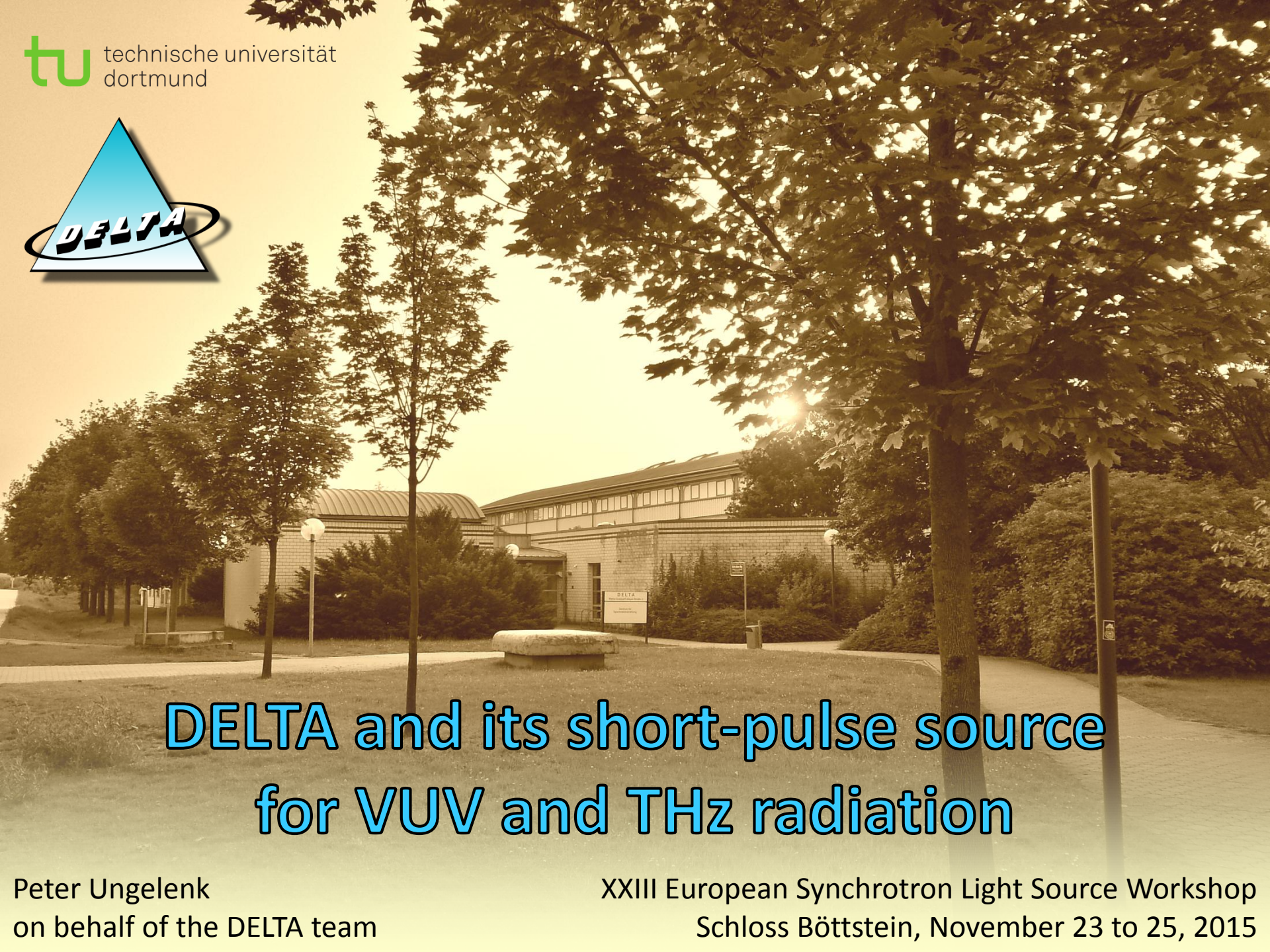
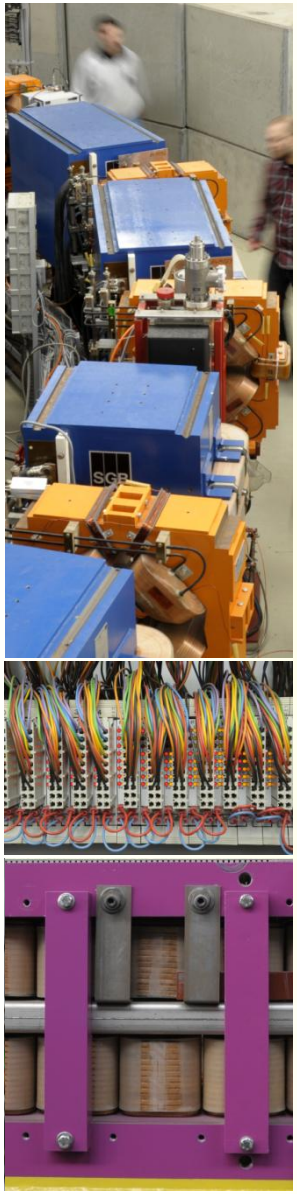
technische universität
dortmund



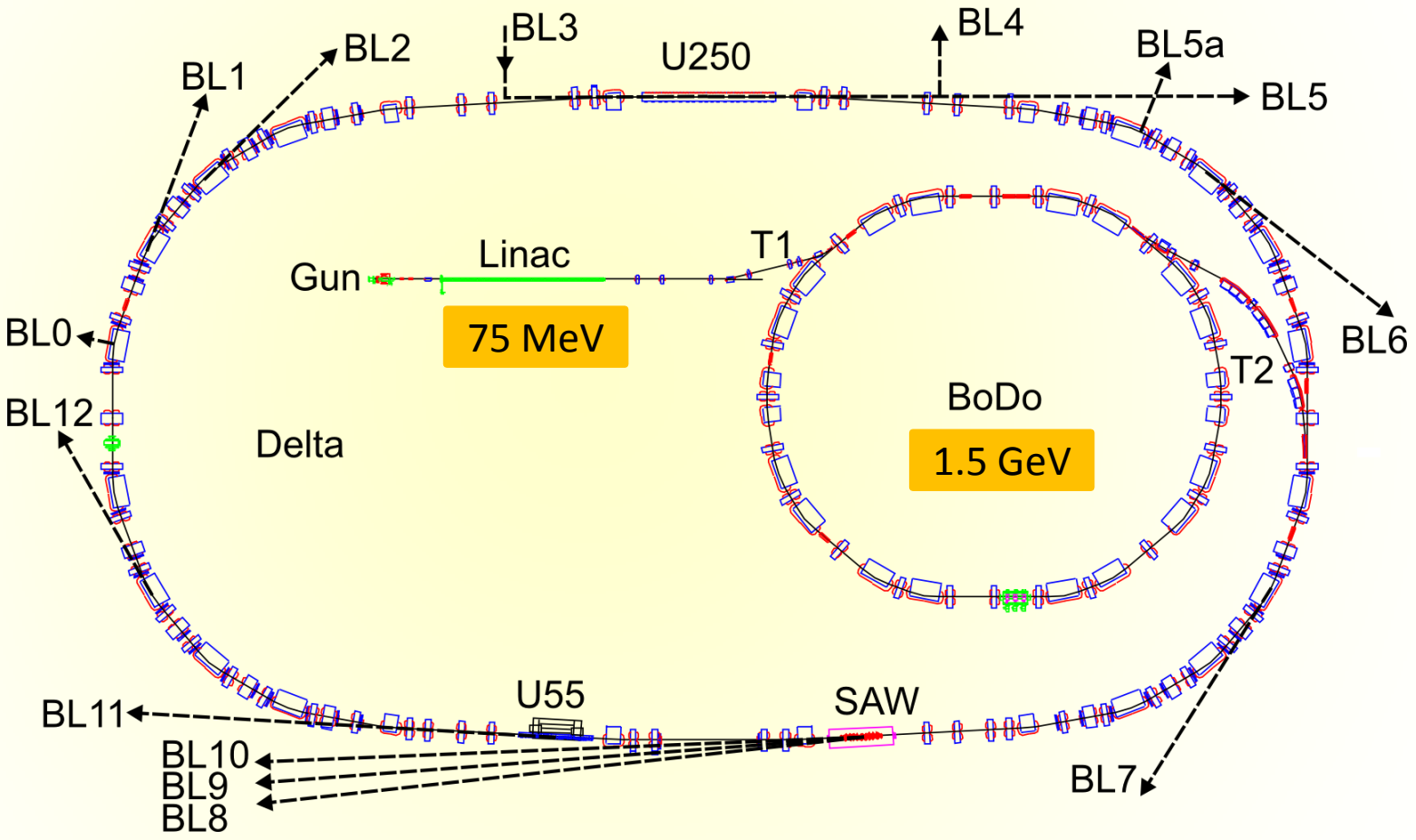
DELTA and its short-pulse source for VUV and THz radiation

Peter Ungelenk
on behalf of the DELTA team

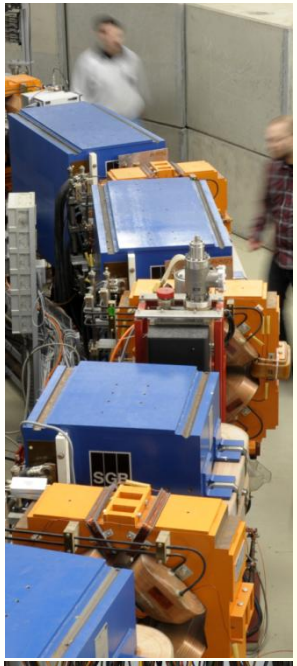
XXIII European Synchrotron Light Source Workshop
Schloss Böttstein, November 23 to 25, 2015



