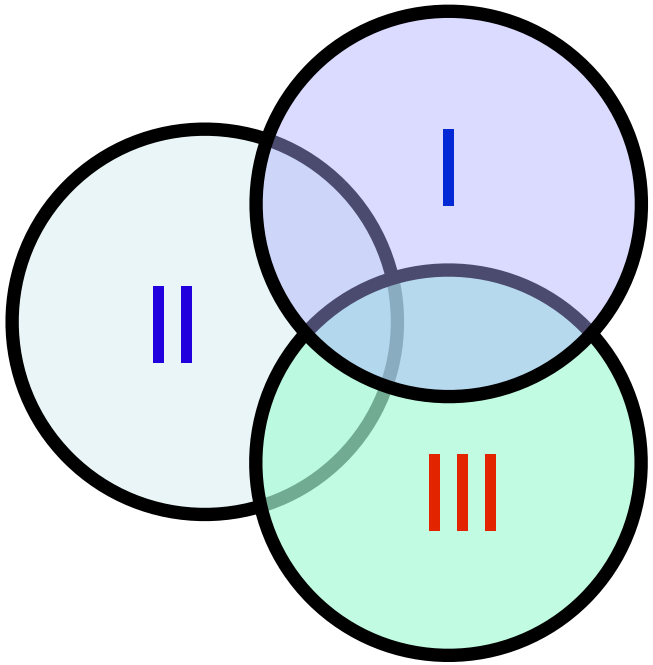
PT3: ps – fs Electron and Photon beams
Subtopic - (Coh.) photon radiation & interaction

speaker: A.-S. Müller

Inst. f. Synchrotron Radiation / ANKA

KIT



- I Laser induced radiation & synchronization
- II Ultra-fast pulse diagnostics
- **III (Coh.) photon radiation & interaction**

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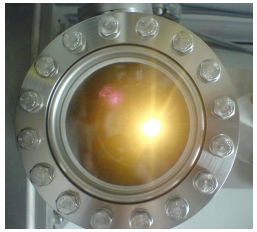
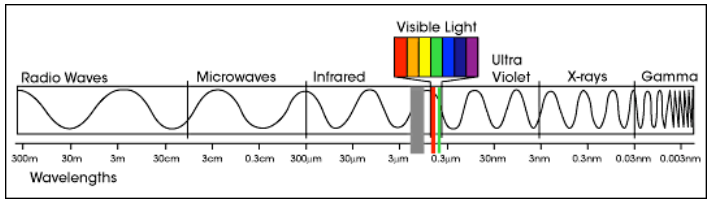
HELMHOLTZ GEMEINSCHAFT

Grand Challenges and Approaches

- Accelerator based light sources enable
  - ➜ research in frontier areas of science (physics, chemistry, biology, medicine, material sciences, ...)
  - ➜ needed to address the grand challenges of society, science and industry



- Develop light sources to the needs of a growing user community
  - ➜ higher intensities, brilliances, average flux
  - ➜ increased stability
  - ➜ covering the entire e.m. spectrum from THz to hard X-rays with coherent radiation



- Common tasks on this road
  - ➜ affect all accelerator centers operating or building light sources

Generation of radiation

- Linacs & Rings
  - ➜ both are used to generate light to provide to users
  - ➜ interaction of photons with e-beam can be the cause of instabilities
- Different mechanisms to generate (coherent) radiation, e.g.
  - ➜ insertion devices for special properties of radiation
  - ➜ FEL: SASE,... and laser induced radiation (talk by H. Schlarb)
  - ➜ CSR, CER in linacs and rings
  - ➜ CTR in linacs (FELs and broadband THz sources)
- Electron-photon interaction essential for
  - ➜ compression of bunches in linacs by conventional methods or by use of special photo injectors
  - ➜ understanding of micro-bunching instability
  - ➜ rings with short bunches in low-alpha operation
  - ➜ micro structures or variable pulse lengths in storage rings

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short bunches

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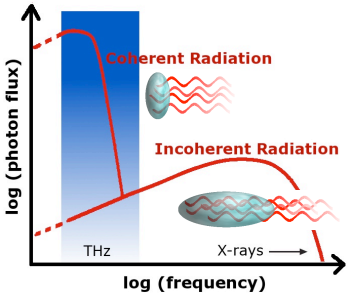
understanding before optimization

short bunches

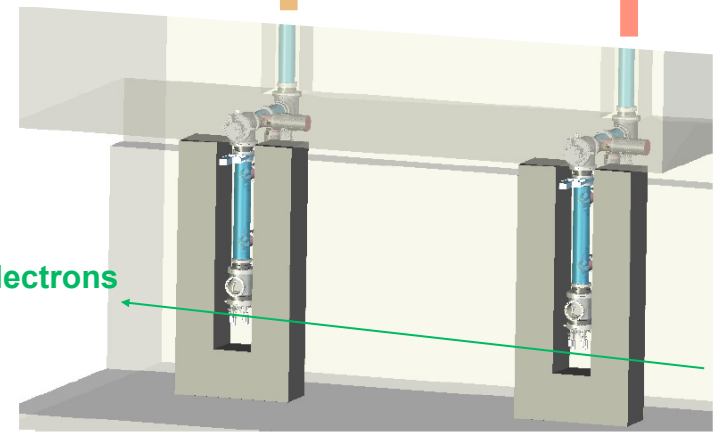
(in)stability

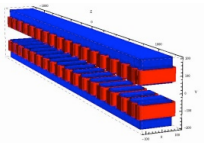
Short Bunches - Linacs

- Short bunches are the prerequisite
  - ➜ for generation of coh. radiation (both FELs and THz sources)
  - ➜ excellent time resolution
- Needed: bunch compressors
  - ➜ compression starts at the gun.....
  - ➜ design, studies, simulations (instabilities!)
- Presently studied for **FLASH, XFEL, ELBE, FLUTE, TBONE, B*ERL*inPro**
- Existing (mostly bilateral) cooperations/first contacts to be intensified within ARD



