CHG at the DELTA storage ring

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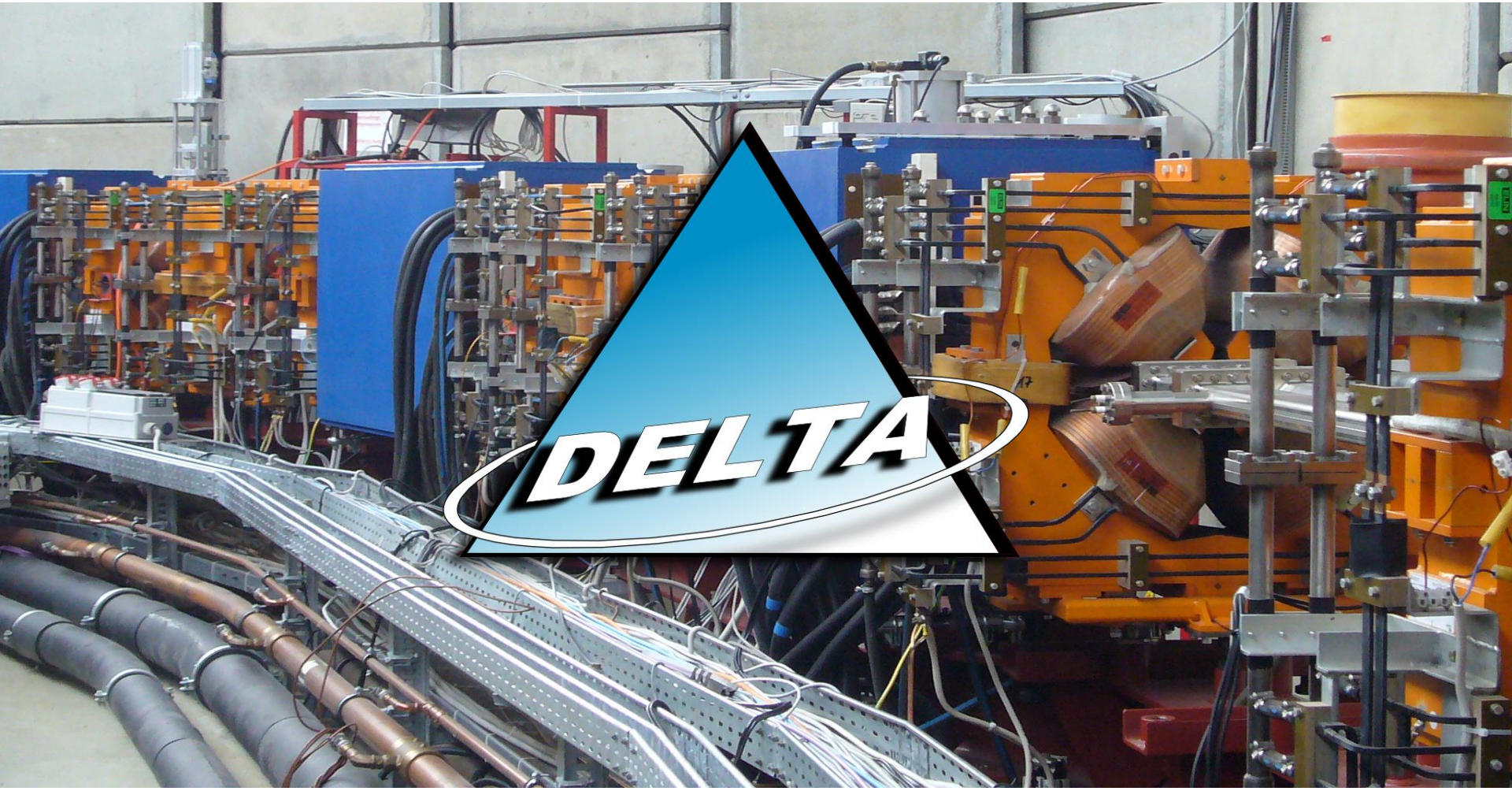

FEL2011, Shanghai

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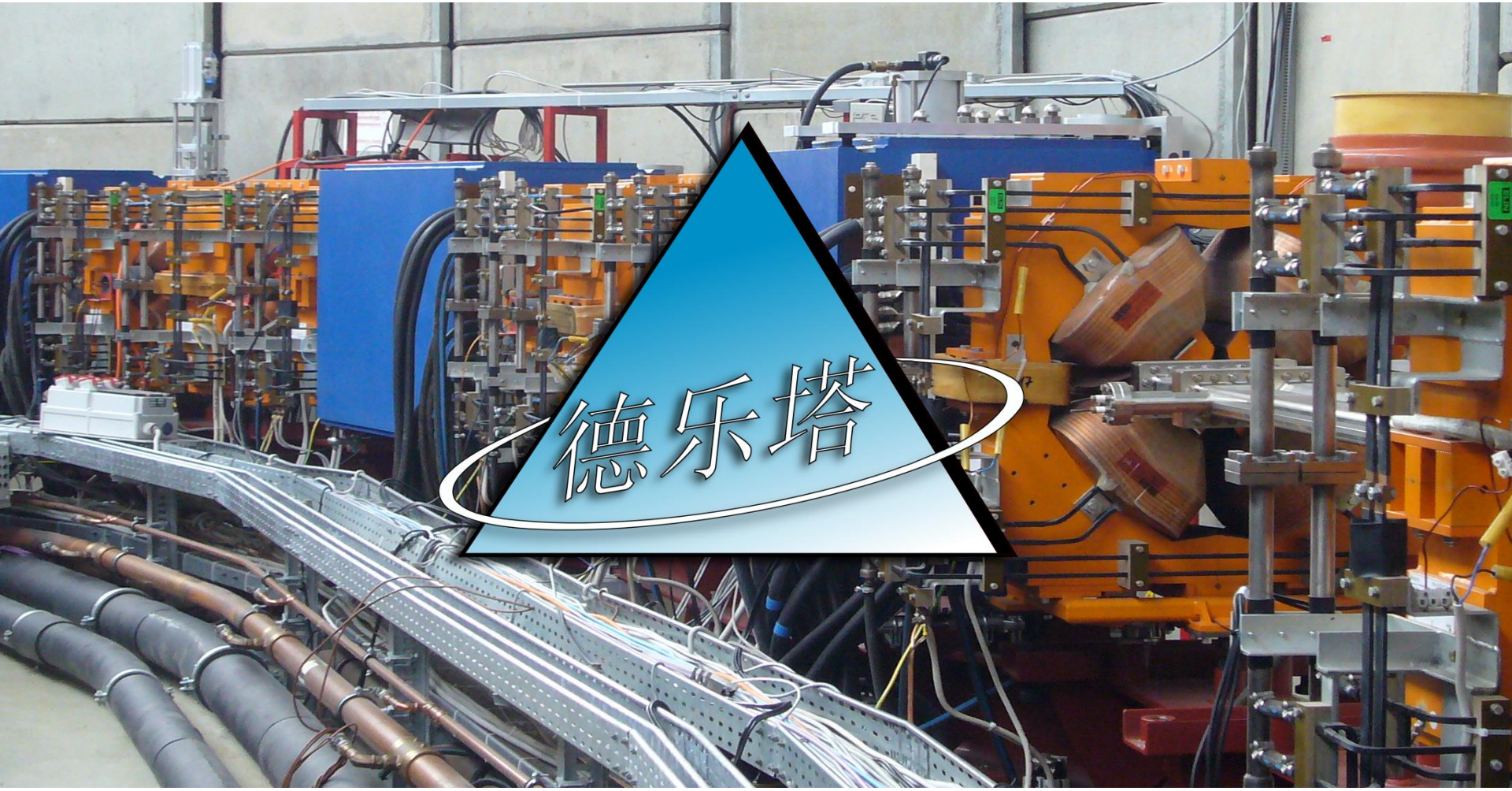
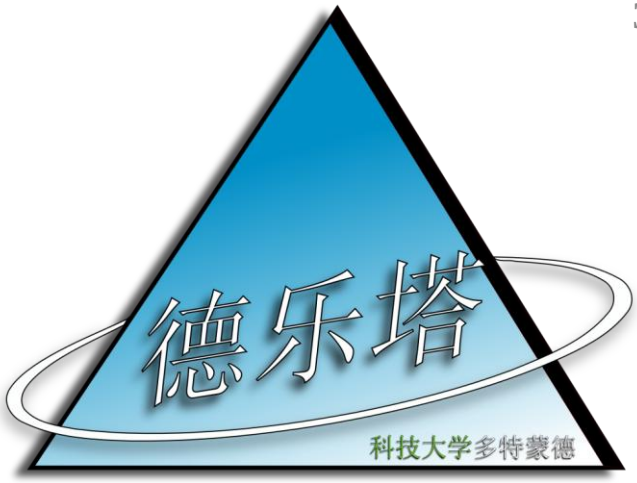