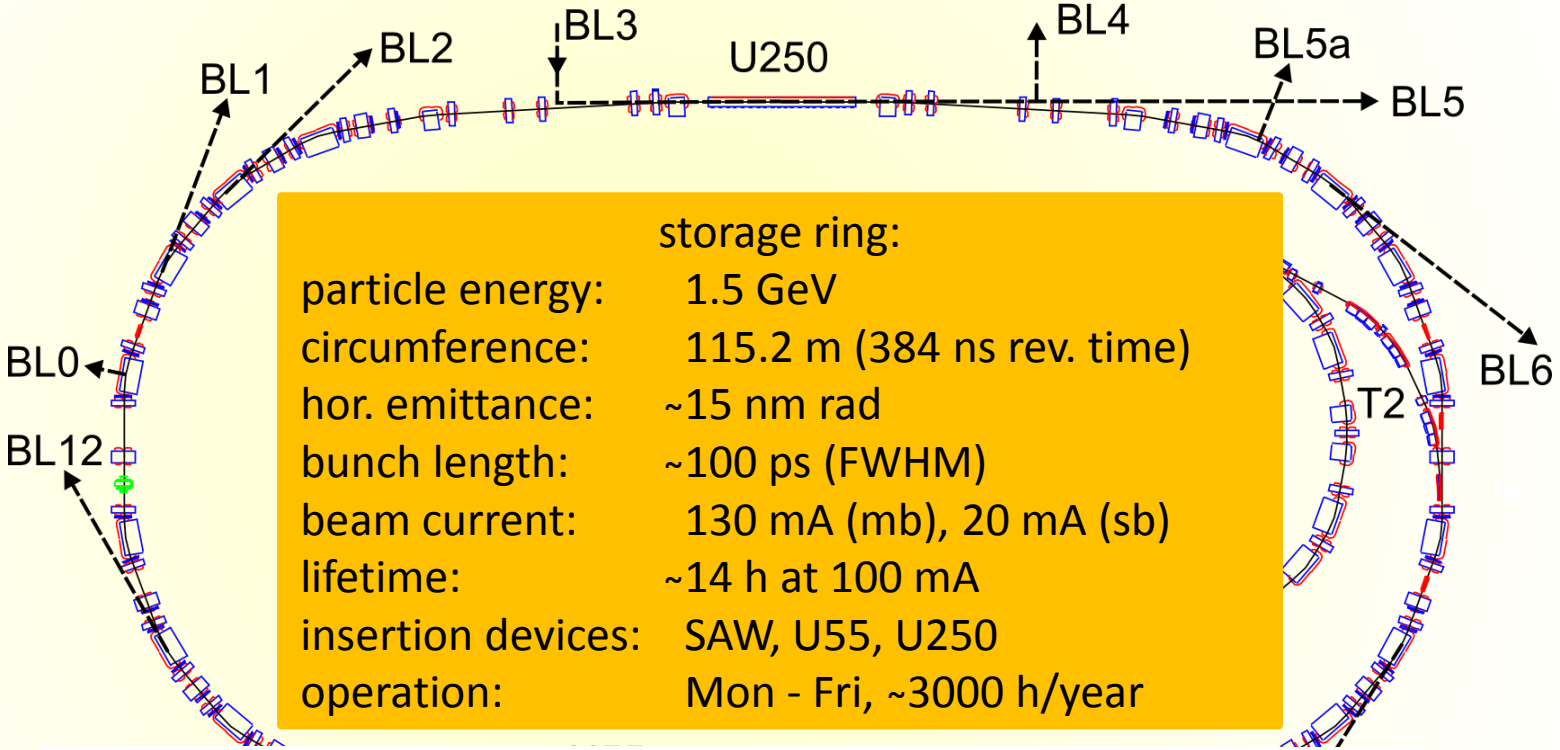
DELTA: overview and status



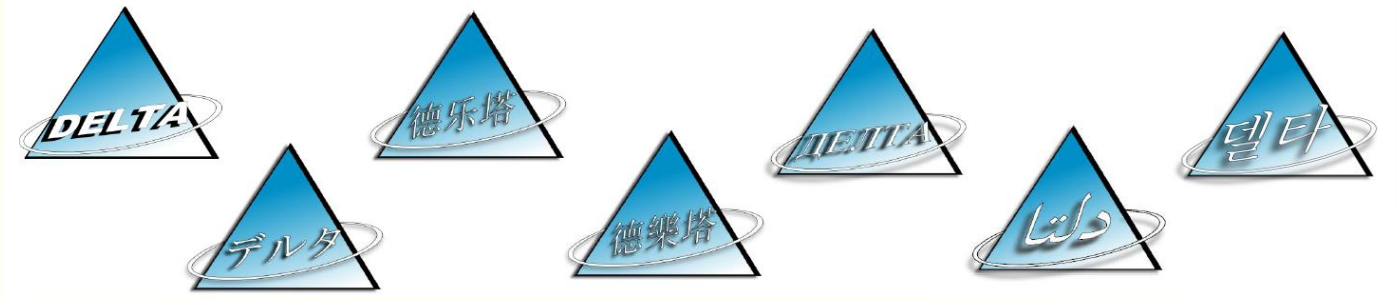
floor plan: D. Schirmer, DELTA Int. Rep. 001-05, University of Dortmund (2009) [modified]

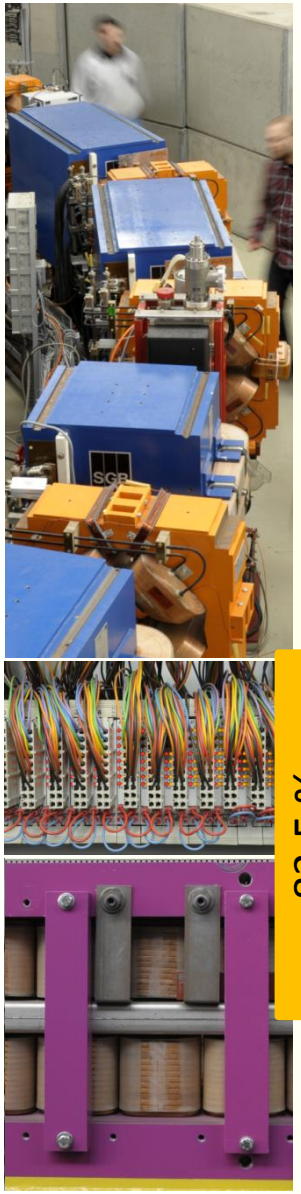


DELTA: overview and status



storage ring:	
particle energy:	1.5 GeV
circumference:	115.2 m (384 ns rev. time)
hor. emittance:	~15 nm rad
bunch length:	~100 ps (FWHM)
beam current:	130 mA (mb), 20 mA (sb)
lifetime:	~14 h at 100 mA
insertion devices:	SAW, U55, U250
operation:	Mon - Fri, ~3000 h/year



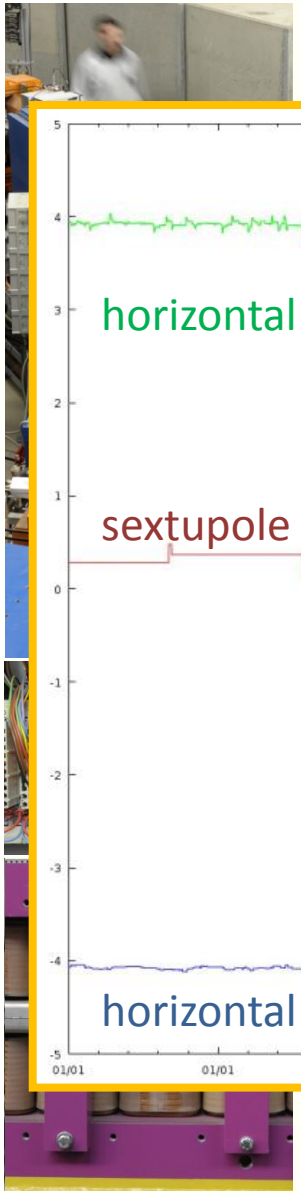


DELTA: overview and status

	availability:	issues:
I/2014	70.2 %	- defective kicker PS - defective booster DACs
II/2014	98.0 %	
III/2014	68.3 %	- large voltage fluctuations (defective "powerformer")
IV/2014	71.2 %	- tests and calibration measurements for new powerformer - short-circuit in main power distribution causing damage
I/2015	84.4 %	- power failure, defective kicker PS, LHe shortage (SAW refill) - work on roof of adj. building, failure of old radiation protection system
II/2015	80.2 %	- failure of new radiation protection system (main PC)
III/2015	98.3 %	
IV/2015	...	- strong orbit fluctuations (shorted sextupole coil)

83.5 %

data and comments: courtesy of J. Friedl



DELTA: overview and status

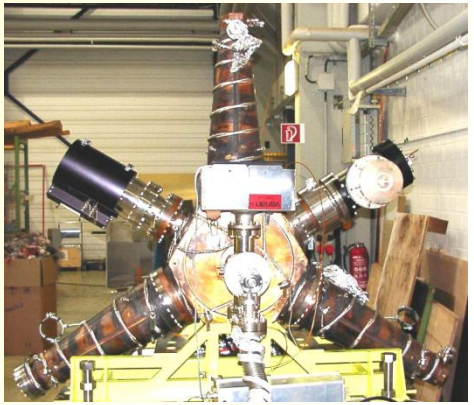
IV/2015	...	- strong orbit fluctuations (shorted sextupole coil)

data and plot: courtesy of P. Hartmann

DELTA: projects and upgrades

- new superconducting 7-T wiggler funded
  - replacement of SAW
  - higher field, more periods
  - closed-cycle cooling
  - next step: call for tenders