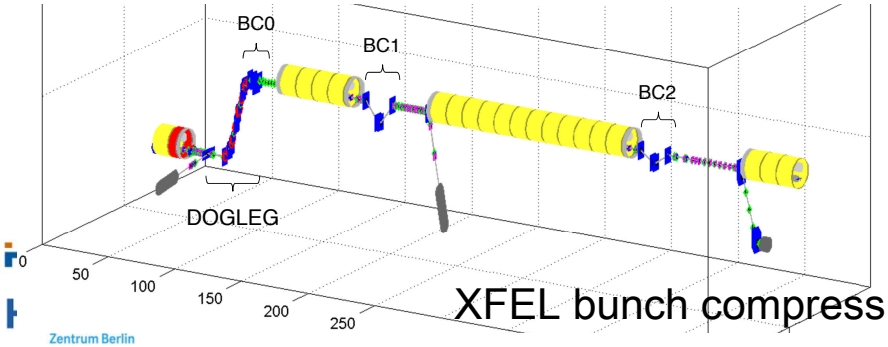
TELBE THz beamlines





8 period undulator

CDR/CTR screen



XFEL bunch compression system

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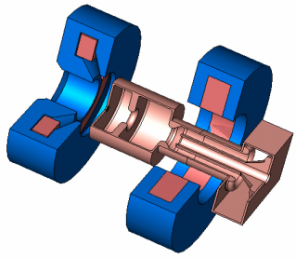
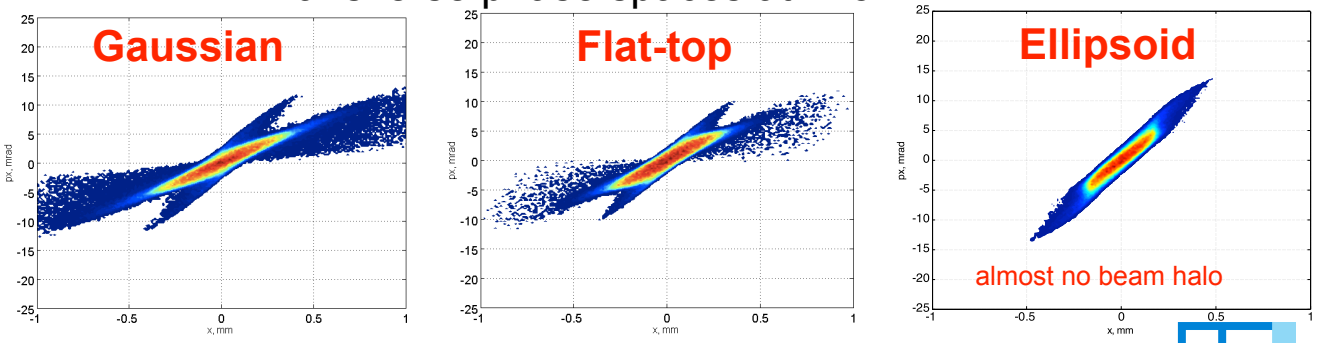
Short Bunches - Linacs

- Important issue: initial conditions for bunch compression
- Proposal: use special photo cathode laser pulse in RF gun to simplify the following bunch compression
  - ➜ 3D ellipsoidal photo cathode laser pulses
  - ➜ test at **PITZ**

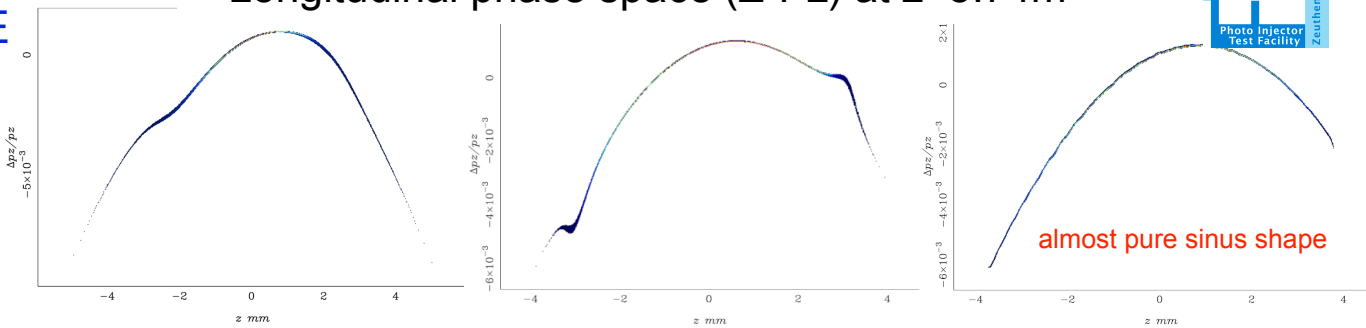


- Possible application at many facilities, e.g.
  - ➜ EU -XFEL
  - ➜ TELBE
  - ➜ FLUTE, TBONE
  - ➜ .....

Transverse phase spaces at z=5.74m



Longitudinal phase space (Z-Pz) at z=5.74m



PITZ Photo Injector Test Facility Zeuthen

A.-S. Müller
GSI, 21.11.2011

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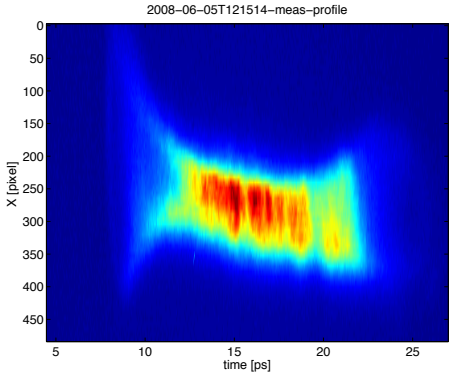
Short Bunches - Linacs

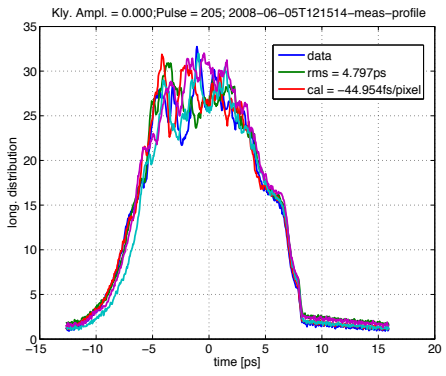
- Harmful effects:
  - ➜ microbunching, space charge effects and CSR
  - ➜ design, studies, simulations, measurements
- Important: complementarity of facilites within ARD w.r.t. bunch lengths, beam energy, bunch charge, rep. rate, makro pulse structure, ...
  - ➜ common physics programme
  - ➜ diagnostics - talk by M. Gensch