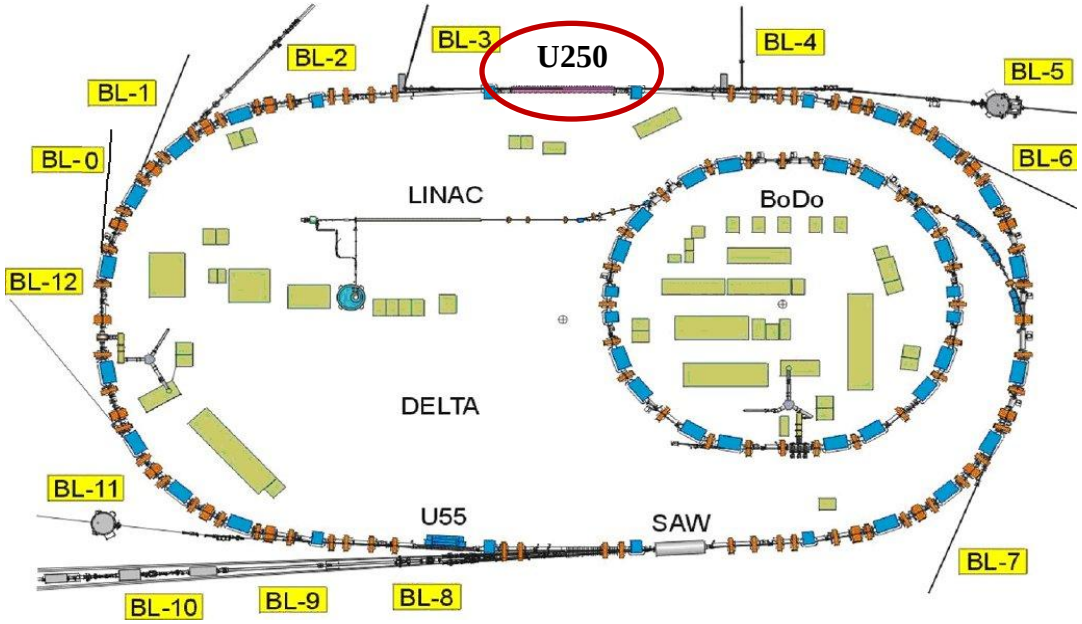
FEL2011, Shanghai

- Construction of a CHG + THz source
- Commissioning
- Improvements
- Outlook



Dortmund Electron Accelerator:

a synchrotron light source operated by the TU Dortmund University, Germany

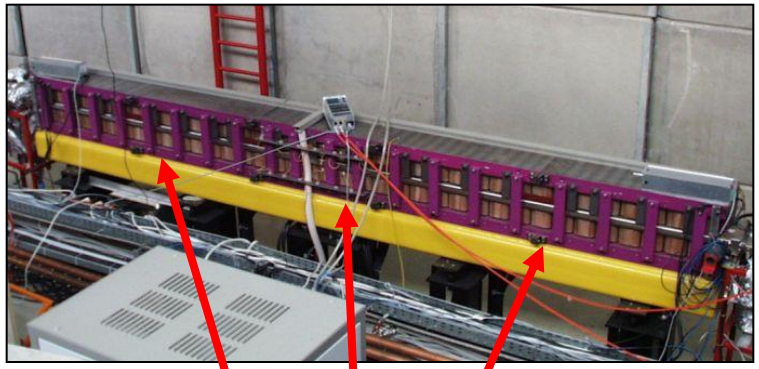


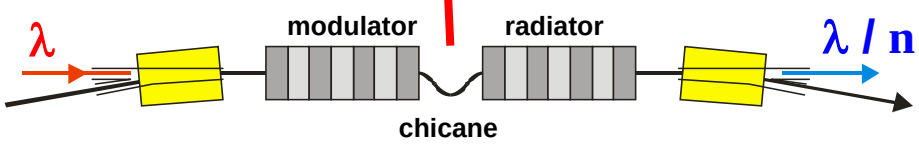
circumference	115.2 m
energy	1.5 GeV
beam current	130 mA
lifetime	8-11 h
hor. emittance	15 nm rad
energy spread	0.1%
bunch length	36 ps

Coherent Harmonic Generation

„light source for ultrashort VUV- and THz-pulses…

…in standard user operation“





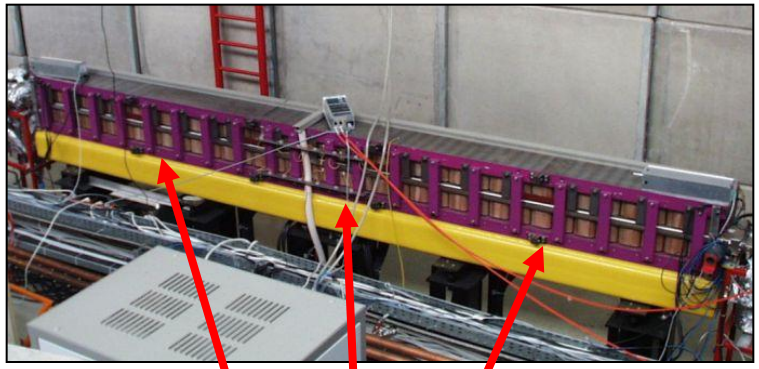
U250 FEL undulator
“optical klystron"

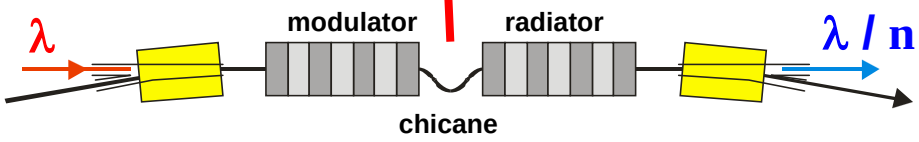
see also:

ACO:	**B. Girard et al., PRL 53 (1984), 2405**
ELETTRA:	**E. Allaria et al., PRL 100 (2008), 174801**
UVSOR II:	**M. Labat et al., PRL 101 (2008), 164803**

