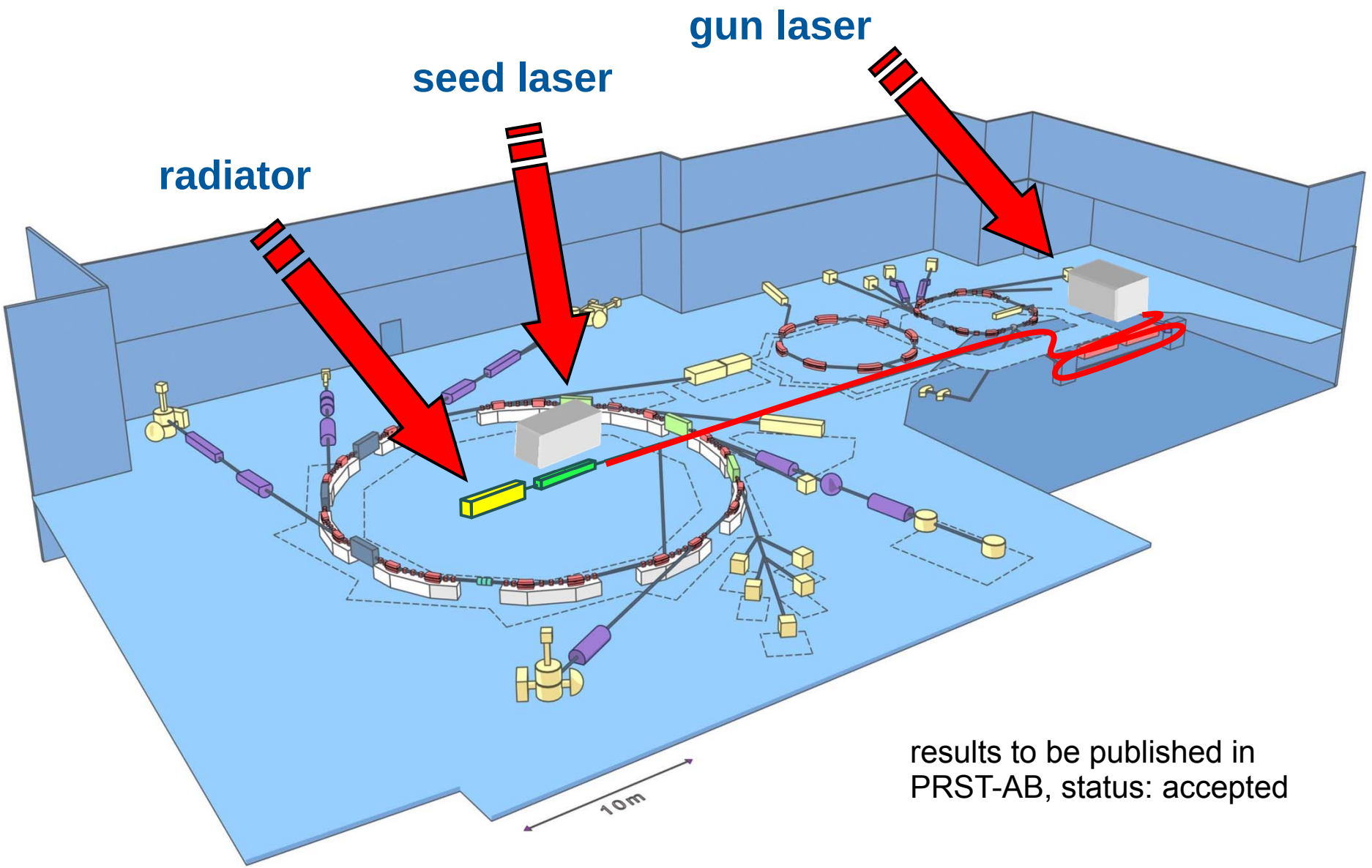
Femtosecond VUV-Pulses with Variable Polarization from Coherent Harmonic Generation at the MAX-lab Test FEL