First Microbunching observations FLASH

Transverse deflecting device



screen image of streaked electron bunch

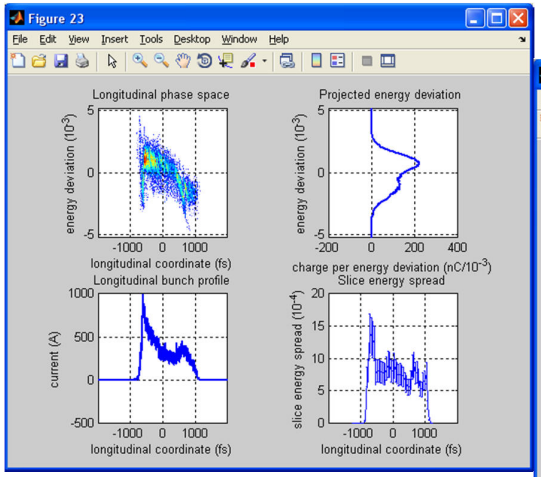


longitudinal projection

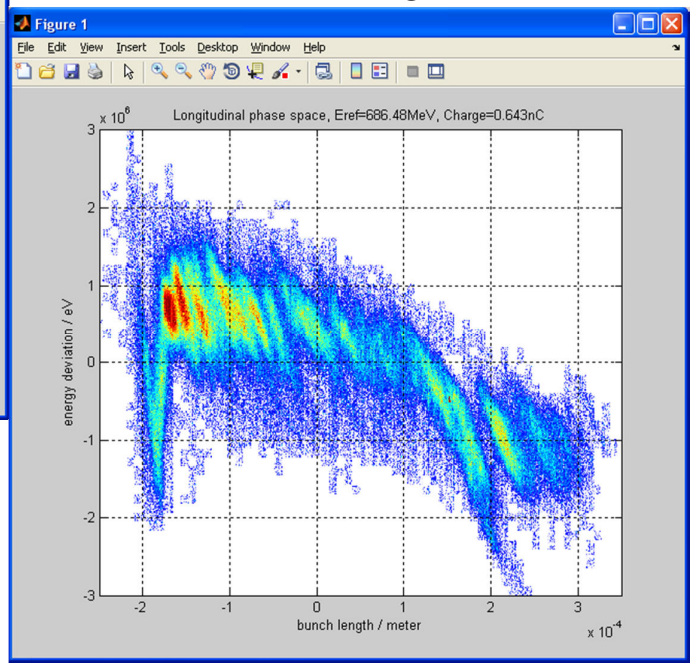
Uncompressed bunch: (nearly oncrest phases)
→ ripples on longitudinal charge image
→ strong fluctuation from shot to shot

courtesy Holger Schlarb

Short Bunches - Linacs

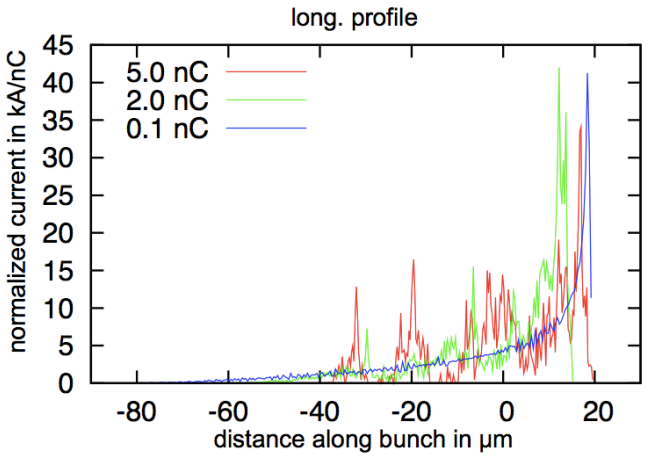


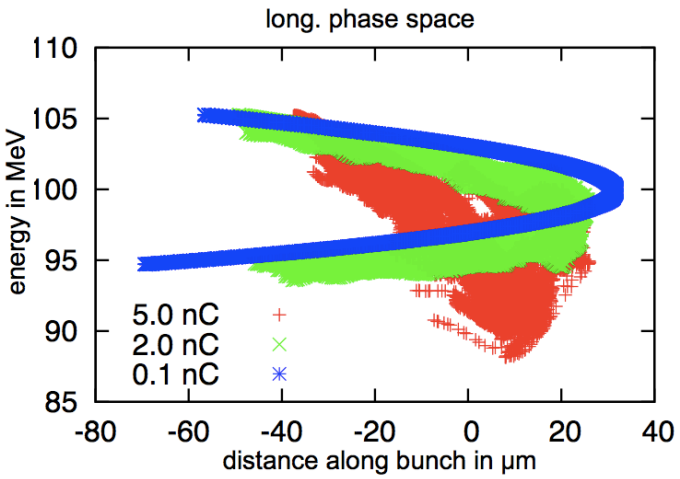
microbunching in FLASH



CSR effects in TBONE

0.65nC





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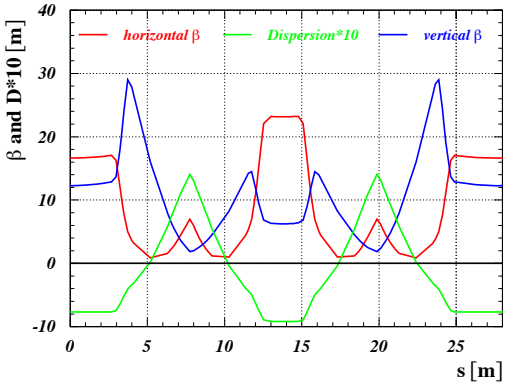
Short Bunches - Storage Rings

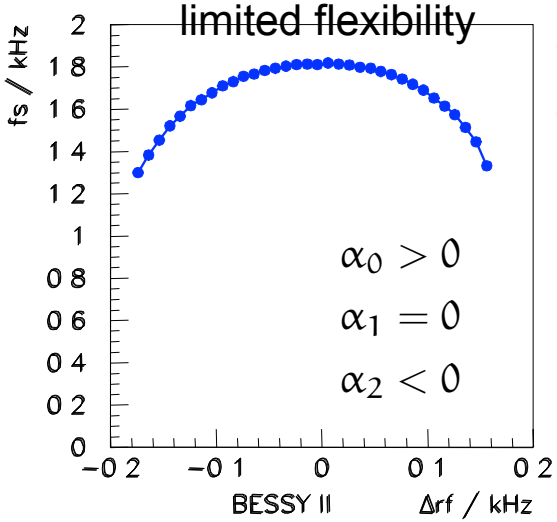
- As for linacs, short bunches are the prerequisite
  - ➜ for generation of coherent radiation
  - ➜ to achieve ps time resolution
- Common goals:
  - ➜ optimize the emission of radiation for the user communities
  - ➜ conciliate the needs of X-ray and THz/IR users
- Studies at **BESSY II** , **MLS** and **ANKA**
- Topics under study:
  - ➜ low-alpha operation (existing cooperation contract HZB - PTB - KIT)
  - ➜ CHG, EEHG etc. (FZJ and TU Dortmund; see talk by H. Schlarb)
  - ➜ investigations of high freq. impedance and instabilities (e.g. for damping rings in future linear colliders within a European framework)
  - ➜ new in ARD: **extension to multi-user** mode by "**Variable pulse length Storage Rings**" or **seeded micro structures** (HZB and KIT)