Coherent Harmonic Generation

✓ first CHG and THz pulses seen
✓ …in standard user operation





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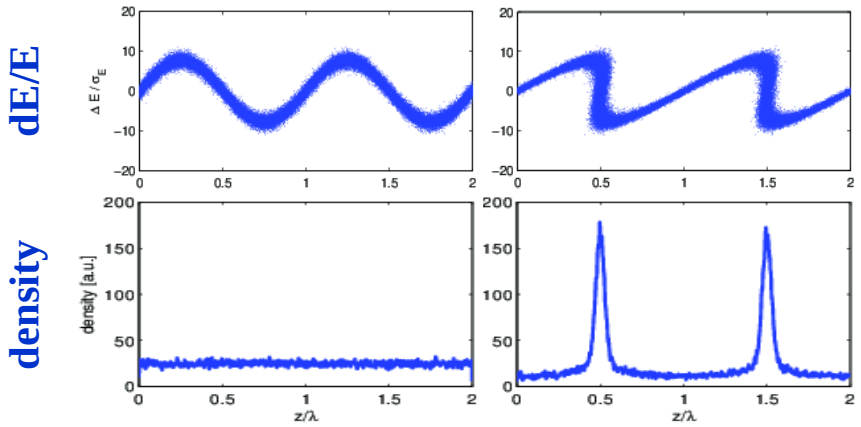
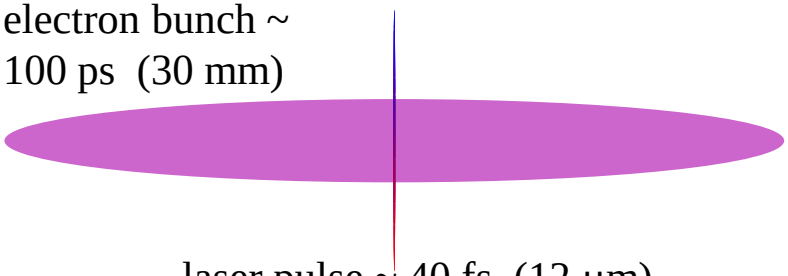
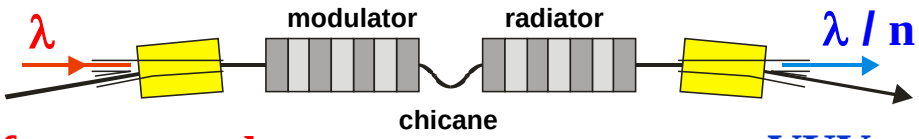
Coherent Harmonic Generation

generating ultrashort VUV pulses







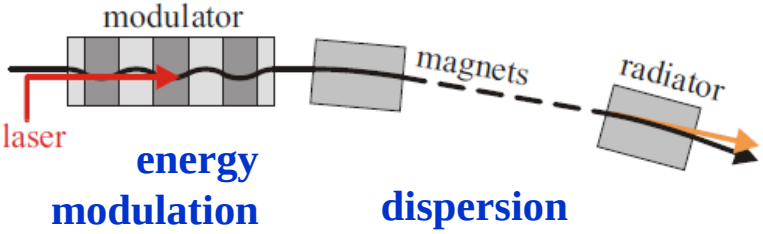
femtosecond laser pulses

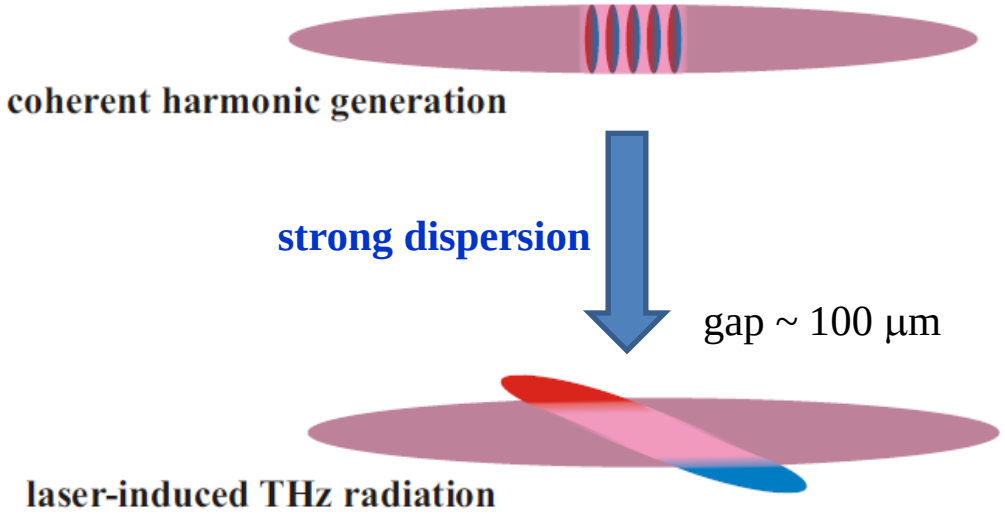
VUV-pulses: coherent => intense
short wave (λ / n)
ultrashort (50 fs)
synchronous to laser

Coherent THz Pulses

several meters downstream from modulator, off-energy electrons leave gap in bunch