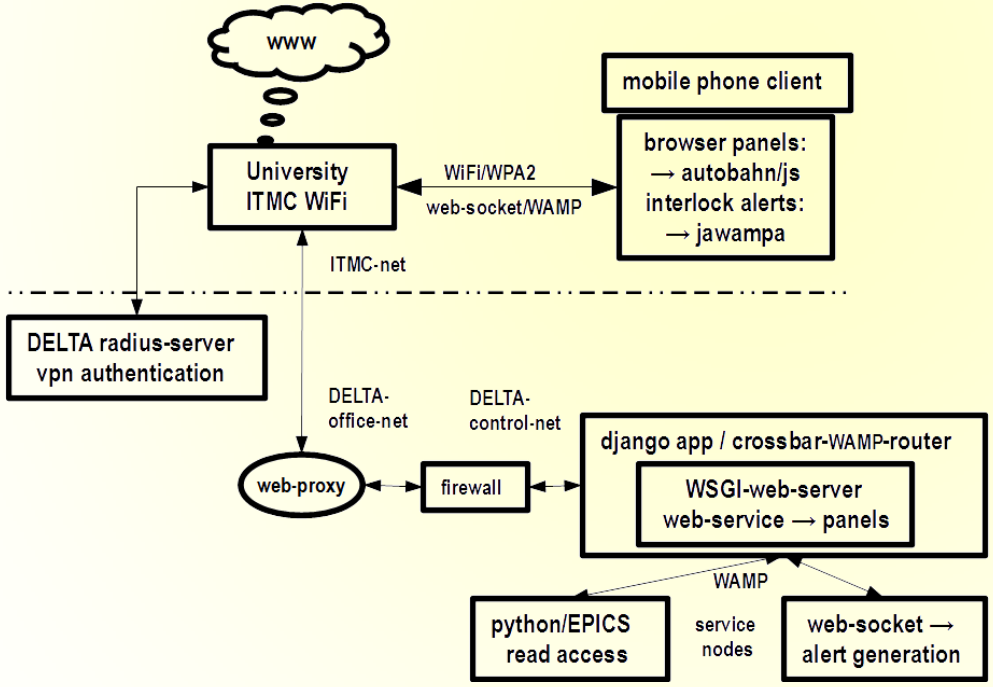
- RF upgrade funded
  - second cavity for storage ring (EU HOM-damped cavity) with solid-state amplifiers (75 kW)
  - solid-state amplifiers for booster (20 kW)
  - status: call for tenders completed (amplifiers)
  - next steps: placement of order (amplifiers), call for tenders (cavity)



involved: W. Brembt, P. Hartmann, B. Hippert, S. Khan, V. Kniss, P. Kortmann, M. Paulus, D. Schirmer, G. Schmidt, C. Sternemann, M. Tolan, T. Weis

DELTA: projects and upgrades

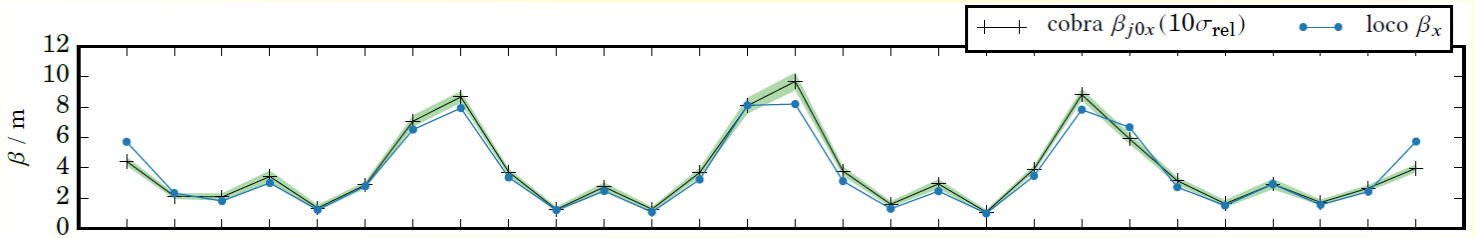
- control system consolidation and upgrades
  - replacement of I/O units based on CAN, GPIB, and RS-232/485 by TCP/IP-controlled devices
  - development of web applications and Android-based mobile devices for a staff-free control room



involved: D. Schirmer, A. Althaus, F. Bahnsen; see D. Schirmer et al., Proc. of ICALEPCS2015, MOPGF036

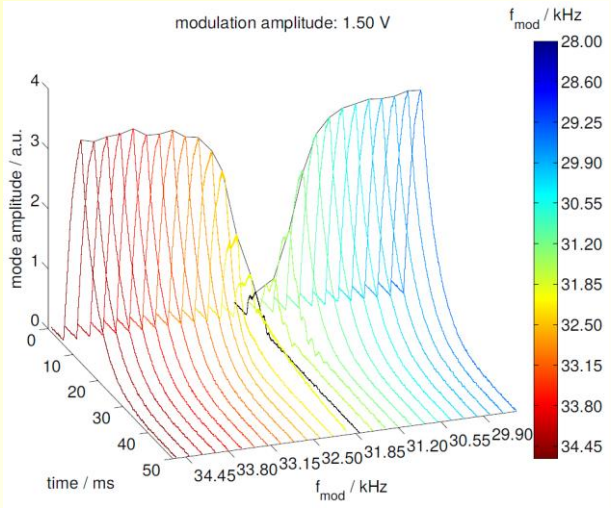
DELTA: projects and upgrades

- new method for measuring the optical functions[1]
  - "Closed-Orbit Bilinear-Exponential Regression Analysis" (COBRA)
  - "Occam's razor" applied to LOCO – no numerical tracking, no magnet information, no absolute positions of monitors and correctors required



MLS data, courtesy of D. Engel and A. Jankowiak

- investigation of coupled-bunch instabilities[2]
  - measurement of damping times of coupled-bunch modes via digital bunch-by-bunch feedback systems
  - studies of RF phase modulation and its damping effects



[1] B. Riemann, Ph.D. thesis, in preparation (Jan 2016), TU Dortmund University

[2] M. Sommer, M. Höner, B. Isbarn, S. Khan, B. Riemann, C. Waldera, T. Weis; see M. Sommer et al., Proc. of IPAC2015, p. 179

DELTA: participations and collaborations

- HZB (Berlin):
  RF for BERLinPro and BESSY VSR

- DESY (Hamburg):
  FEL seeding at FLASH (HGHG, EEHG)

- KIT (Karlsruhe):
  generation and detection of THz radiation,
  analysis of coupled-bunch instabilities

DELTA: education

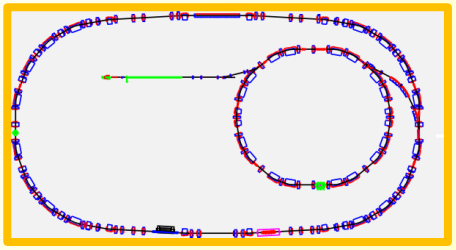
- opportunities for participation in accelerator operation and research
  - undergraduate assistants
  - bachelor students
  - master students (currently 12)
  - Ph.D. students (currently 7)

- two-semester course in accelerator physics
  - lecture, exercises, seminar
  - field trips
  - currently > 40 students

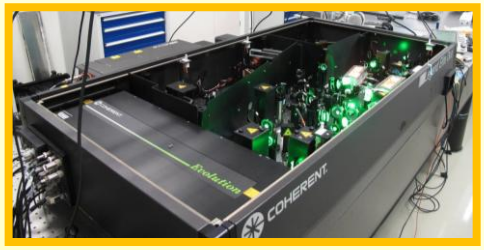
images: Wikimedia Commons/U.S. Marine Corps (top), S. Khan (center, bottom)

Short pulse facility: motivation

- goal: **short wavelengths & ultrashort pulses**



+



- additional benefit: **ultrashort and coherent THz pulses**

- "coherent harmonic generation" (CHG) principle
- idea[1] and proof of principle[2] in the 1980s
- CHG at ELETTRA in Triest, Italy[3] (only at reduced energy)
- CHG at UVSOR II in Okasaki, Japan[4] (only at reduced energy)

- CHG at DELTA[5]: compatible with standard user operation mode, dedicated CHG/THz shifts on approx. 50 days per year

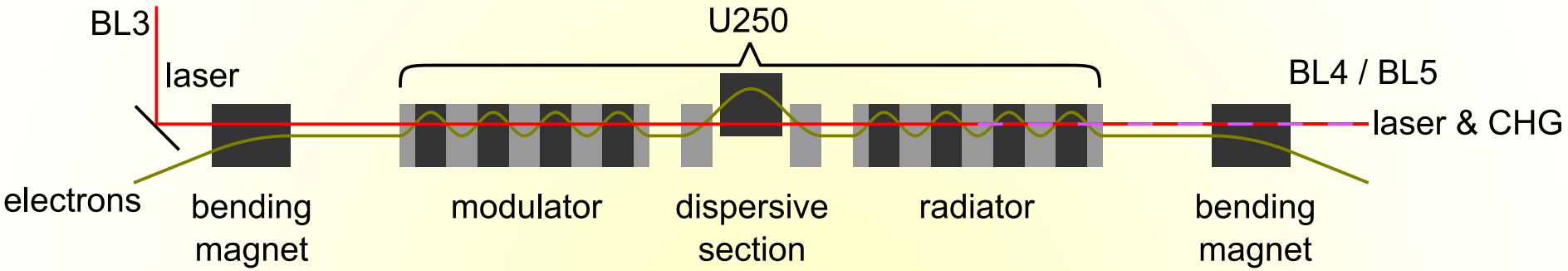
involved:

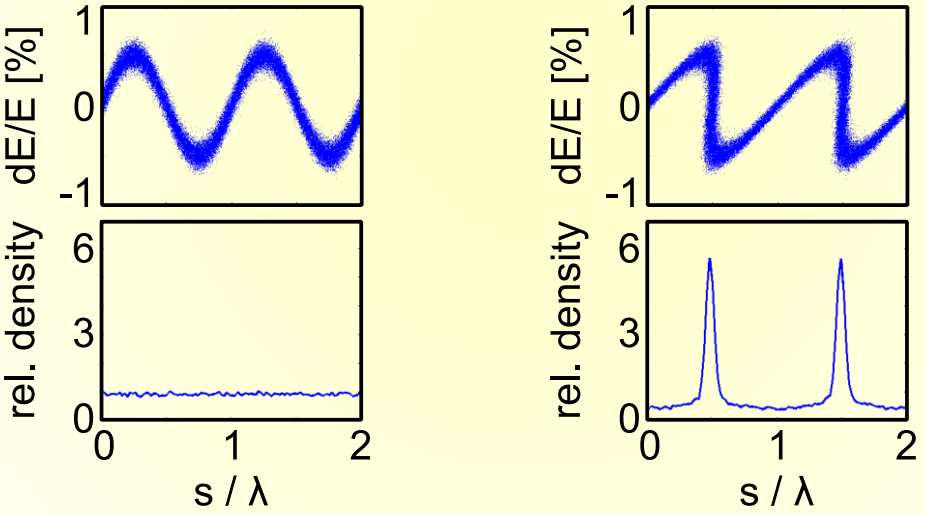
F. Bahnsen, M. Bolsinger, F. Götz, S. Hilbrich, M. Höner, H. Huck, M. Huck, M. Jebramcik, S. Khan, N. Lockmann, C. Mai, A. Meyer auf der Heide, R. Molo, R. Niemczyk, H. Rast, A. Schick, G. Shayeganrad, P. Ungelenk, D. Zimmermann (TU Dortmund)

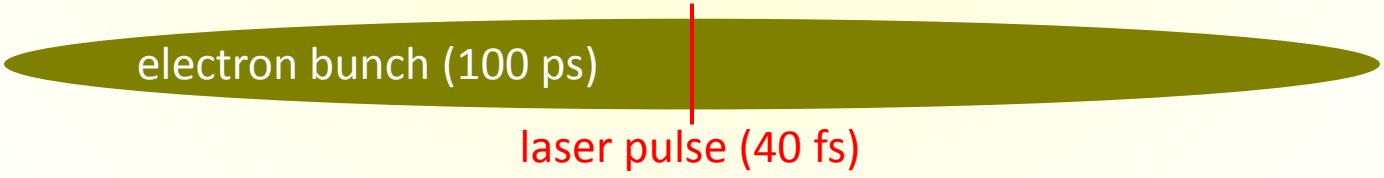
U. Bovensiepen, S. Cramm, S. Döring, A. Eschenlohr, M. Gehlmann, M. Ligges, L. Plucinski, C. Schneider, S. Xiao (FZ Jülich and U Duisburg-Essen)

[1] R. Coisson and F. D. Martini, Phys. Quant. Electron. 9, 939 (1982); [2] R. Prazeres et al., Nucl. Instr. and Meth. A 272, 68 (1988); [3] G. De Ninno et al., Phys. Rev. Lett. 101, 053902 (2008); [4] M. Labat et al., Nucl. Instr. and Meth. A 593, 1 (2008); [5] S. Khan et al., Synchrotron Radiation News 26, Issue 3, p. 25 (2013)

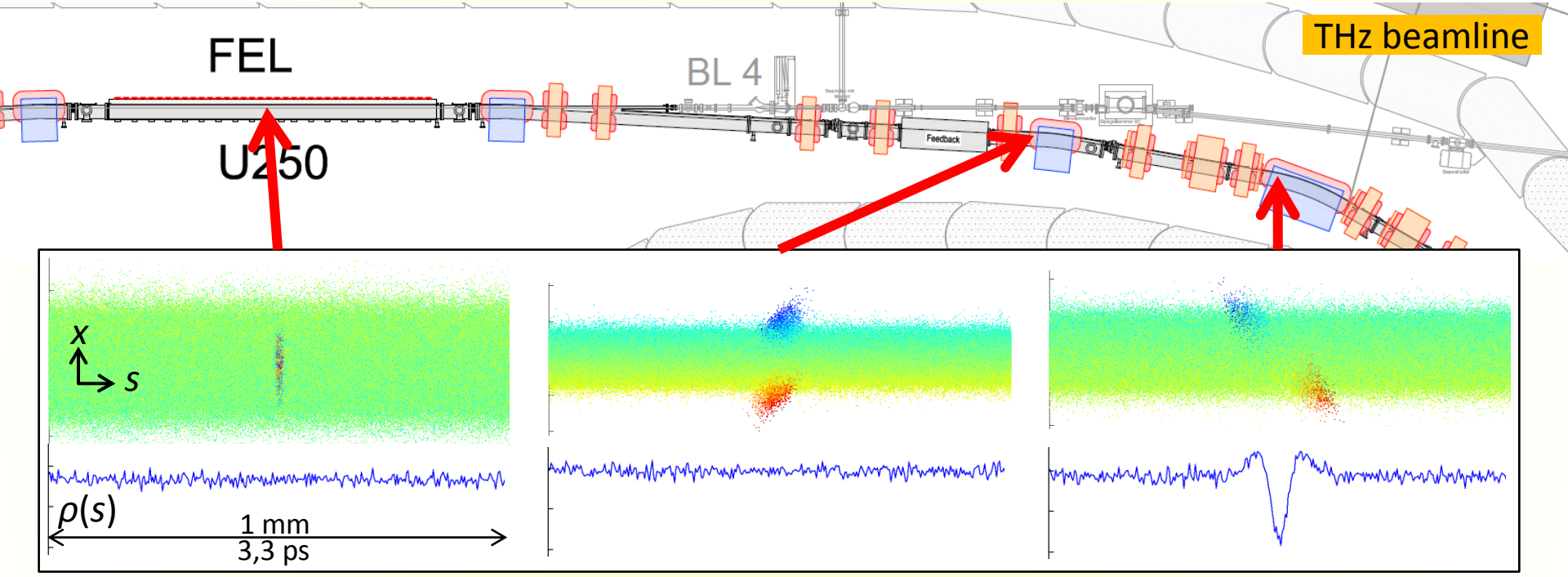
Short pulse facility: CHG principle

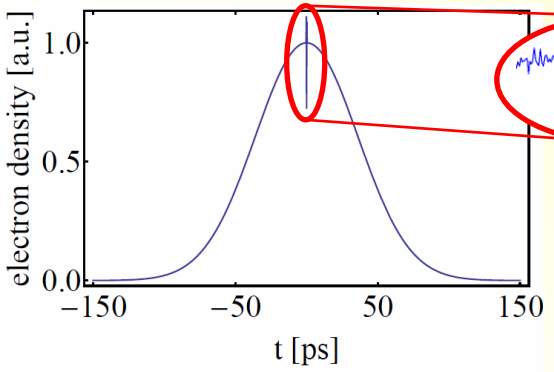




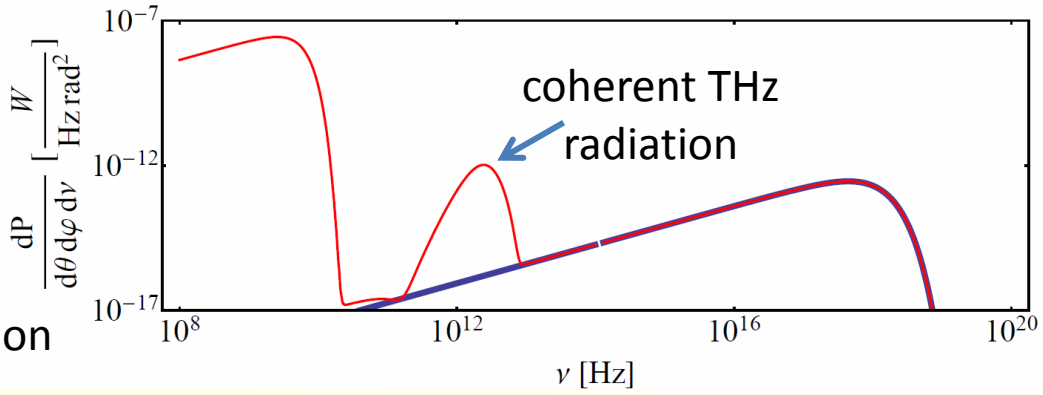


Short pulse facility: coherent THz pulses



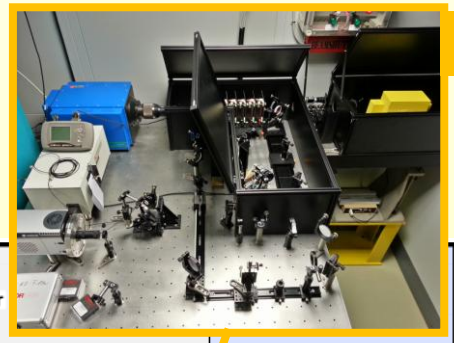


Fourier transformation

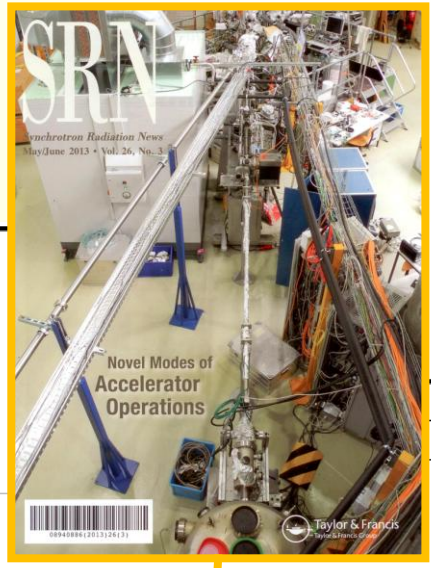


Short-pulse facility: setup

laser



diagnostics



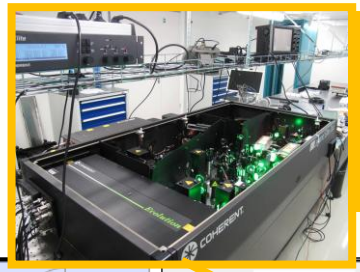
pump-pulse beamline

U250

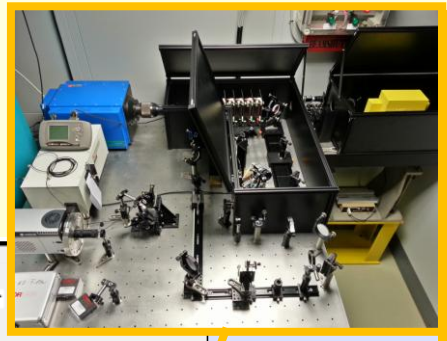
THz beamline

VUV beamline
(FZ Jülich)