Short Bunches - Storage Rings

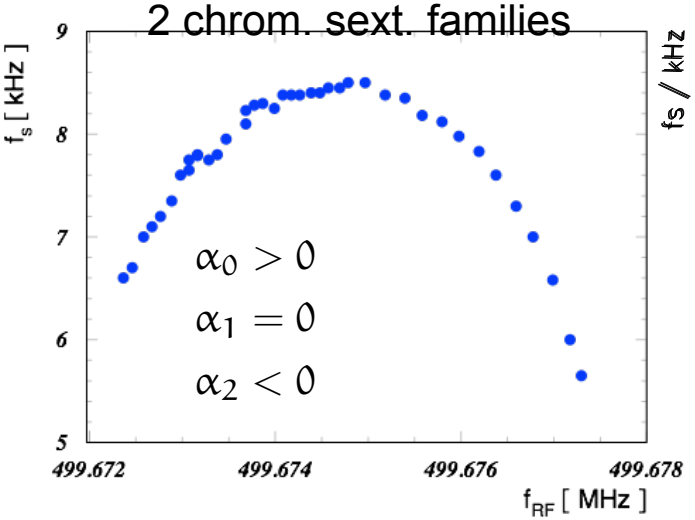
- Low-alpha operation
  - ➜ HZB, PTB and KIT, existing coop. contract
  - ➜ common experiments, exchange of students, sharing of technology (e.g. detectors)



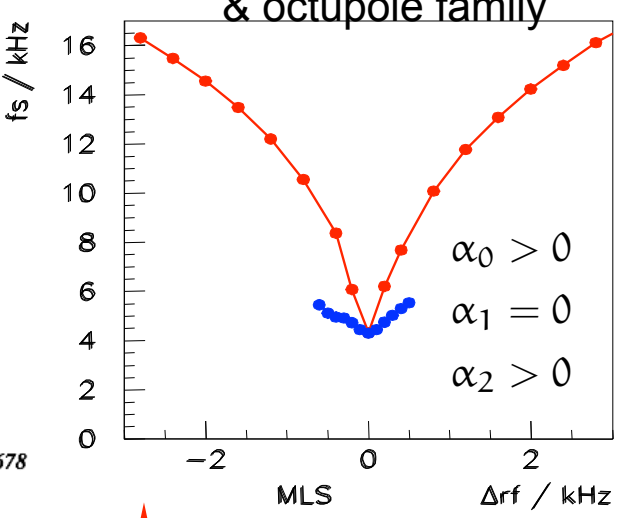
BESSY II, 1.7 GeV
4 chrom. sext. families,
limited flexibility



ANKA, 1.3 GeV
Low alpha optics,
2 chrom. sext. families



★ **MLS**, 630 MeV
3 chrom. sextupole families,
& octupole family



★ **MLS: first ring with low alpha correction scheme**

A.-S. Müller
GSI, 21.11.2011

Short Bunches - Storage Rings

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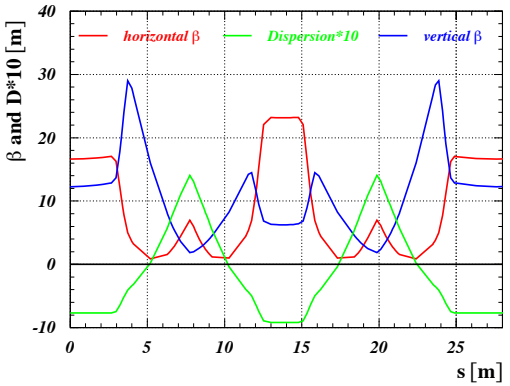

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4 chrom. sext. families,
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ANKA, 1.3 GeV
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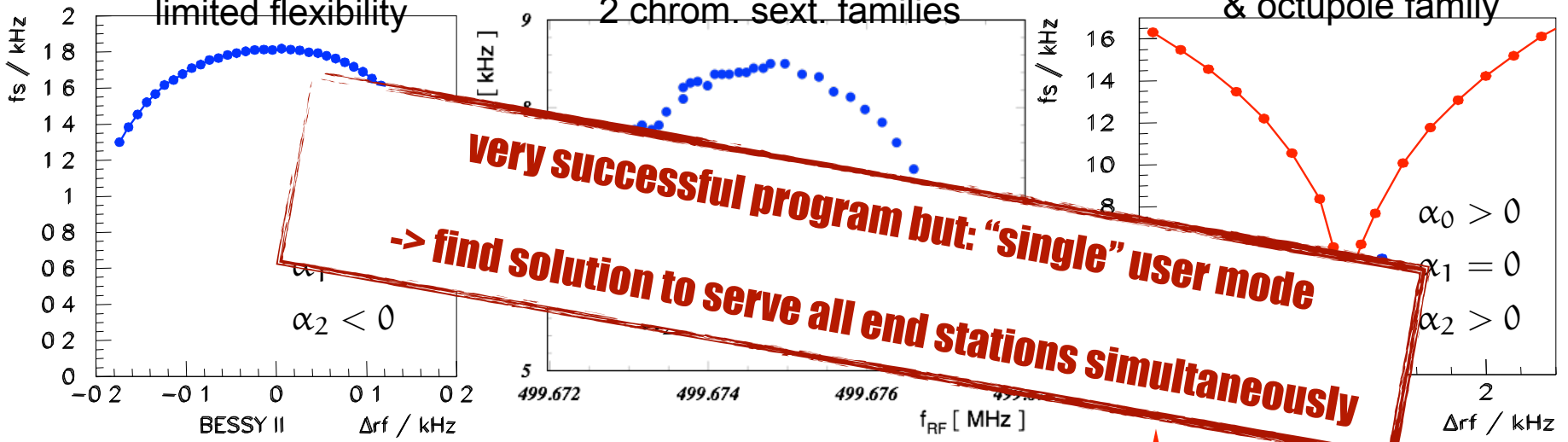


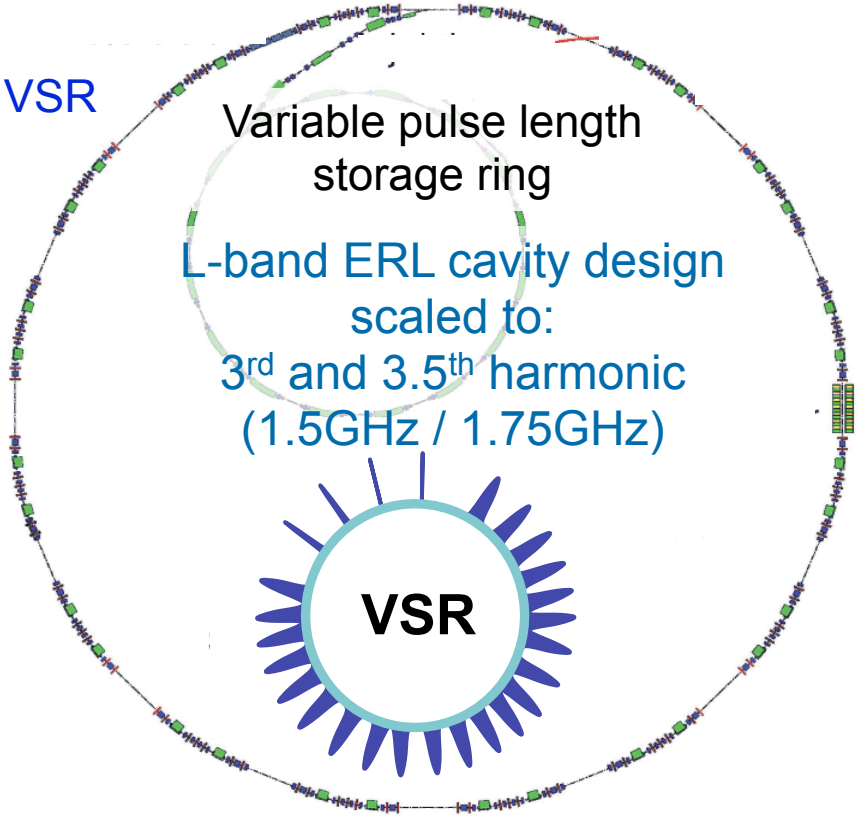
very successful program but: "single" user mode