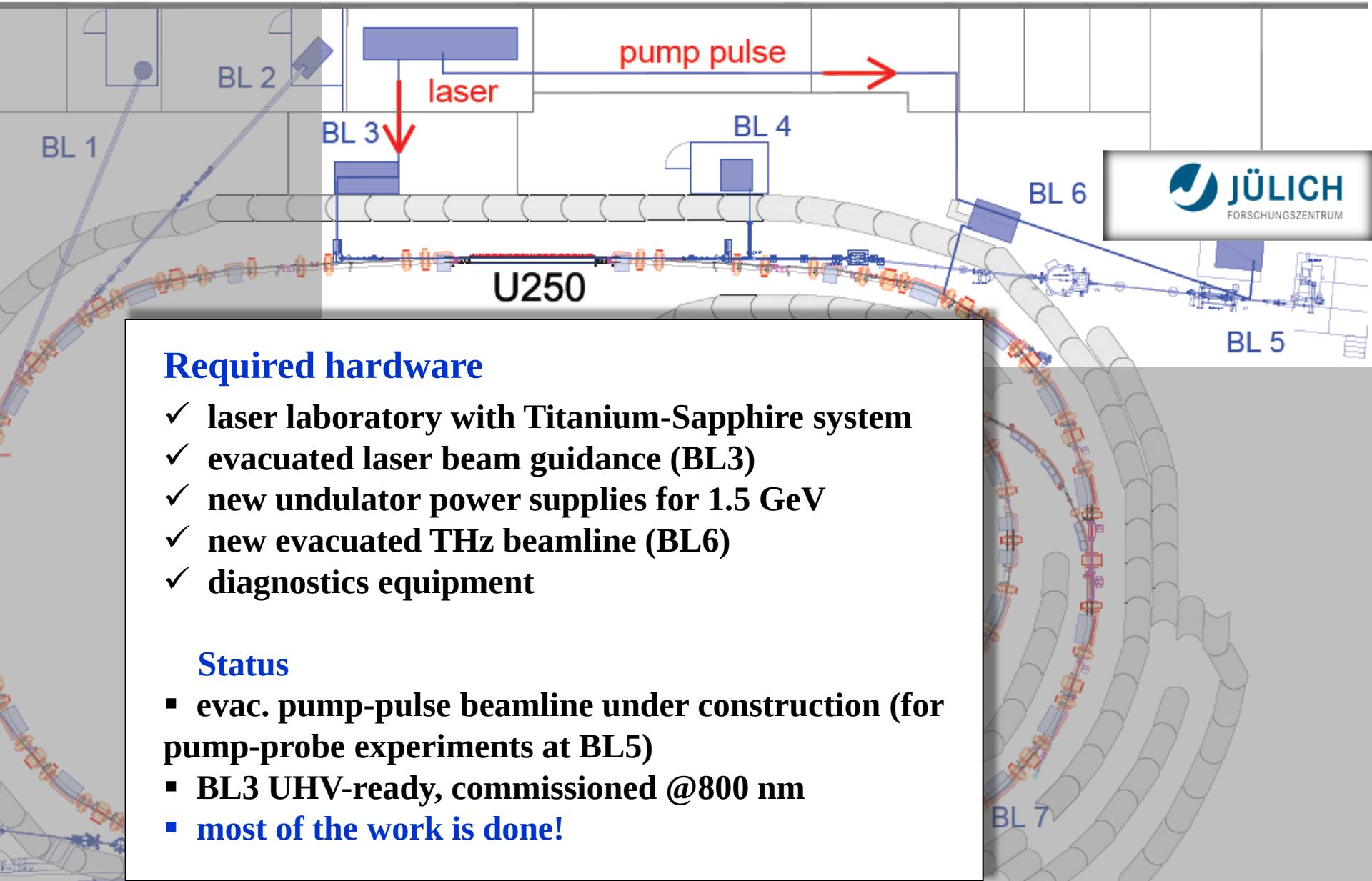
⟶ coherent THz radiation





THz-pulses: coherent => intense
ultrashort (100 µm)
synchronous to laser

Construction

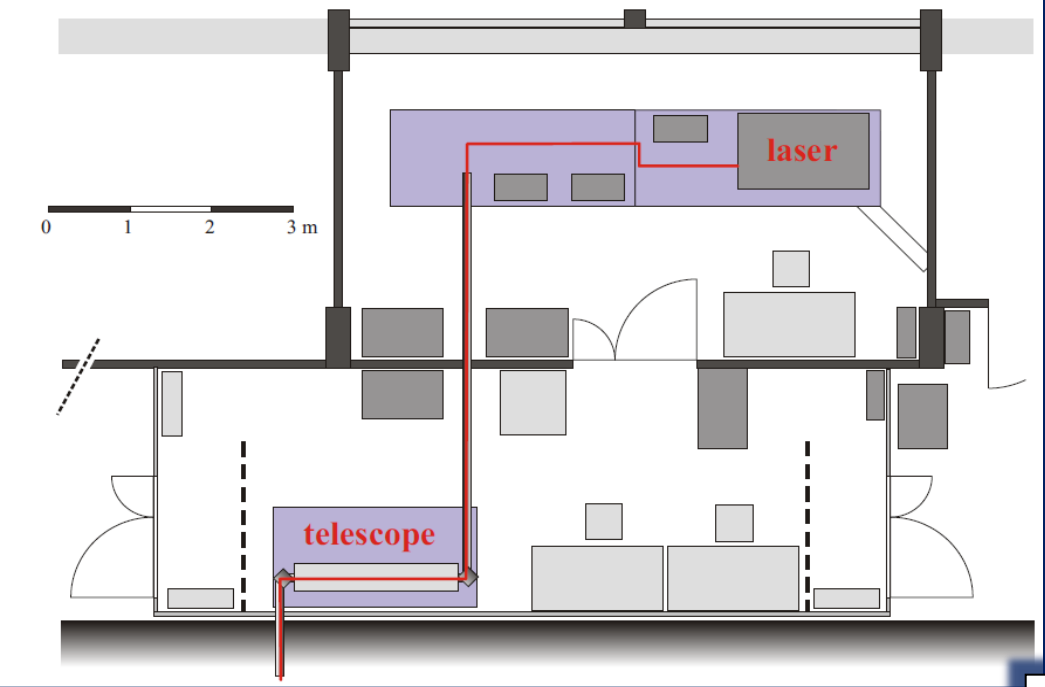


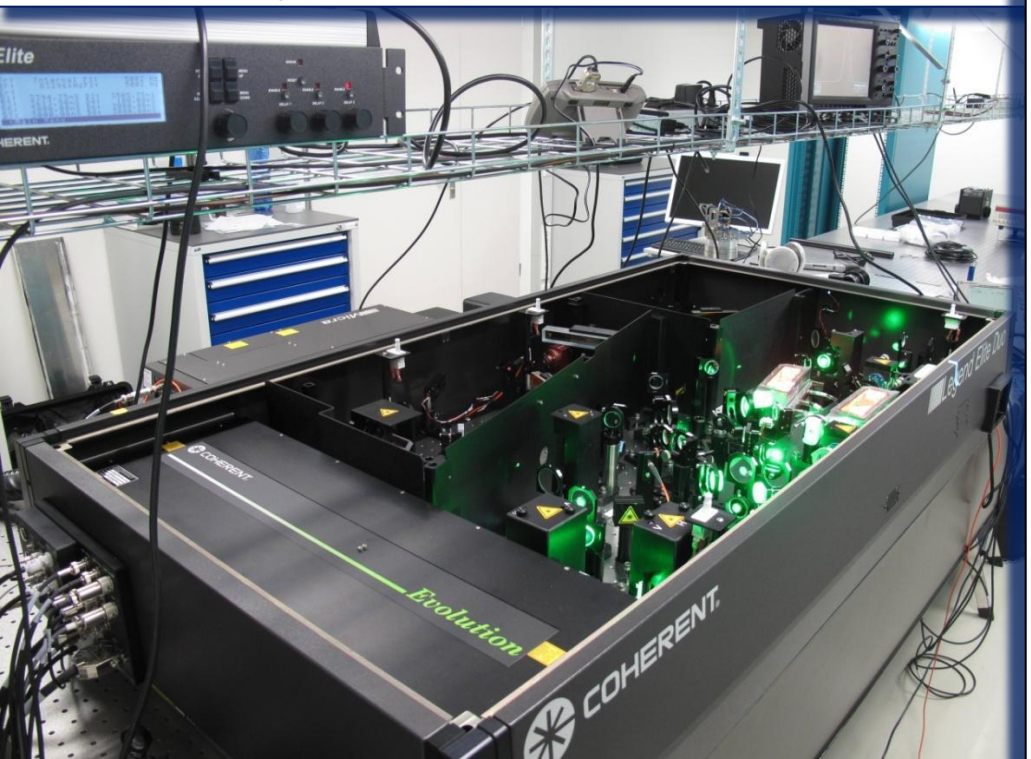
Required hardware

- ✓ laser laboratory with Titanium-Sapphire system
- ✓ evacuated laser beam guidance (BL3)
- ✓ new undulator power supplies for 1.5 GeV
- ✓ new evacuated THz beamline (BL6)
- ✓ diagnostics equipment

Status

- evac. pump-pulse beamline under construction (for pump-probe experiments at BL5)
- BL3 UHV-ready, commissioned @800 nm
- most of the work is done!





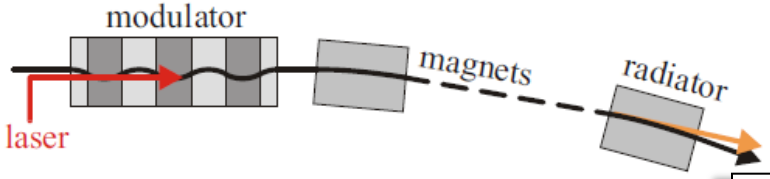
Ti:Sapphire laser system

- new, air-conditioned laboratory

- wavelength 795 nm
- pulse energy 8 mJ @ 1 kHz rep.rate
- pulse duration 25-45 fs

