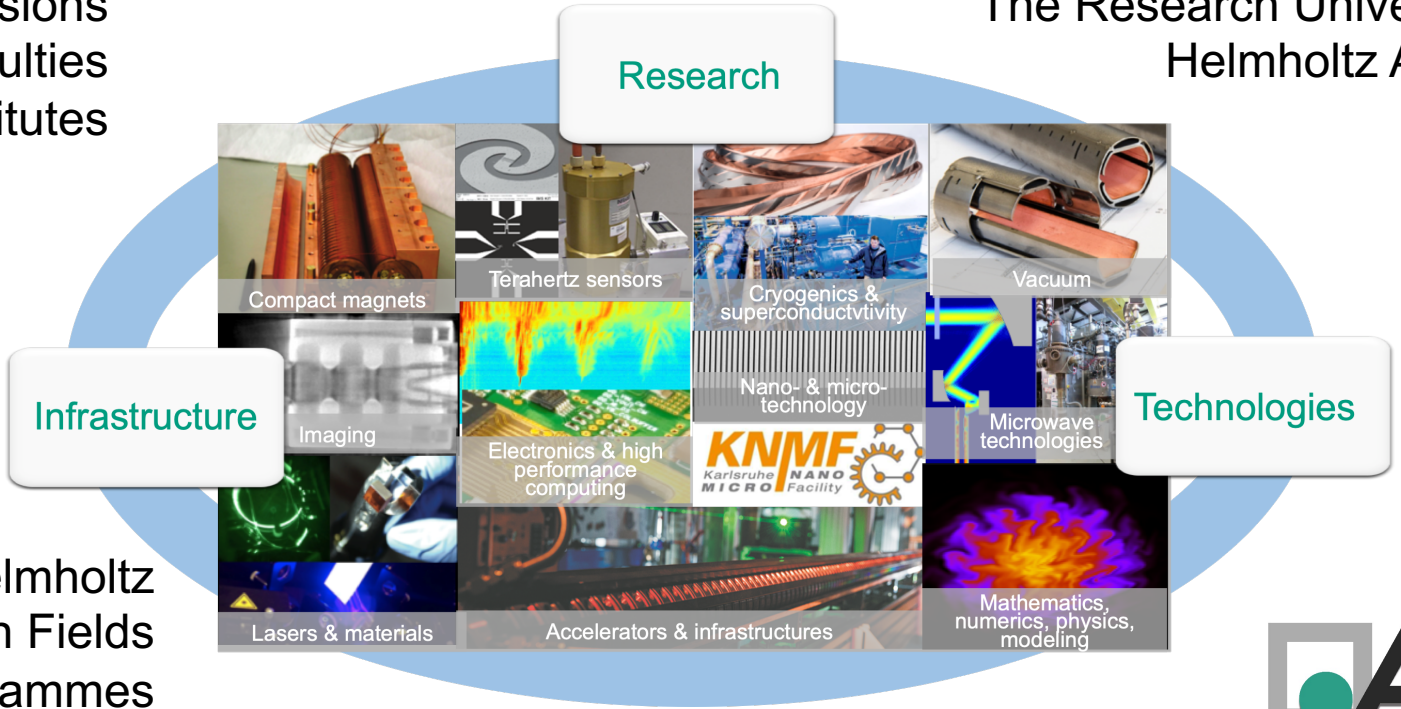
C. Xu

C. Xu et al., DOI: 10.18429/JACoW-IPAC2021-WEPAB289

The Accelerator Technology Platform @ KIT (ATP)

5 Divisions
6 KIT-Faculties
11 Institutes

The Research University in the Helmholtz Association



+ strong industrial partners

Helmholtz
3 Research Fields
6 Programmes

www.ibpt.kit.edu/atp

ATP
Accelerator Technology Platform @ KIT

Acknowledgements

Thank you for your attention

- The accelerator team:

  Axel Bernhard, Edmund Blomley, Tobias Boltz, Nicky Bruchon, Miriam Brosi, Erik Bründermann, Hyuk Jin Cha, Kantaphon Damminsek, Dima El Khechen, Samira Fatehi, Stefan Funkner, Julian Gethmann, Andreas Grau, Steffen Grohmann, Bastian Härer, Michael Hagelstein, Daniel Hoffmann, Erhard Huttel, Igor Kriznar, Artem Kuzmin, Sebastian Maier, Anton Malygin, Sebastian Marsching, Yves-Laurent Mathis, Wolfgang Mexner, Akira Mochihashi, David Moss, M. Nabinger, Michael J. Nasse, Yuancun Nie, Gudrun Niehues, Marvin D. Noll, Alexander Papash, Meghana Patil, Micha Reißig, Robert Ruprecht, David Saez de Jauregui, Andrea Santamaria Garcia, Carl Sax, Jens Schäfer, Thiemo Schmelzer, Patrick Schreiber, Markus Schwarz, Nigel J. Smale, Johannes L. Steinmann, Pawel Wesolowski, Christina Widmann, Andreas Will, Chenran Xu, and Anke-Susanne Müller
- KIT Partner Institutes (ETP, IHM, IMS, IPE, IPS, LAS, IAR, IPQ)
- Collaboration partners:

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