-> find solution to serve all end stations simultaneously

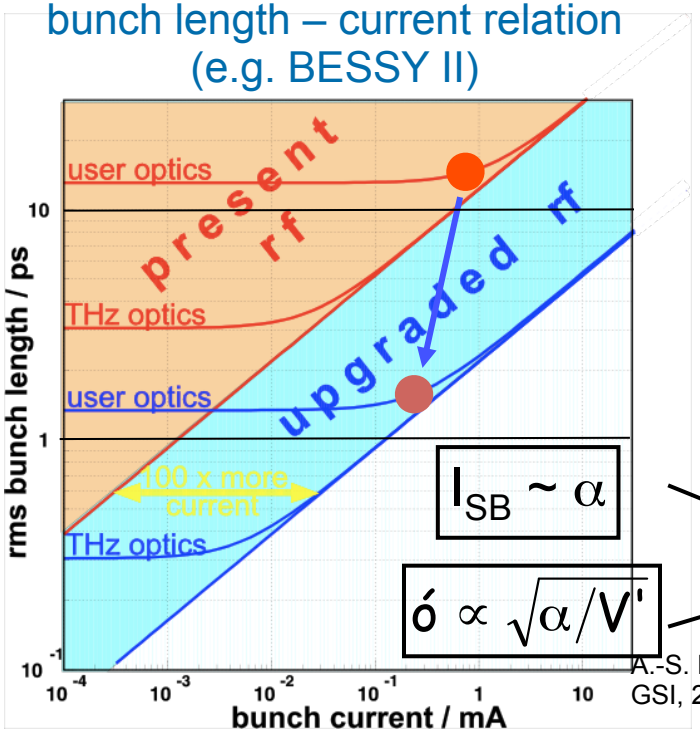
★ MLS: first ring with low alpha correction scheme

Short Bunches - Storage Rings

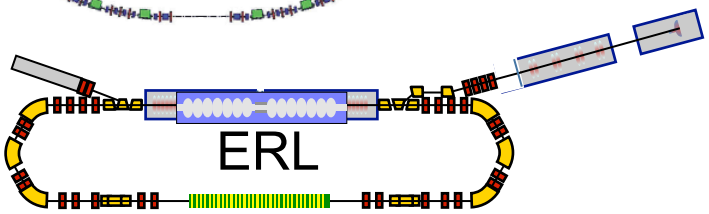
- Idea: provide short pulses (ps and shorter) at all end stations simultaneously with high flux, high brilliance
  - ➜ Variable pulse length storage rings - VSR
- Project at BESSY II
  - ➜ Multi cell sc cavities in storage rings
- Strong connection to PT1



bunch length – current relation (e.g. BESSY II)



$I_{SB} \sim V'$ for fixed σ



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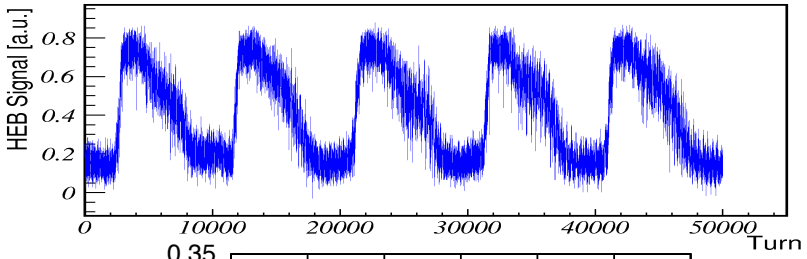
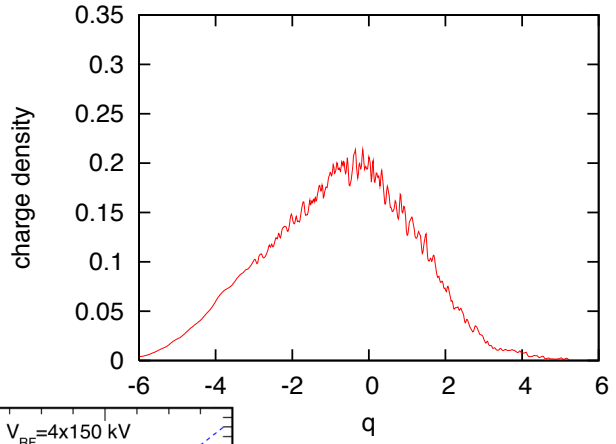
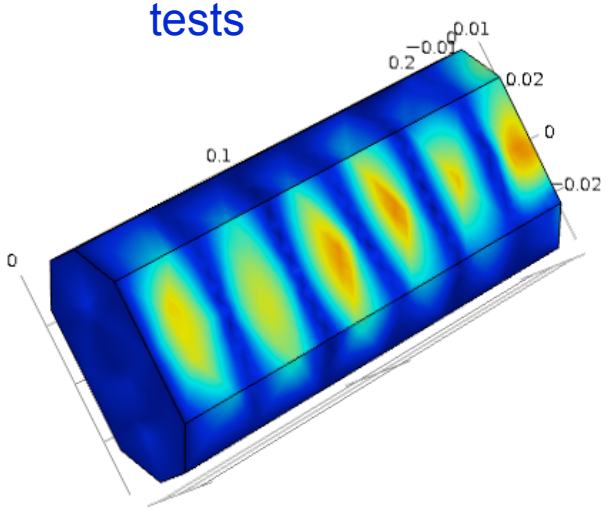
Short Bunches - Storage Rings