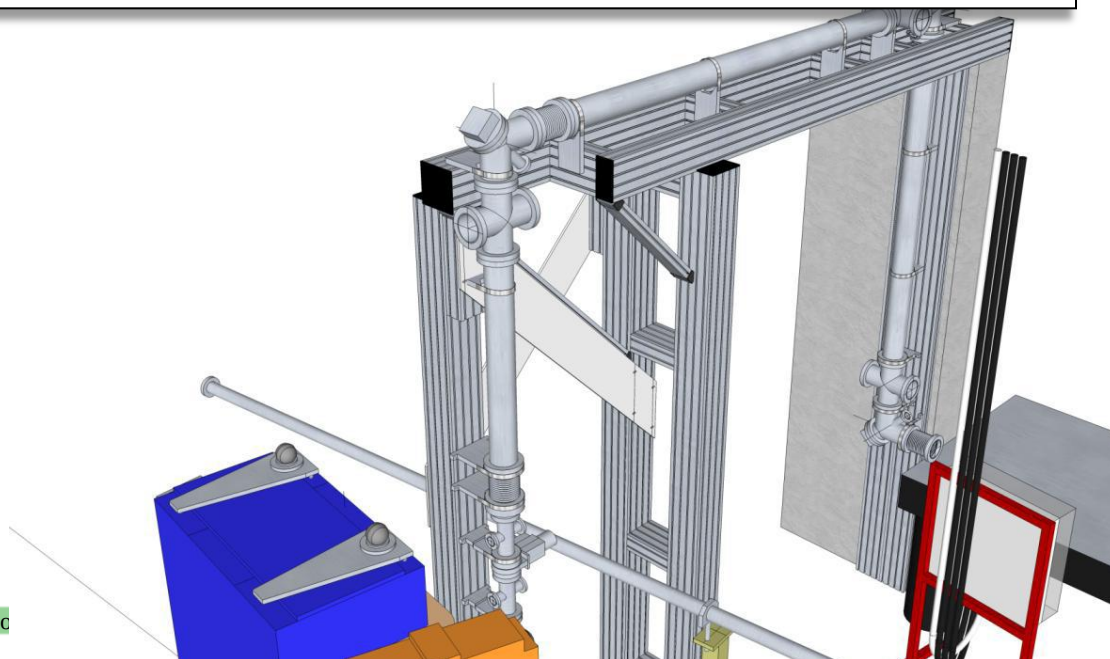
- THG
- optical parametric amplifier
- SPIDER

THz Beamline



Dedicated THz beamline 13 m downstream from undulator

- evacuated
- gaussian telescope with 6 toroidal mirrors
- liquid He-cooled InSb-bolometer
- FT-IR spectrometer funded



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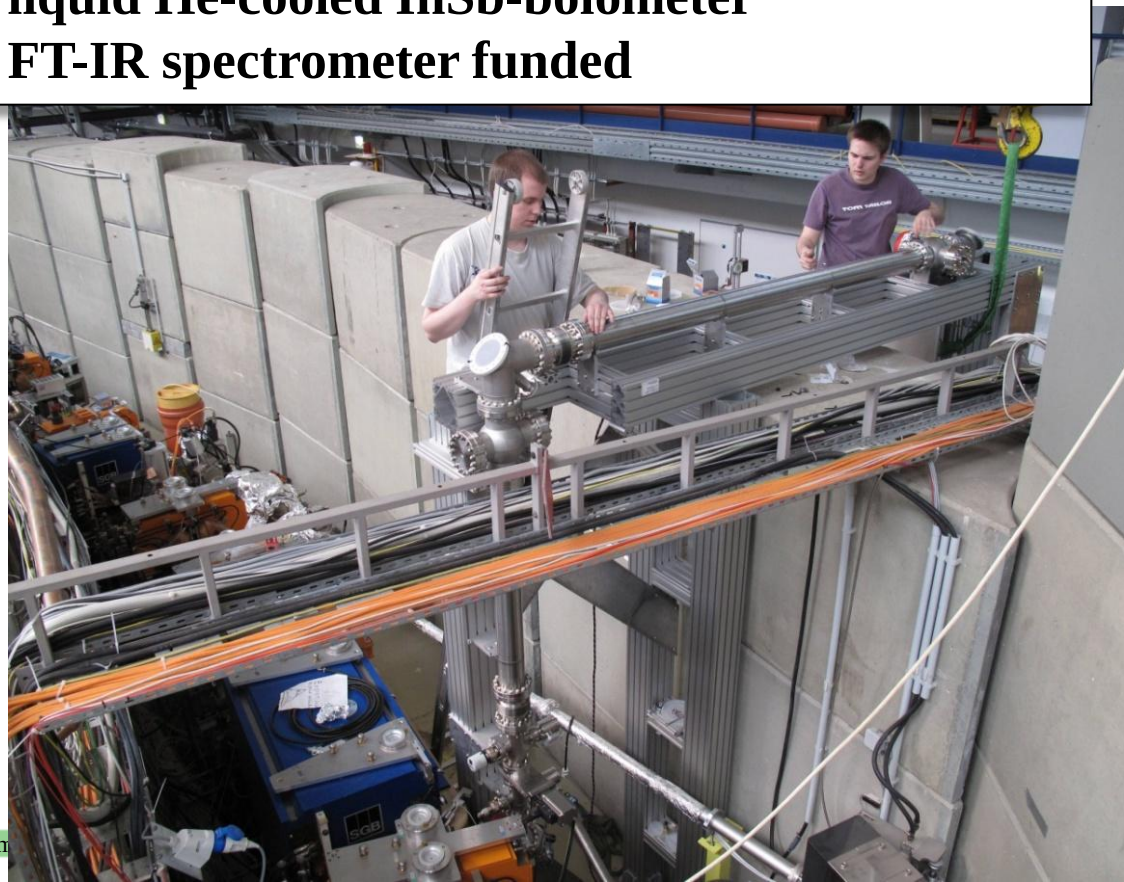
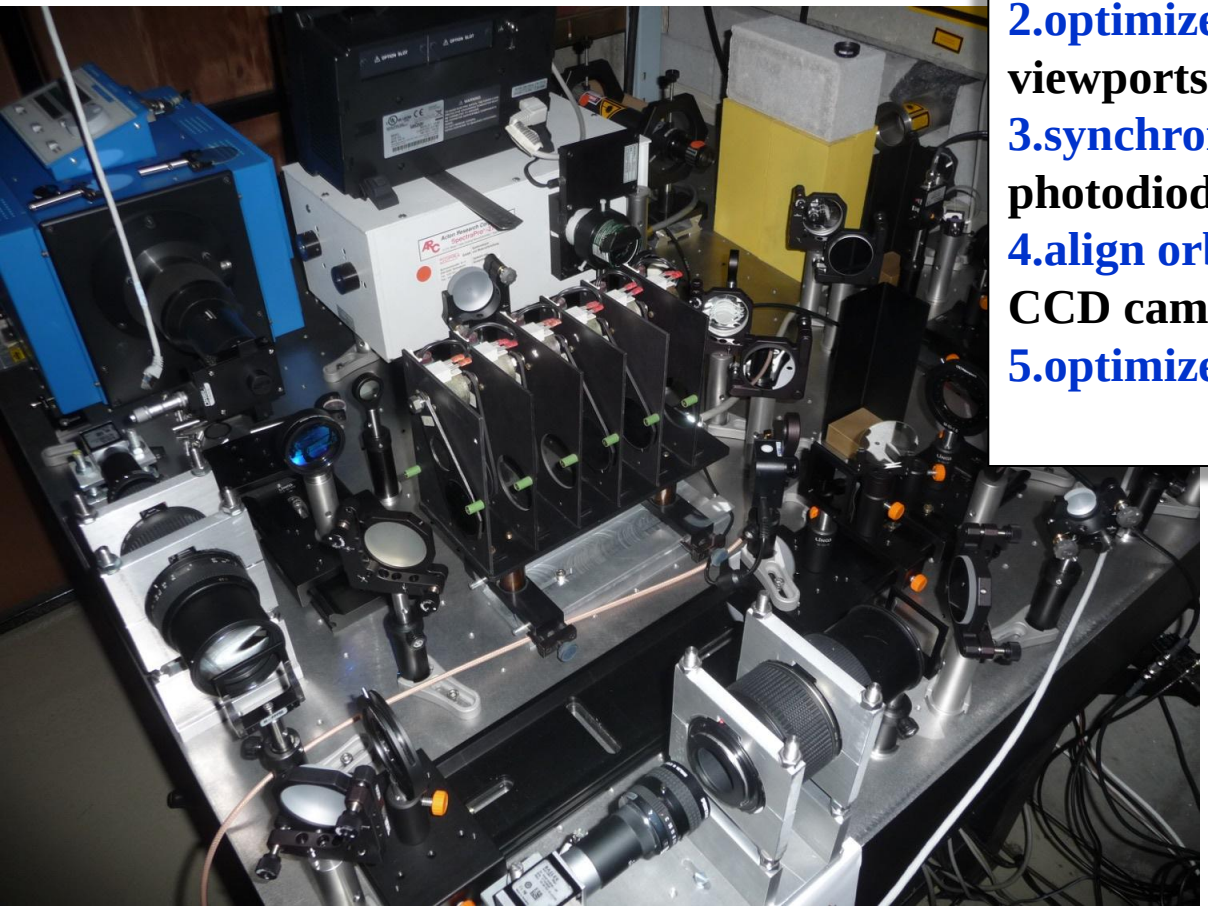