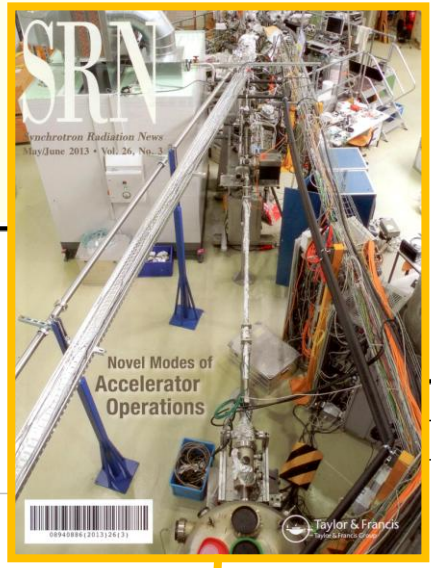
Short-pulse facility: setup

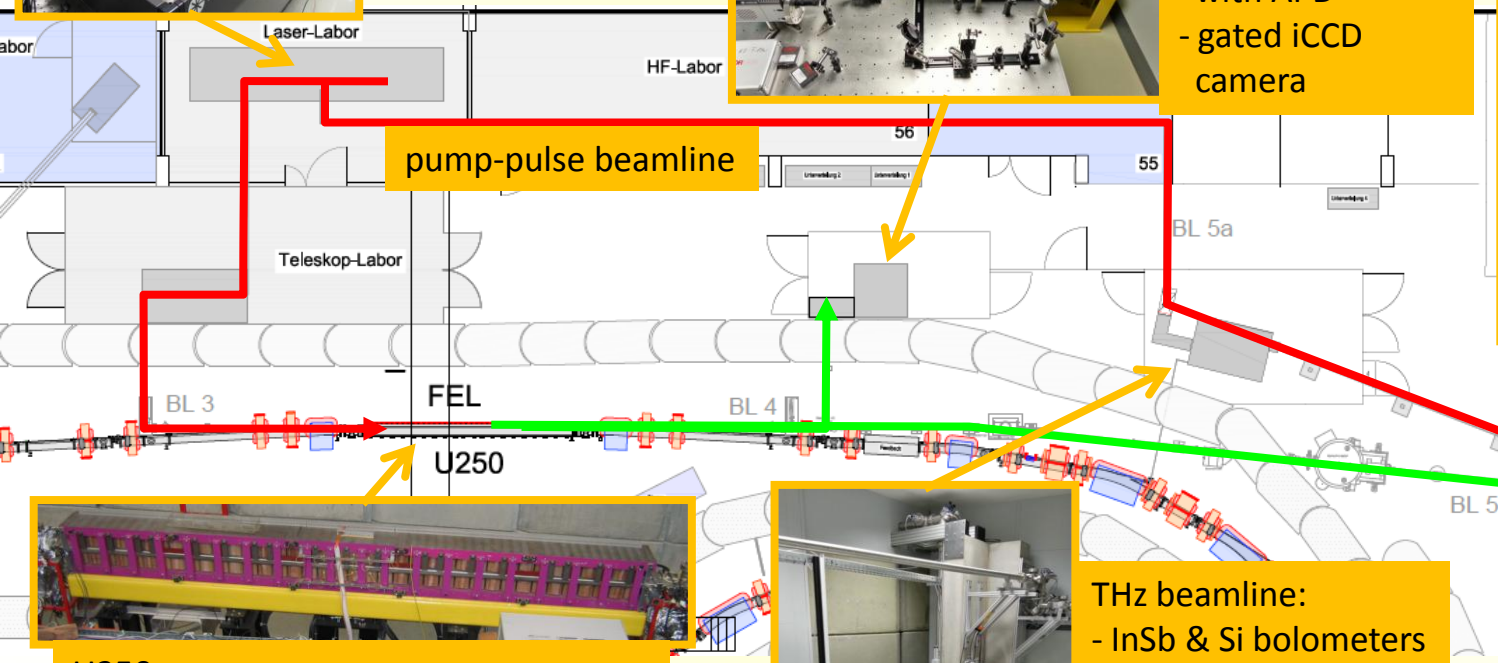


laser:
- 800 nm, 40 fs, 8 mJ
- 400/266 nm via SHG/THG



diagnostics:
- streak camera
- Czerny-Turner monochromator with APD
- gated iCCD camera





pump-pulse beamline

U250:
- modulator (7 periods, up to 800 nm)
- chicane (3 periods, r_{56} up to 130 µm)
- radiator (7 periods, up to 800 nm)

THz beamline:
- InSb & Si bolometers
- YBCO detector
- Schottky diode
- FTIR & MPI spectrometer

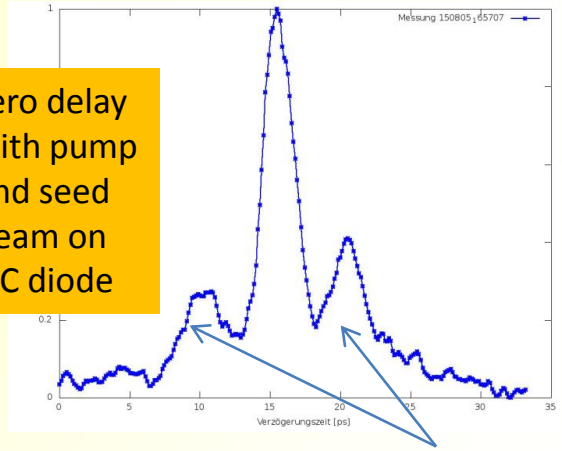
VUV beamline:
(FZ Jülich)
- plane-grating monochromator
- angle-resolving photoemission spectrometer

Short-pulse facility: history and goals

- 2010/2011: procurement & construction
- June 2011: first laser-induced CHG & THz signals

- seeding with 800 nm:
  - CHG up to 4th harmonic (200 nm) detected
  - characterization studies, THz studies (next slides)

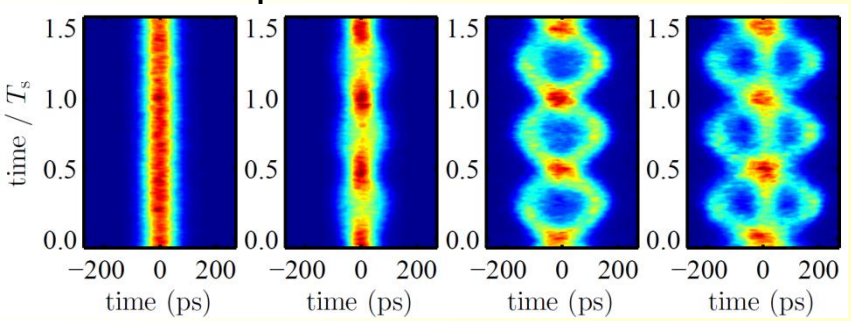
- seeding with 400 nm (via SHG):
  - CHG up to 5th harmonic (80 nm) detected (in VUV BL)
  - characterization studies (next slides), preparations for pump-probe experiments

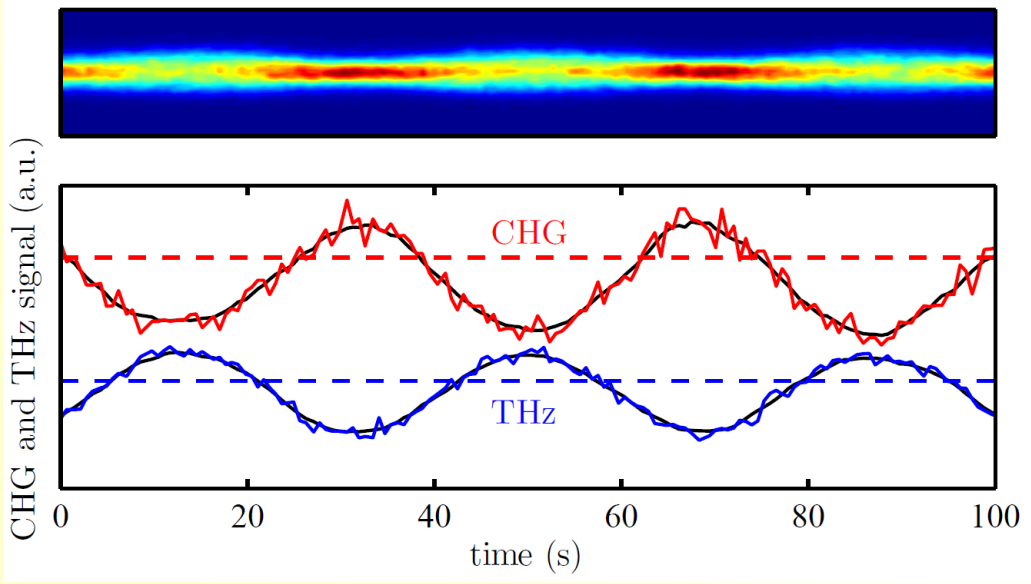


- goal:
  - first pump-probe experiment at 133 nm (3rd harmonic of 400 nm)
  - later: pump-probe experiments at 53 nm (5th harmonic of 266 nm)