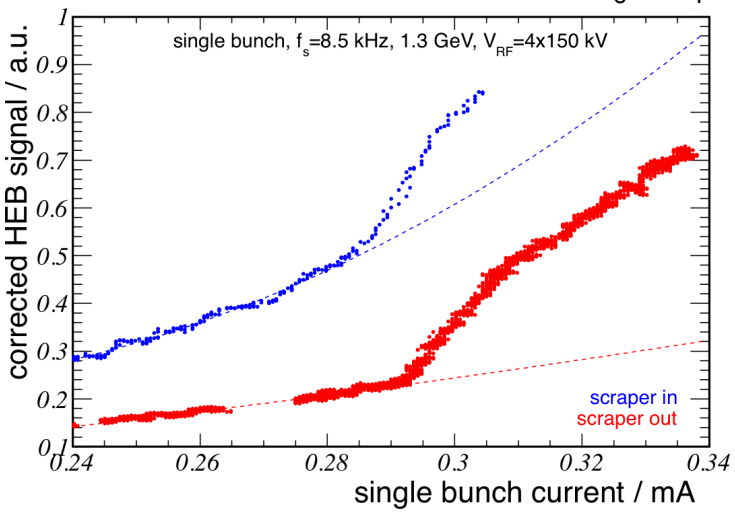
- Idea: stabilize the instability by a seeding of micro structures on longer bunches
  - ➜ couple microwave radiation to the beam to trigger the bursts of high intensity THz radiation form long electron bunches
- Project at ANKA
  - ➜ design, simulations and experimental tests

Bursting THz radiation in ANKA









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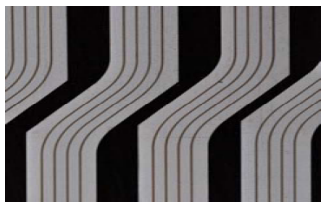
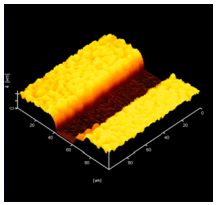
Insertion Devices

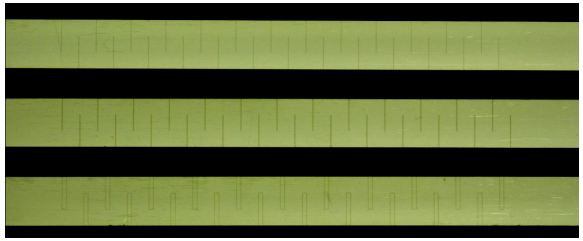
- Investment for the future
  - ➜ next generation technology for rings, linacs & ERLs
- Complementary developments at HZB, DESY & KIT
  - ➜ technology transfer and cooperations with industry
  - ➜ in ARD: HTS developments

High temperature developments at KIT

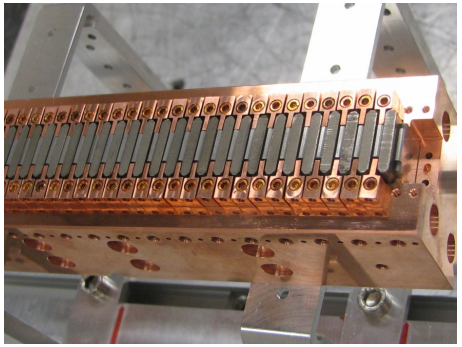
HTS tape stacked undulator

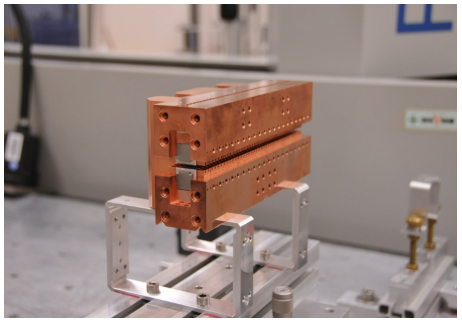






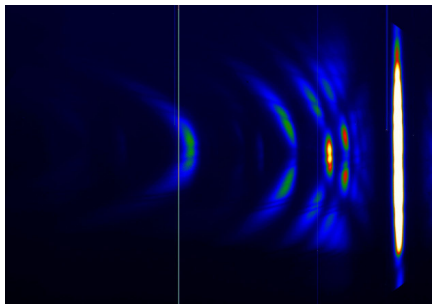
Cryogenic undulator development at HZB





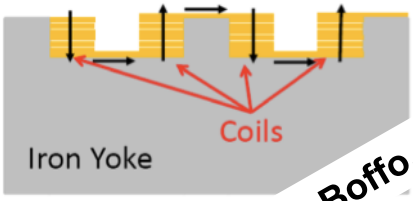
PrFeB-magnets as developed in a Collaboration of VAC, HZB, LMU

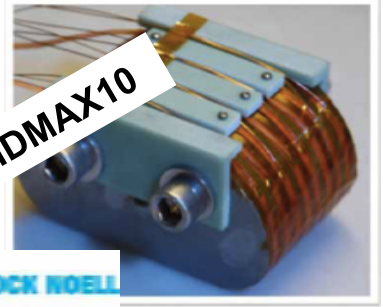
-energy product
(BH)max @ 85 K = 520 kJ/m^3
-B_r(10K)=1.7T
-Hcj=73kOe



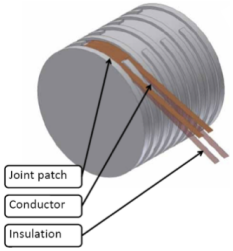
First tests with electron at MAMI

HTS tape planar undulator





C. Boffo, IDMAX10



BABCOCK NOELL

with Superpower 2G HTS wire

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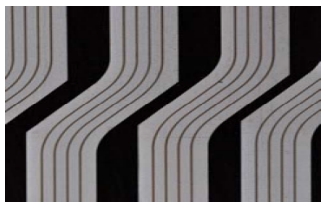
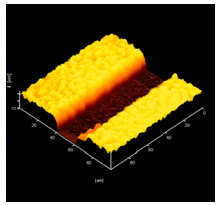
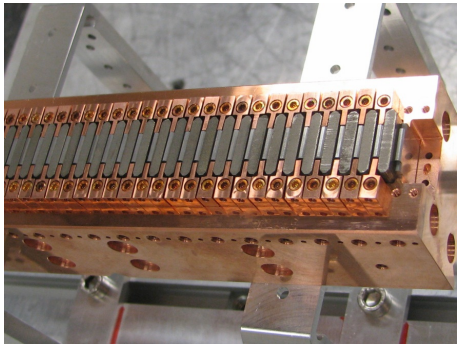
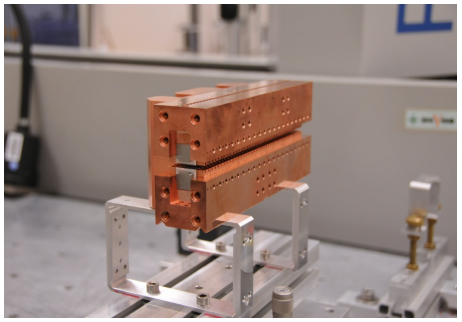
HTS tape stacked undulator