Johannes Bahrdt, Helmholtz-Zentrum Berlin

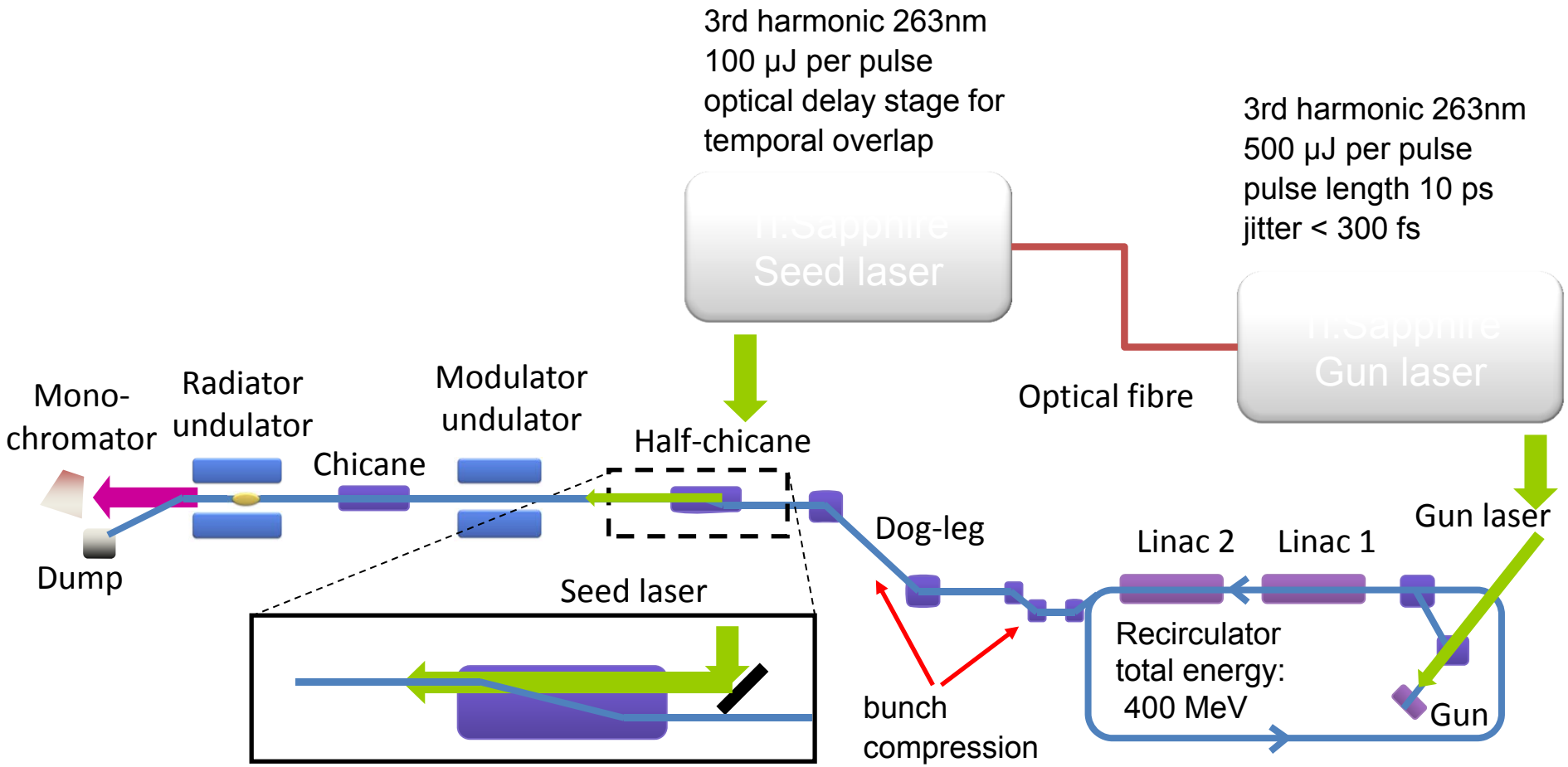
23.03.2011

Free Electron Laser Test Facility at MAX-lab



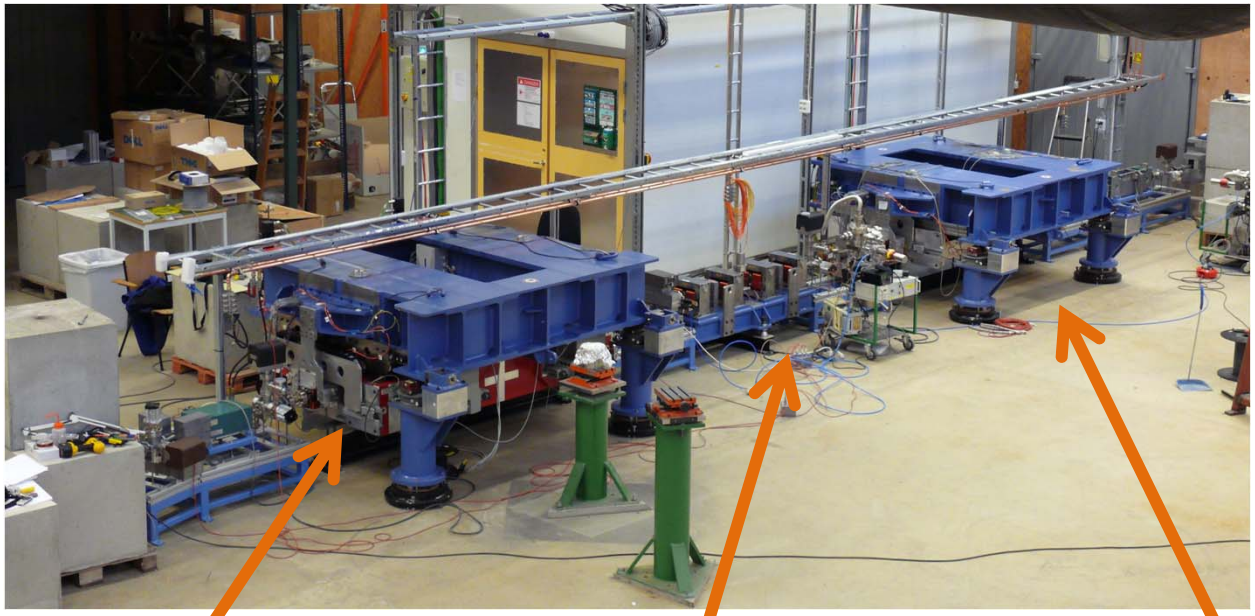
results to be published in
PRST-AB, status: accepted