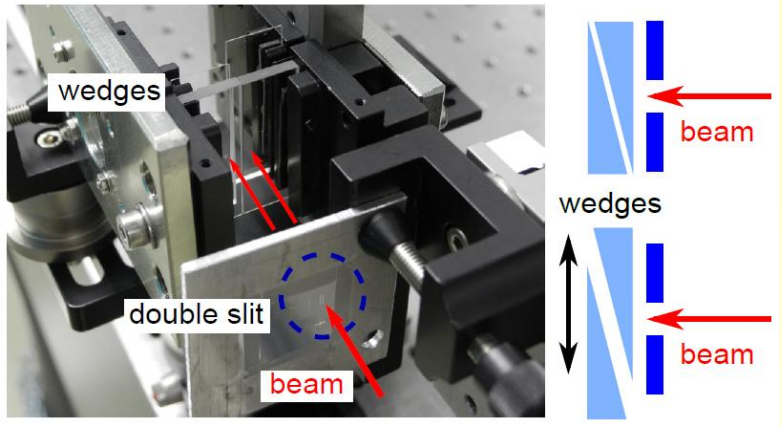
Short-pulse facility: CHG studies

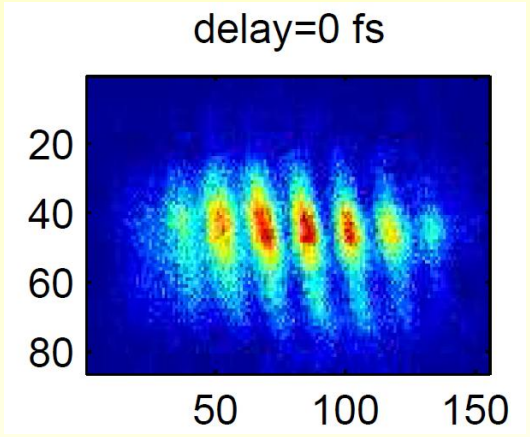
- CHG (and THz) during application of an RF phase modulation[1]

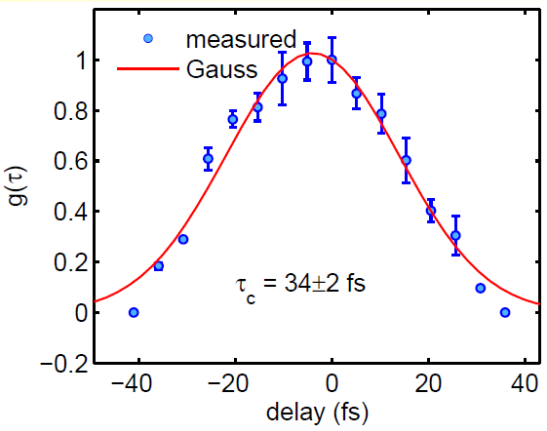




- coherence studies[2]



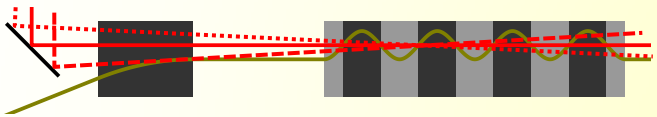


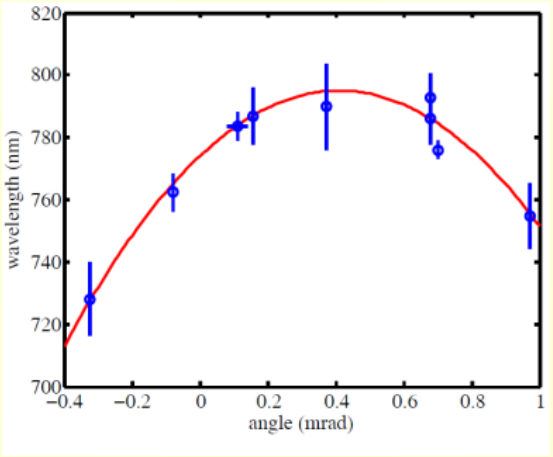


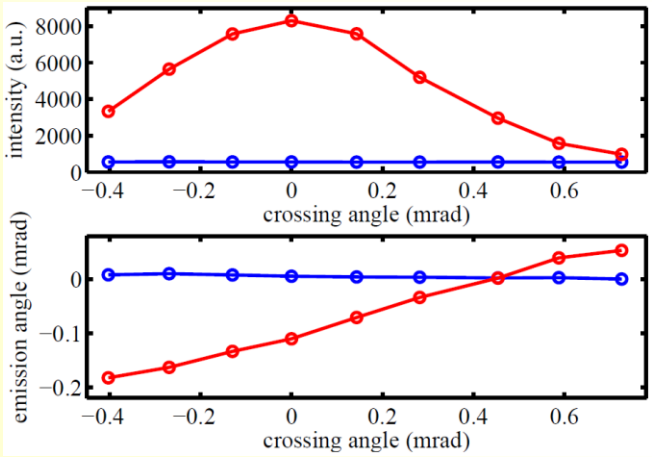
[1] M. Huck et al., Proc. of IPAC2014, p. 1848; [2] S. Khan et al., Proc. of IBIC2014, p. 202

Short-pulse facility: CHG studies

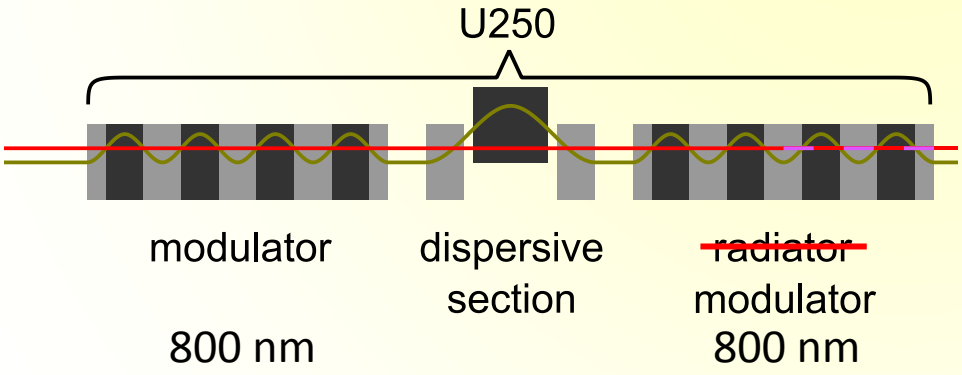
- variation of the laser-electron crossing angle[1]

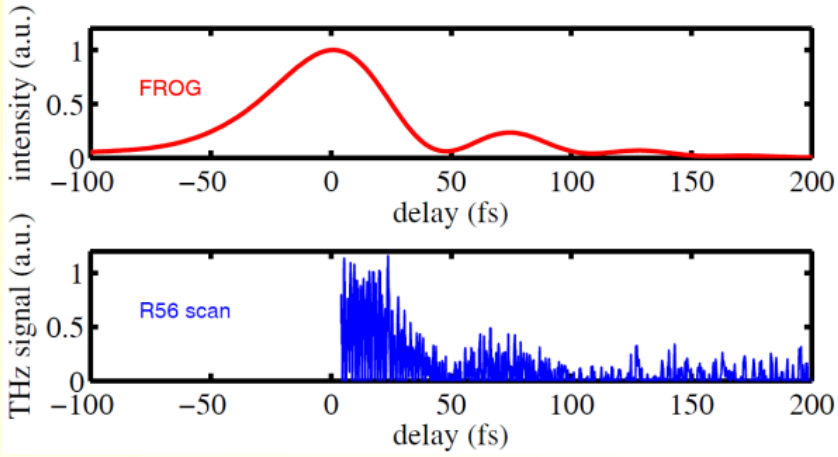






- high-cost low-resolution autocorrelator[2]



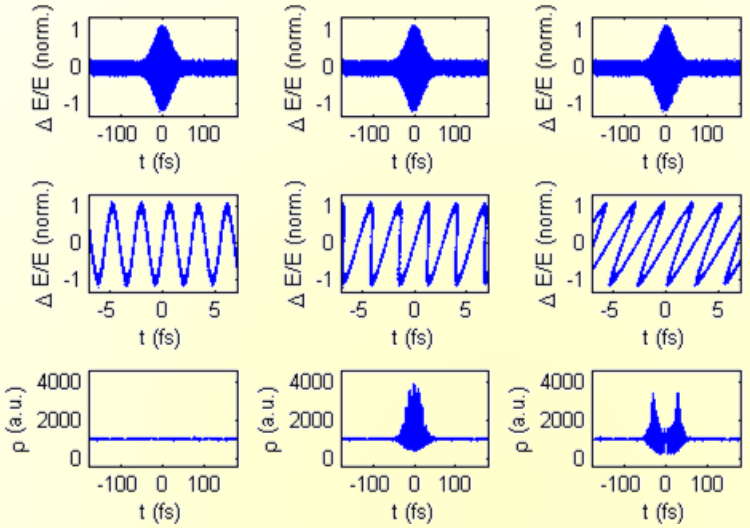


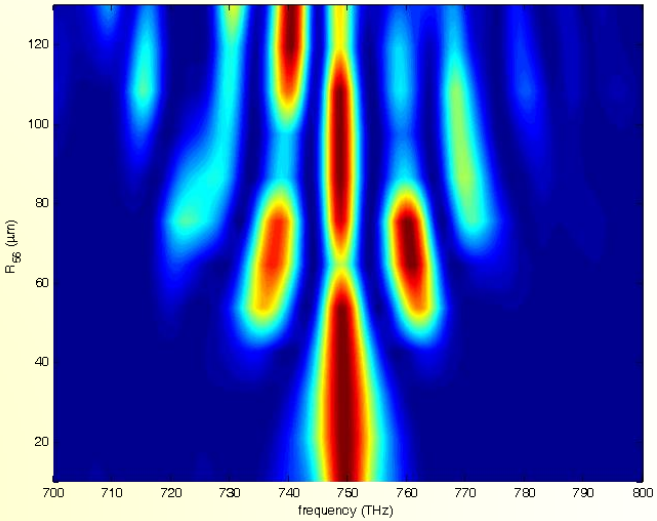
[1] S. Khan et al., Proc. of IPAC2015, p. 1452; [2] S. Khan et al., to be published