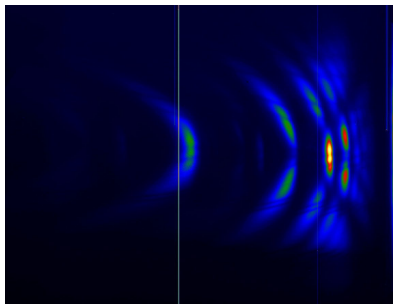
Cryogenic undulator development at HZB





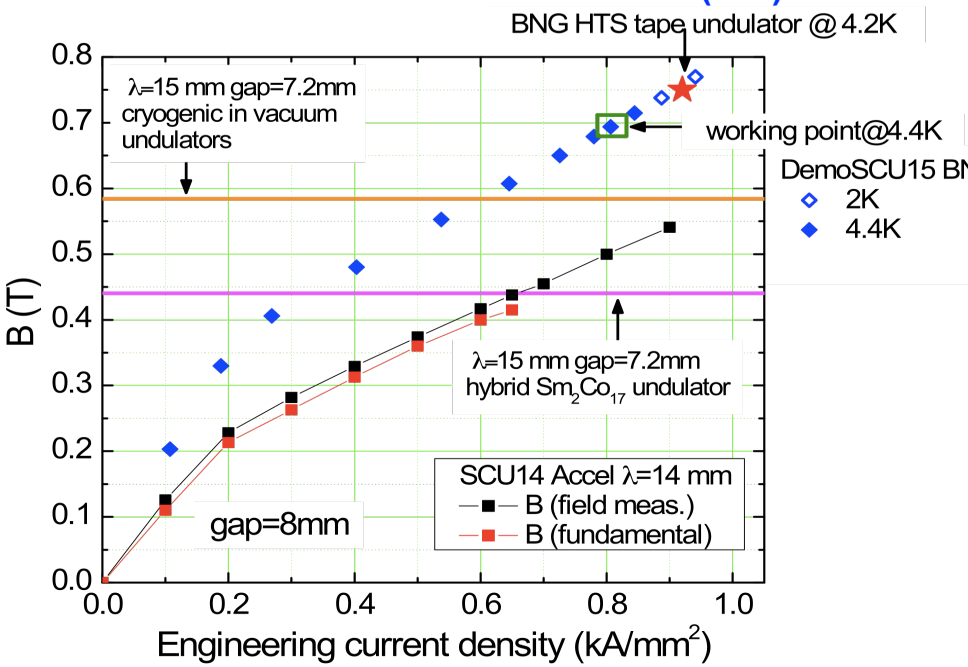
PrFeB-magnets as developed ir
Collaboration of VAC, HZB, LMI

-energy product
(BH)max @ 85 K = 520 kJ/m
-B_r(10K)=1.7T
-Hcj=73kOe



First tests with electron at MAI

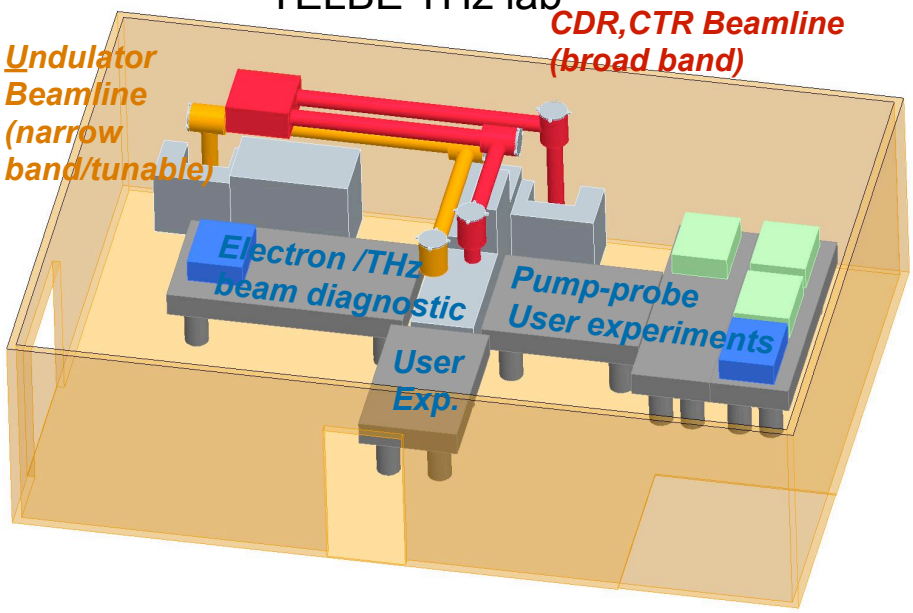
Babcock Noell Gmbh (BNG)
HTS tape planar undulator mockup:
results of recent test at CASPERI (KIT)



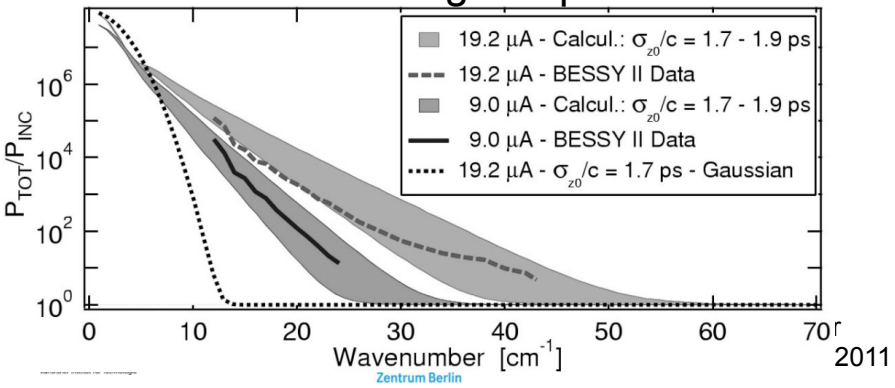
Coherent Radiation Sources

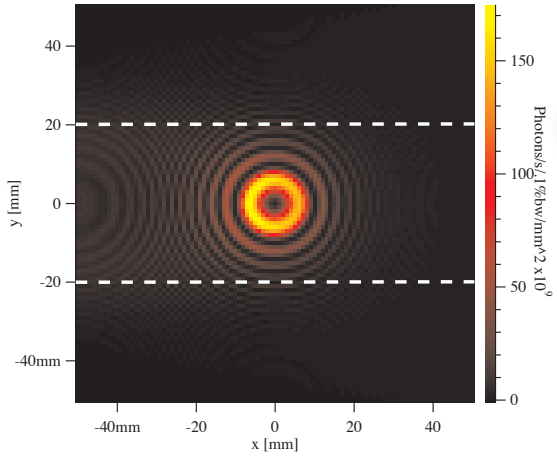
- Characterization of coh. radiation sources
  - ➜ CSR, CER, CTR, ID, etc.
  - ➜ efforts at DESY, HZB, HZDR, KIT, TU Dortmund, TU Berlin
  - ➜ see talks by H. Schlarb & M. Gensch
- Common issues & interests
  - ➜ THz transport, optics, simulations, detection and materials
  - ➜ exchange of personnel, training
  - ➜ development of common simulation code (e.g. “ARD thesis”)