Laser System



Filip Lindau

Undulator System



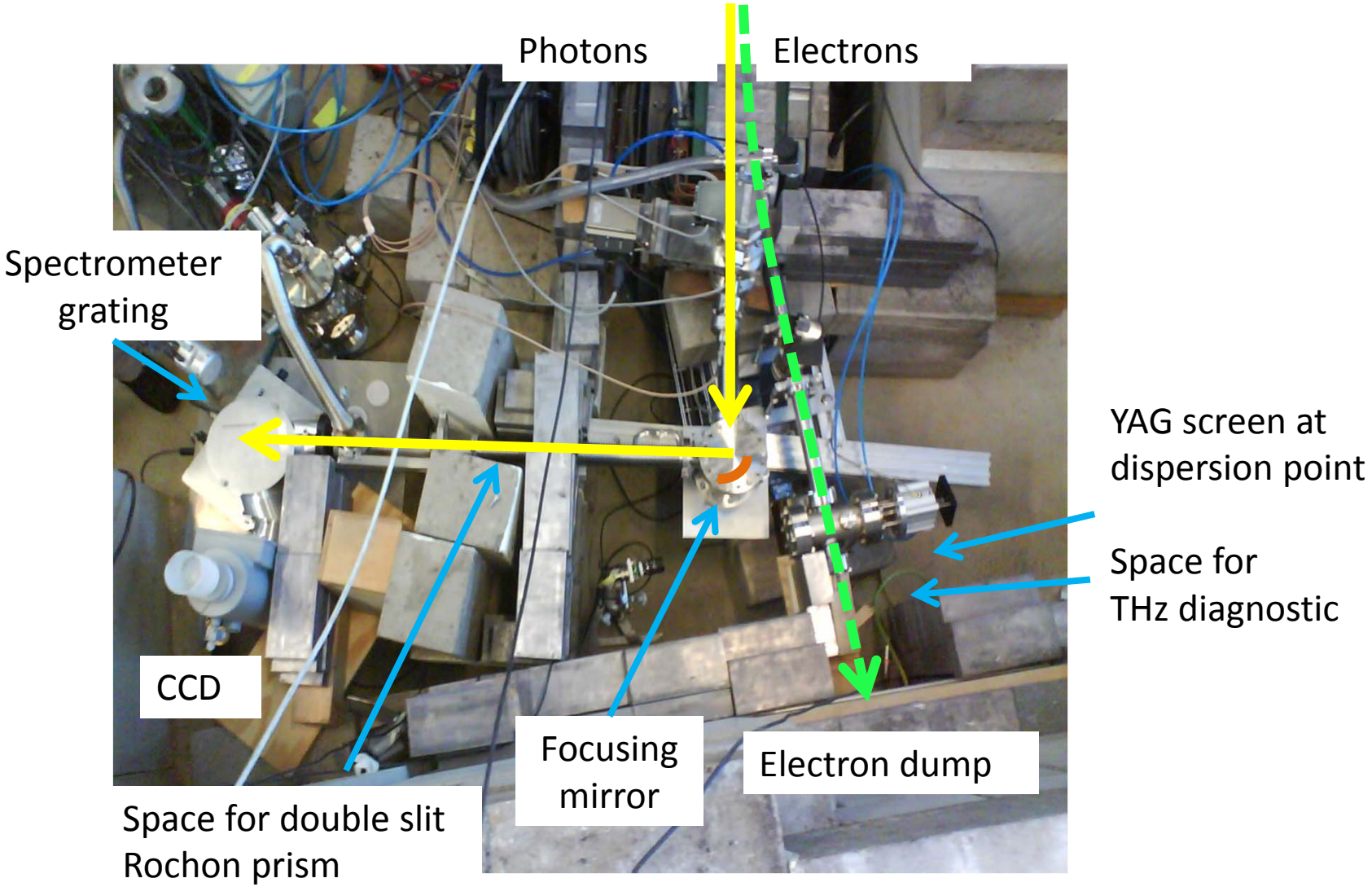
Radiator type	Apple II
Period length	56 mm
# of periods	30
Min. gap	12 mm
K-max	4.3