Diagnostics

water-cooled motorized Al/Cu-mirror guides laser & undulator light into diagnostics hutch



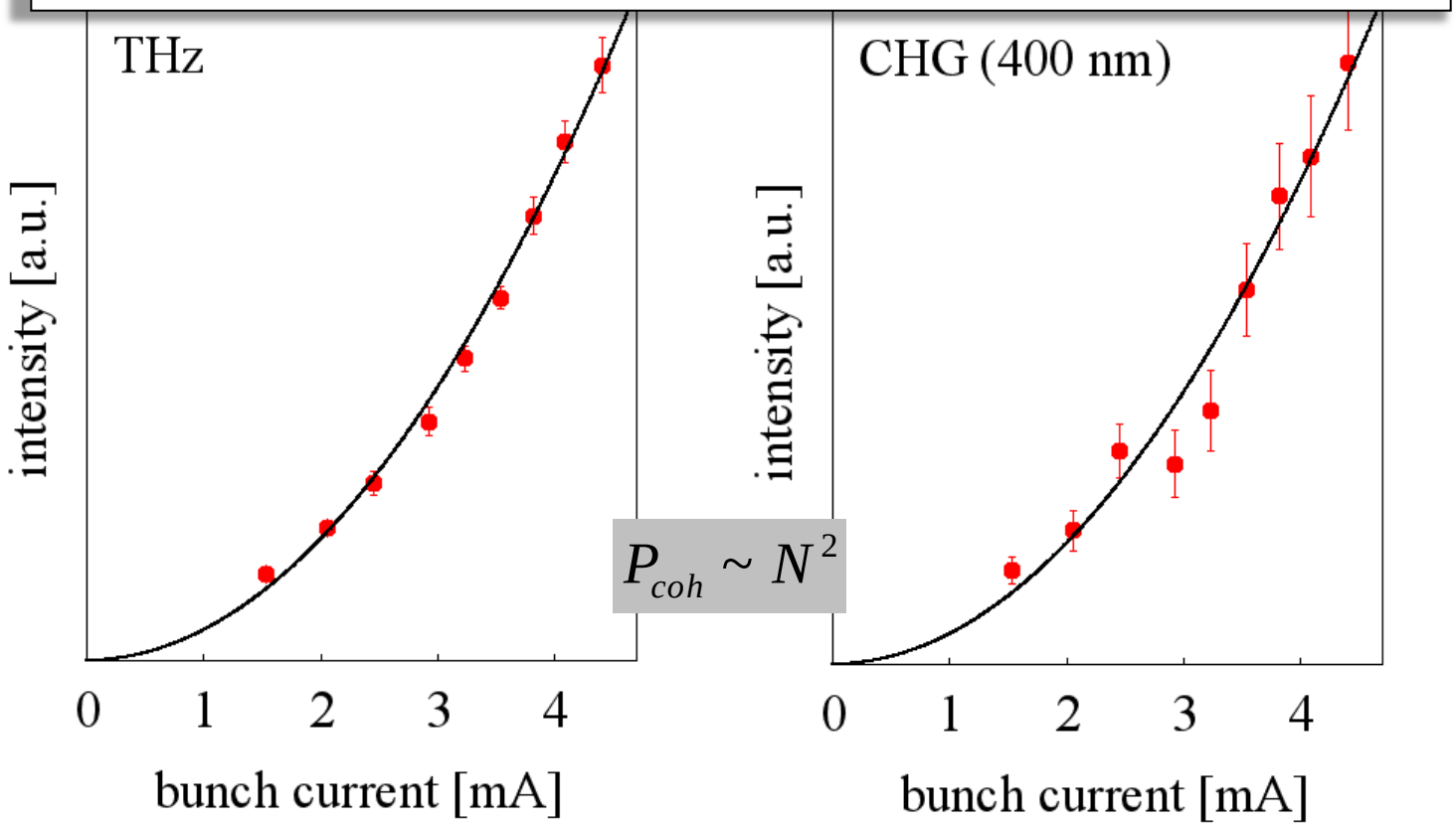
How to create overlap?

1. **optimize laser** (waist, pulse length)
2. **optimize transmission** (screens, viewports, powermeter)
3. **synchronize laser with e-bunch:** photodiode (coarse) + streak camera
4. **align orbit + laser waist transversely:** 2x CCD cameras with different focal lengths
5. **optimize THz and/or CHG signal**

Commissioning

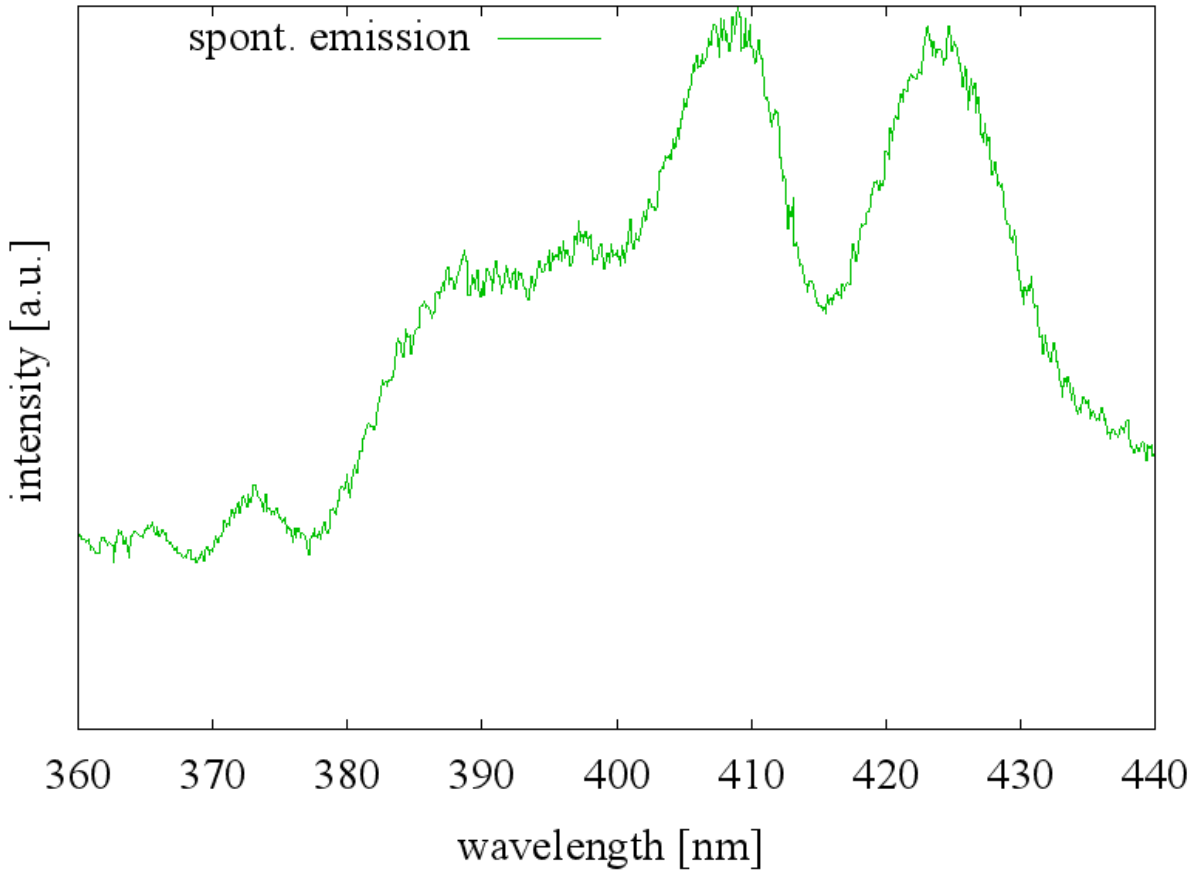
First machine week: first coherent THz and CHG signal !