Short-pulse facility: CHG studies

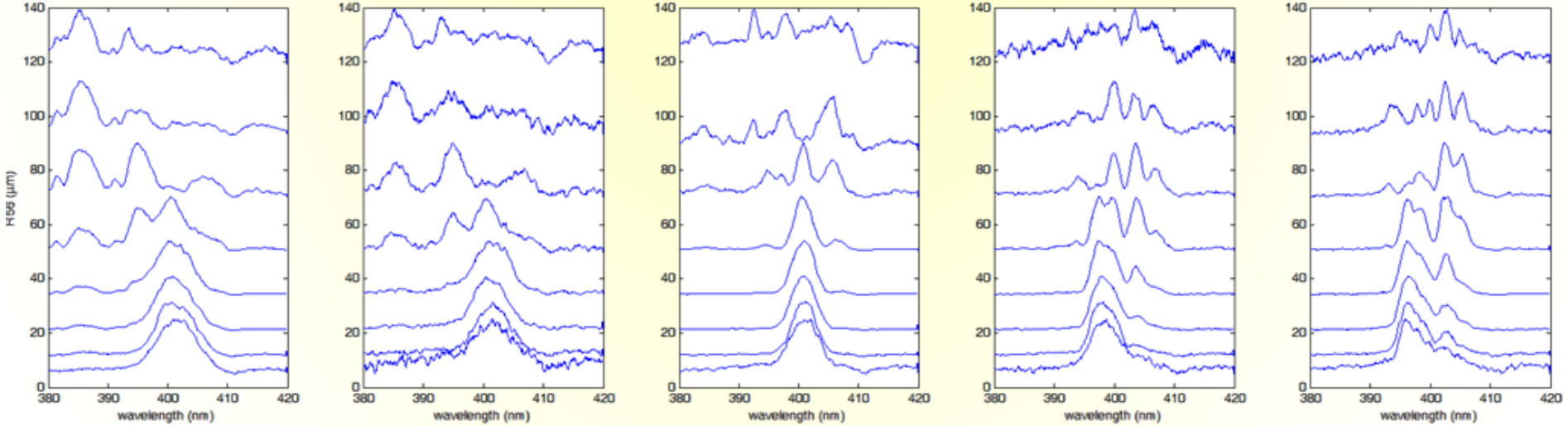
- spectral studies

$$\Delta z = r_{56}\frac{\Delta E}{E}$$





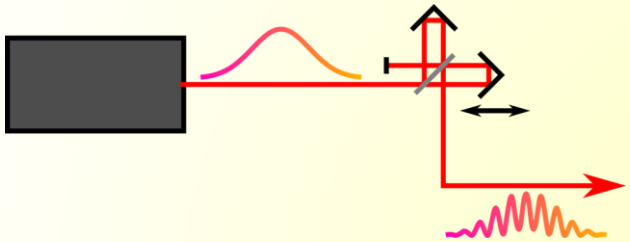
negative chirp | no chirp | positive chirp

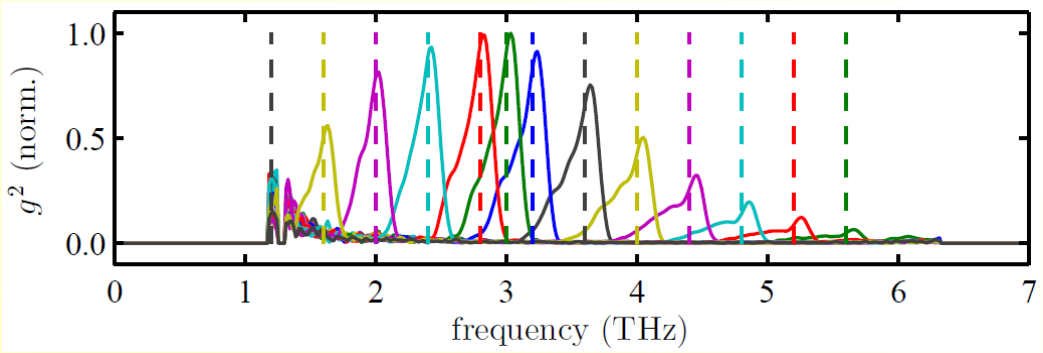


S. Khan et al., to be published

Short-pulse facility: THz studies

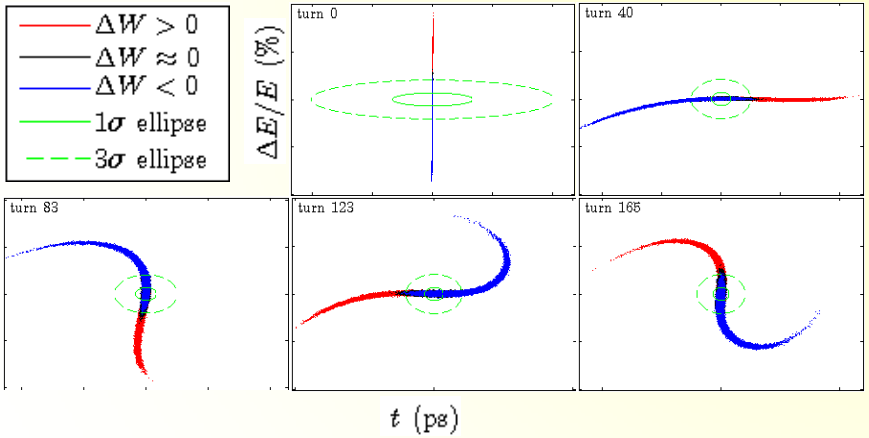
- narrow-band THz pulses via CPB

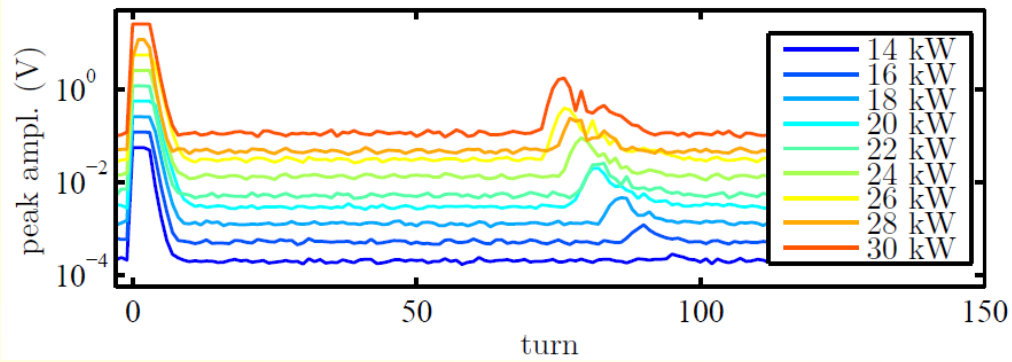




in cooperation with S. Bielawski, C. Evain, M. Le Parquier, E. Roussel, C. Szwaj (U Lille 1/PhLAM);
see P. Ungelenk, Ph.D. thesis, to be published, TU Dortmund University (2015)

- THz pulses after one half synchrotron oscillation period

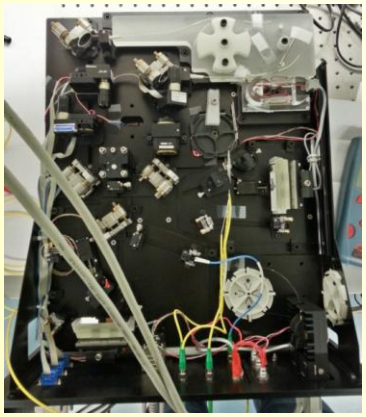


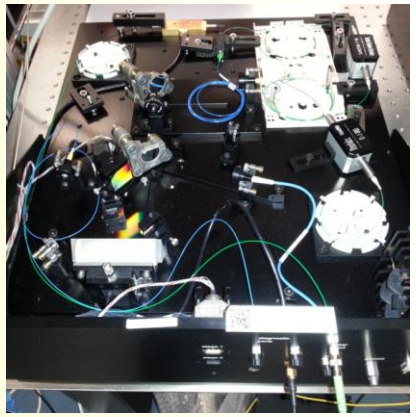


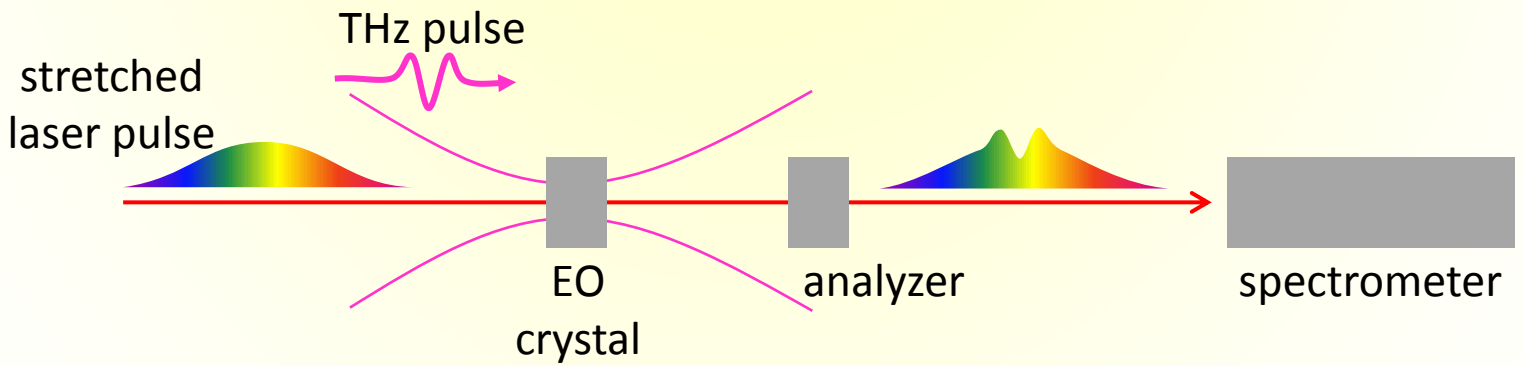
in cooperation with M. Brosi, B. Kehrer, A.-S. Müller, M.J. Nasse, P. Schönfeldt, P. Schütze, S. Walther (KIT/ANKA);
see P. Ungelenk, Ph.D. thesis, to be published, TU Dortmund University (2015)