TELBE THz lab

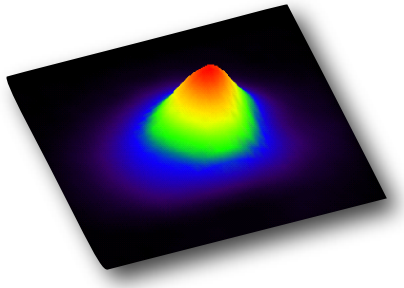


BESSY II THz gain spectrum





ANKA edge radiation



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Coherent Radiation Sources

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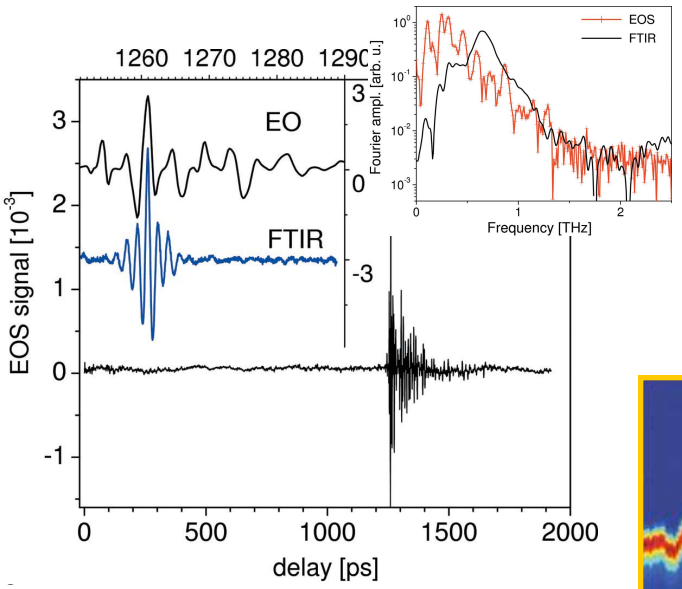
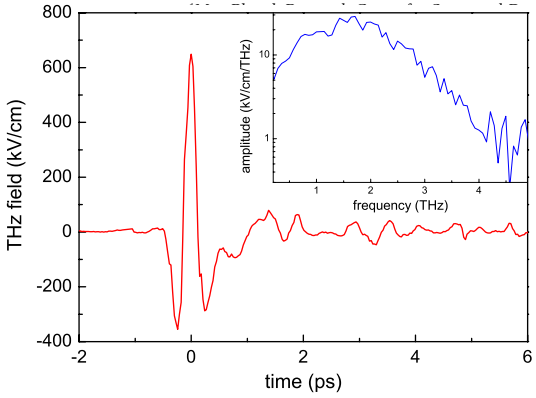
Asynchronous sampling for ultrafast experiments with low momentum compaction at the ANKA ring

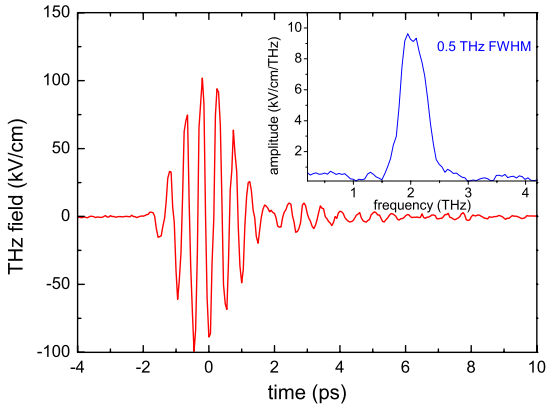
Shyjumon Ibrahimkutty,[a] Daniel Issenmann,[a] Stefan Schleef,[a] Anke-Susanne Müller,[a,b] Yves-Laurent Mathis,[a] Biliana Gasharova,[a] Erhart Huttel,[a] Ralph Steininger,[a] Jörg Göttlicher,[a] Tilo Baumbach,[a,b] Albrecht Bartels,[c] Christof Janke[c] and Anton Plech[a,c]*

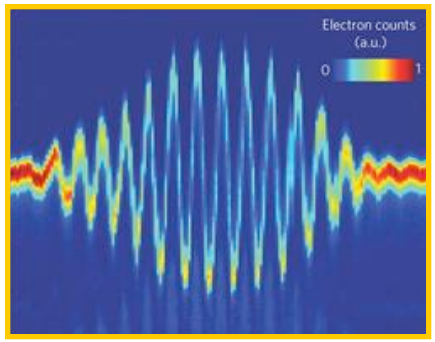


Coherent single-cycle pulses with MV/cm field strengths from a relativistic transition radiation light source

Matthias C. Hoffmann,[1,*] Sebastian Schulz,[2] Stephan Wesch,[2] Steffen Wunderlich,[2] Andrea Cavalleri,[1,3] and Bernhard Schmidt[2]







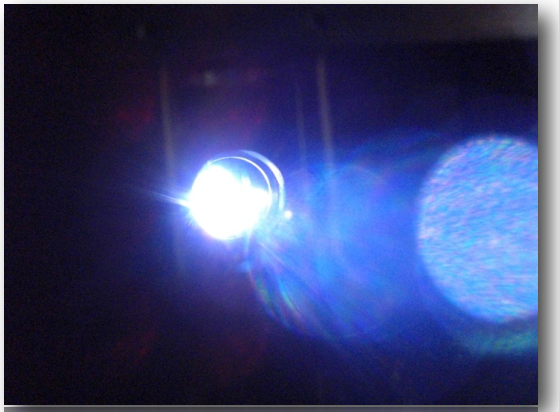
FLASH THz undulator pulse

U. Fruehling et. al., Nature Photonics (2009)

Summary

- Work plans / goals within ARD
  - ➜ rings: short bunches in multi-user mode with VSR and/or microbunching
  - ➜ linacs: optimize bunch compression and understanding of instabilities
  - ➜ insertion device development (close cooperation with industry; commercialization)
  - ➜ unterstanding the physics of (coh.) radiation sources in a scientific network

- ARD is the ideal framework to reach those goals
  - ➜ networking aspects in all PT3 subjects, e.g. workshops HGF+universities
  - ➜ intensify exchange of personnel
  - ➜ education and training
  - ➜ knowledge & technology transfer



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