- **2nd harmonic of 800 nm observed**
- **both THz and CHG grow quadratically with bunch current**
- **CHG demonstrated in standard user operation (1.5 GeV, multibunch + increased charge in few buckets)**



Spectrum

- measured after TiSa-mirror + bandpass filter, 1 µs average
- spontaneous emission: “distorted“ optical klystron spectrum



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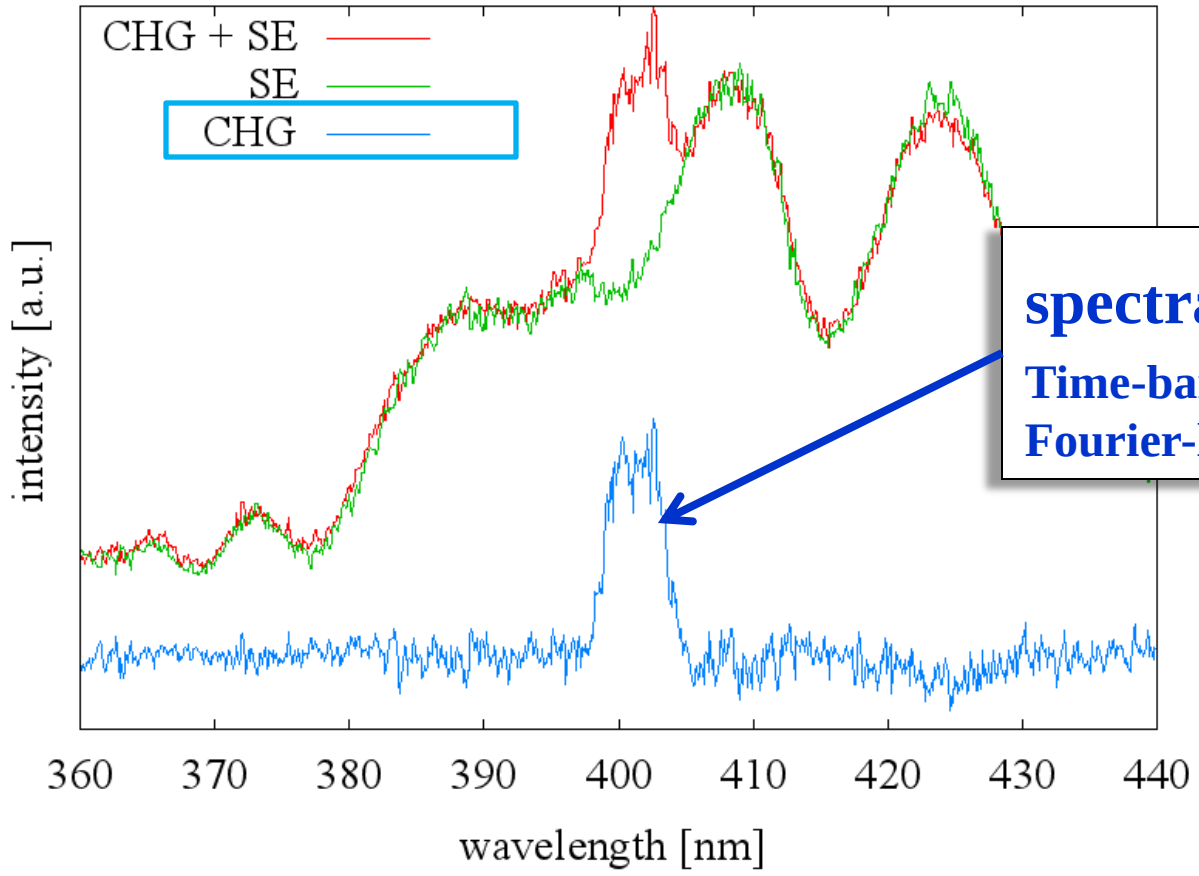
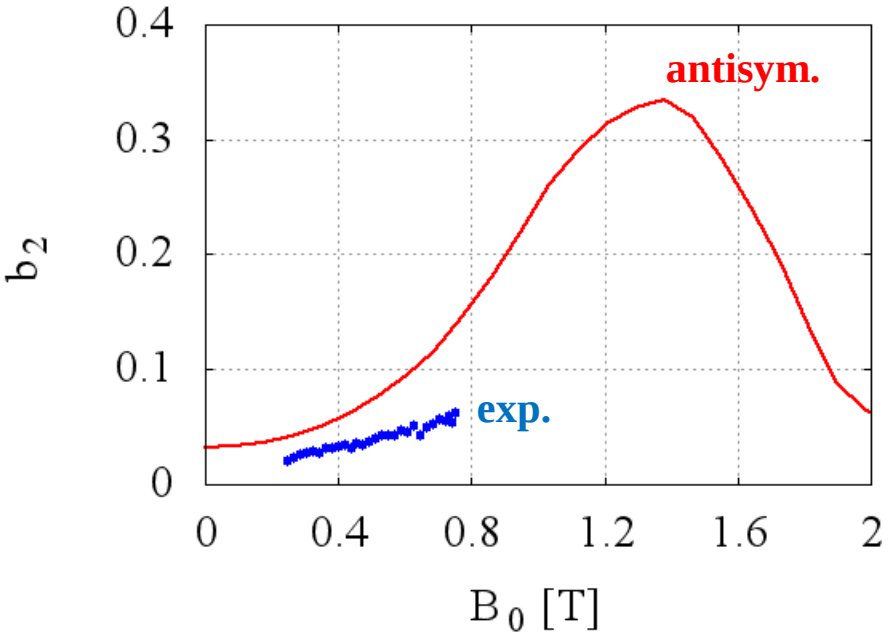


spectral width 5 nm (FWHM)

Time-bandwidth product close to Fourier-limit ($\Delta t \cdot \Delta \nu \approx 0.441$)

Chicane

- Enery modulation limited to ~0.5% by RF
- Strong chicane (R_{56}) required for good bunching factor



$$P(\lambda) = P_1(\lambda)\left[N + \left(\frac{\tau_{laser}}{\tau_{bunch}}\right)^2 N^2 (b(\lambda))^2\right]$$

R_{56} much too small at 800 nm…

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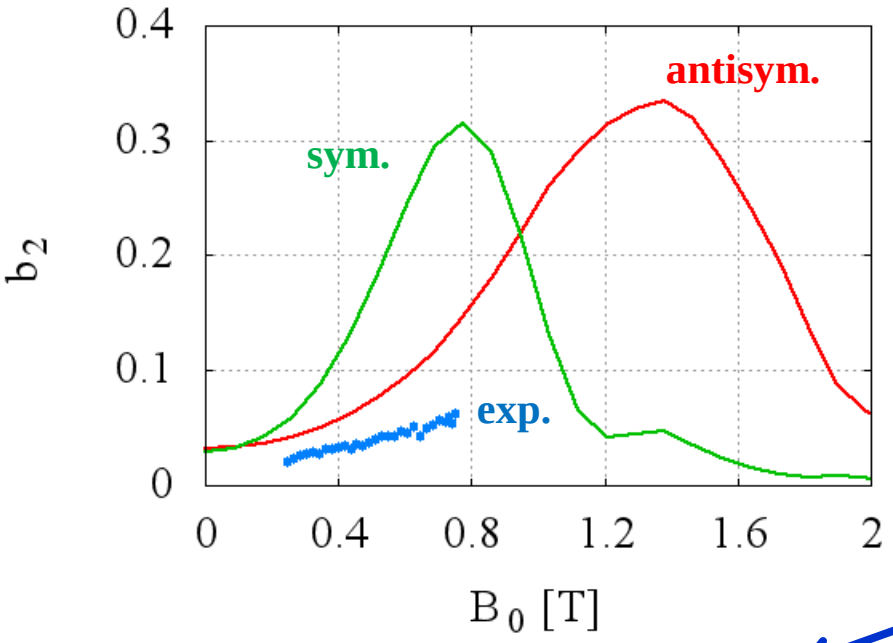