Short-pulse facility: THz studies

- electro-optical setup under construction
  - Yb fiber laser system from PSI delivered
  - gated line camera for single-shot EOSD ordered
  - commissioning & far-field setup as part of a master's thesis
  - long-term goal: near-field setup

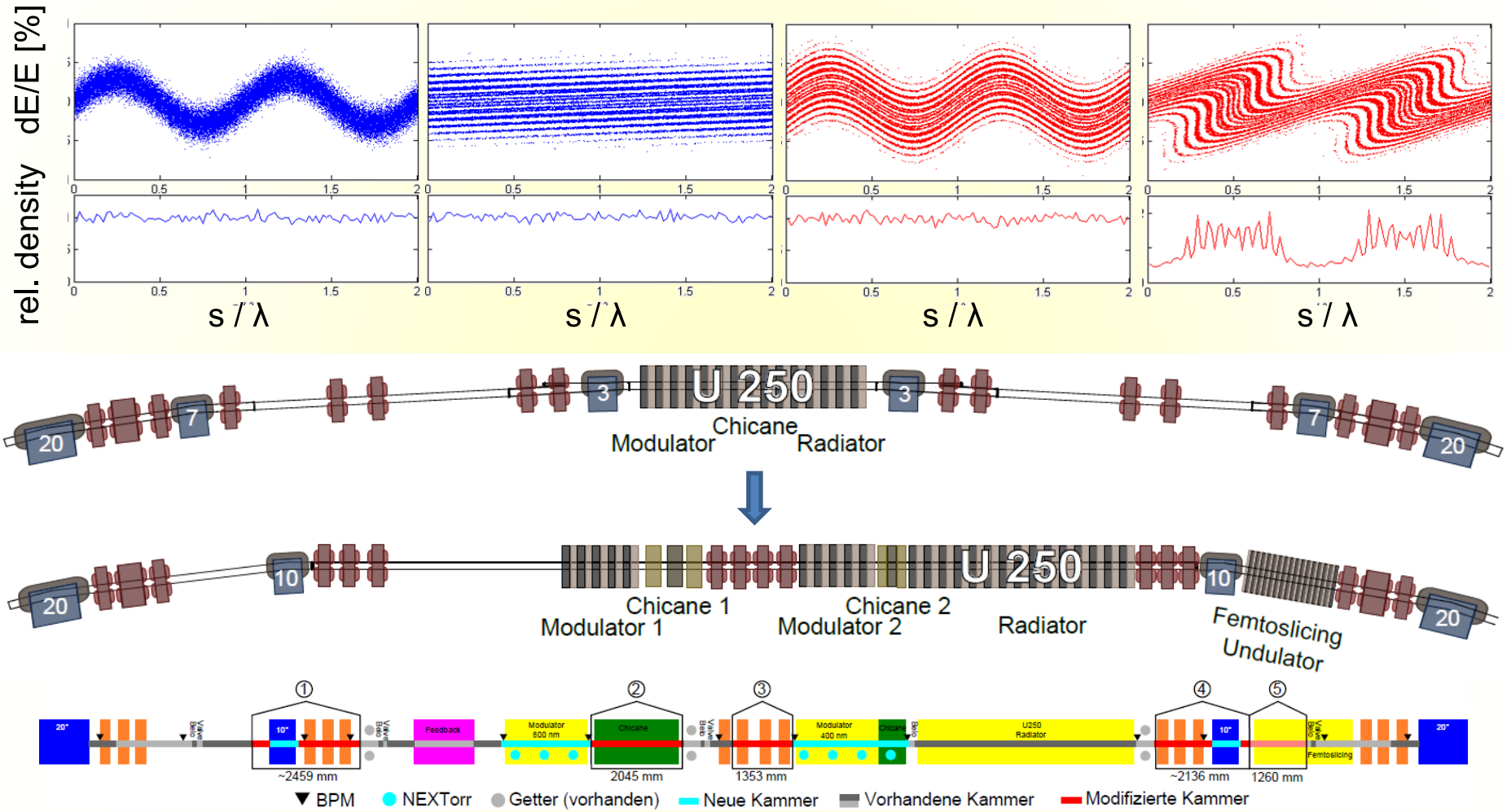






in cooperation with V. Schlott et al. (PSI) and P. Peier (DESY)

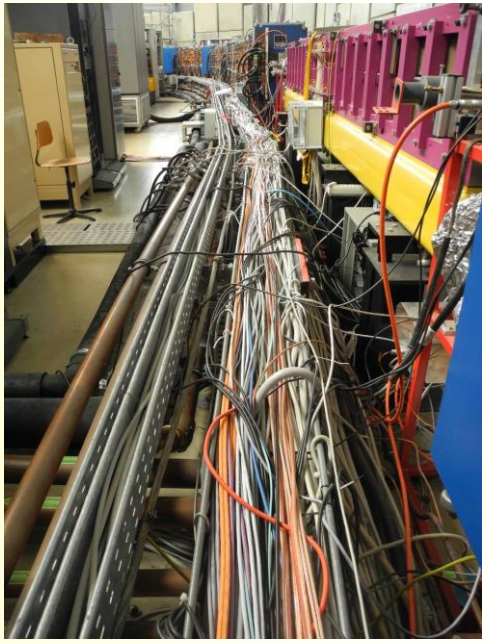
Short-pulse facility: EEHG[1] upgrade

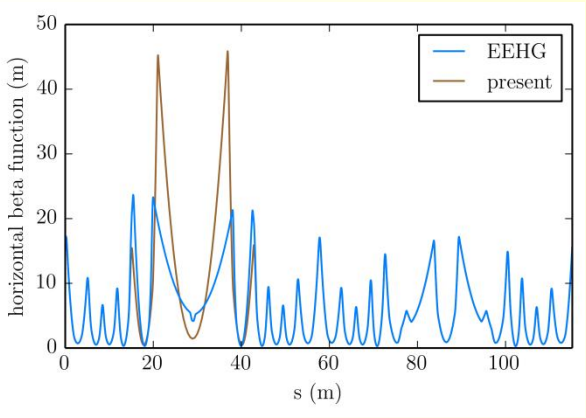


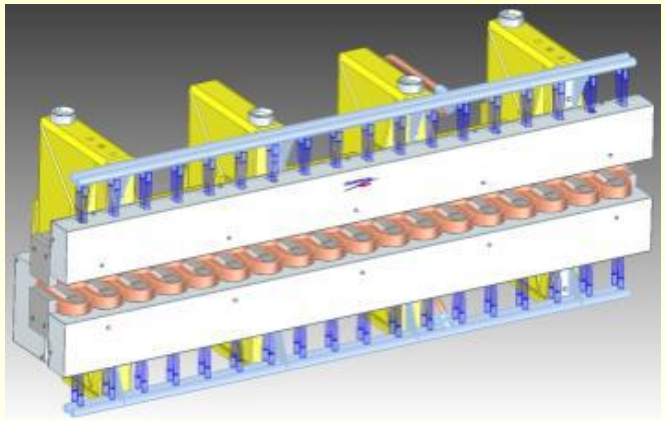
[1] D. Xiang and G. Stupakov, Phys. Rev. ST Accel. Beams 12, 030702 (2009);
image courtesy of R. Molo and F. H. Bahnsen, to be published

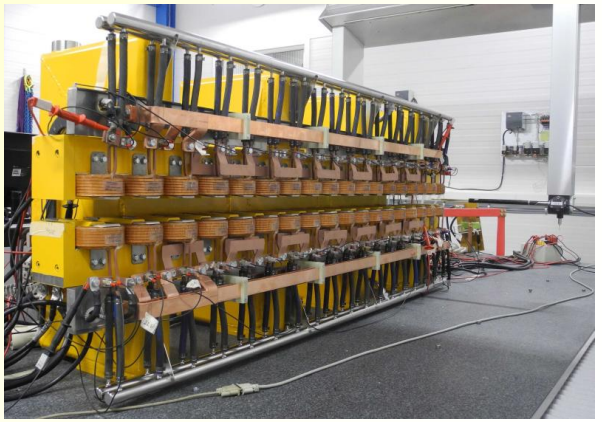
Short-pulse facility: EEHG upgrade

- modified optics found[1], no changes outside new straight section
- dipole and quadrupole magnets can be re-used
- new modulators and PSs delivered, girders designed
- design of chicanes, magnet girders, and vacuum chambers in progress
- modification of existing infrastructure (cabling, water pipes) started, design of new infrastructure in progress
- design of new laser beamlines in progress









[1] S. Hilbrich, Master's thesis, TU Dortmund University (2015)

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