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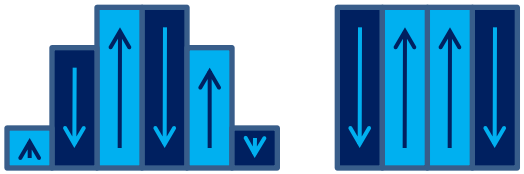
R_{56} much too small at 800 nm…

Solutions:

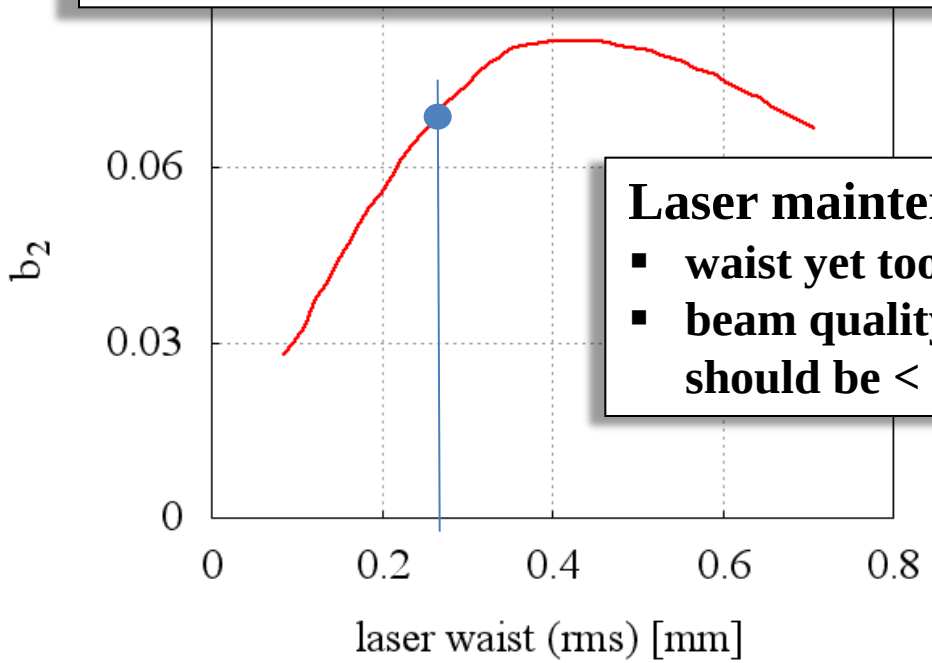
- **Change coil polarities**
- **Or just use 400 or 266 nm for the modulator !**



Present antisymmetric vs. symmetric B-Field config. for chicane

Upcoming Improvements

- New gun, hybrid filling pattern (installed this summer)
- Bunch-by-bunch feedback system (installed)
- Pump-pulse beamline (under construction)
- Shorter wavelength: THG unit (400 or 266 nm)
- Evacuate laser beamline, motorize telescope…

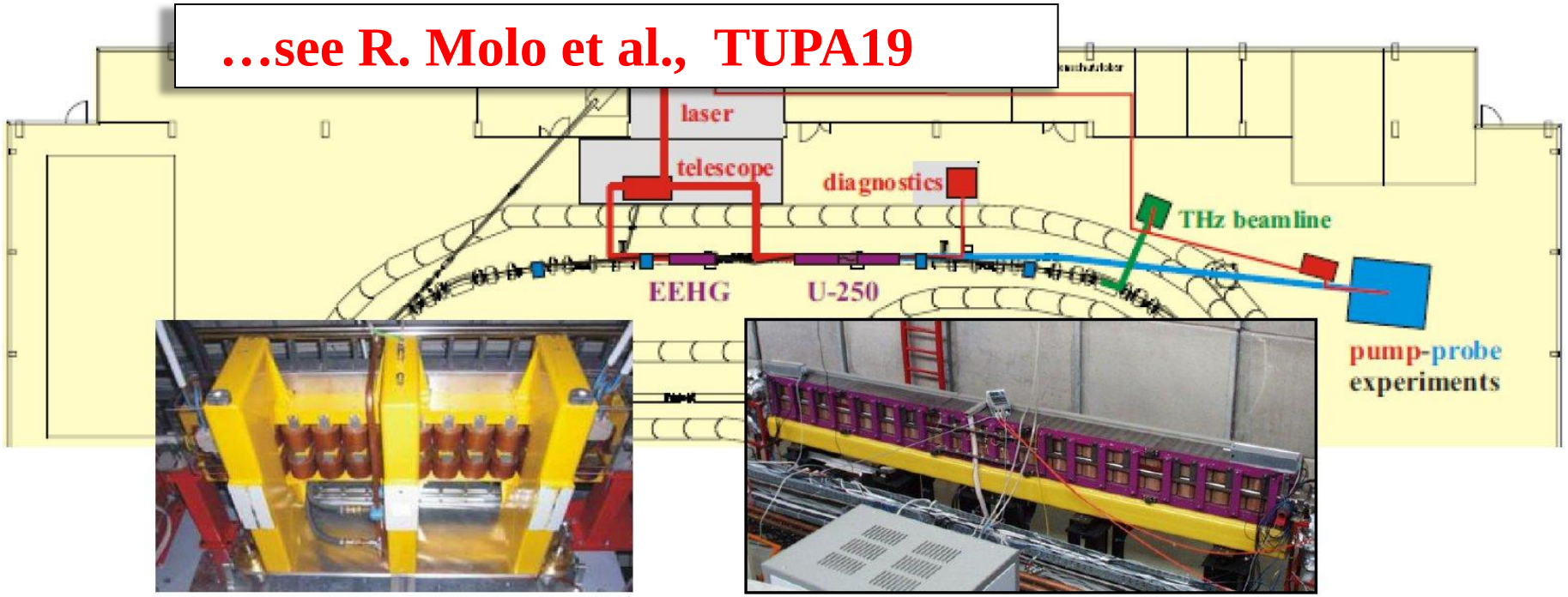


Laser maintenance:

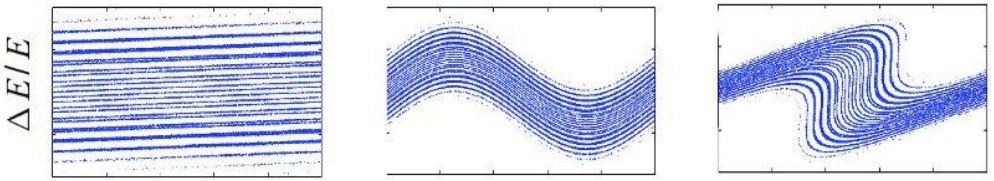
- waist yet too small & astigmatic
- beam quality factor M^2 approx. 2, should be < 1.5

Outlook: echo-enabled harmonic generation (EEHG)

…see R. Molo et al., TUPA19



G. Stupakov, PRL 102 (2009), 074801
D. Xiang et al., PRL 105 (2010), 114801



Acknowledgements

- **DFG (INST 212/236-1 FUGG), BMBF (05K10PE1, 05K10PEB) and the Federal State NRW for funding**
- **The whole DELTA team**
- **Colleagues from other labs (BESSY, DESY, ELETTRA, KIT…)**

Thank you for your attention !