Chicane type	electr.
# of magnets	4
Gap	15 mm
B-max	0.2 T

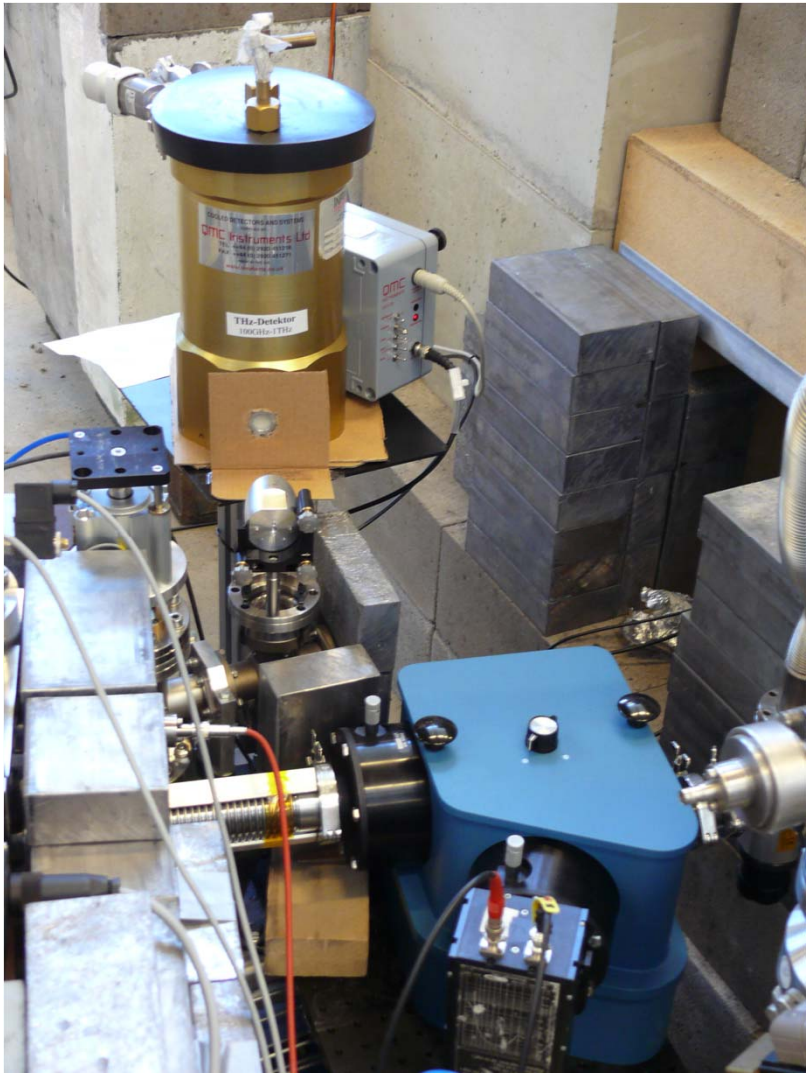
Modulator type	planar
Period length	48 mm
# of periods	30
Min. gap	10 mm
K-max	4.3

BESSY / HZB undulator group

Photon Diagnostics



THz Diagnostic for Bunch Compression Optimiziation

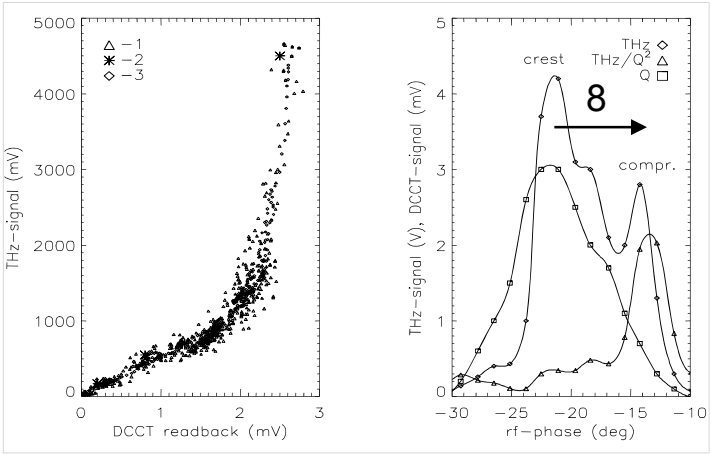


Karsten Holldack

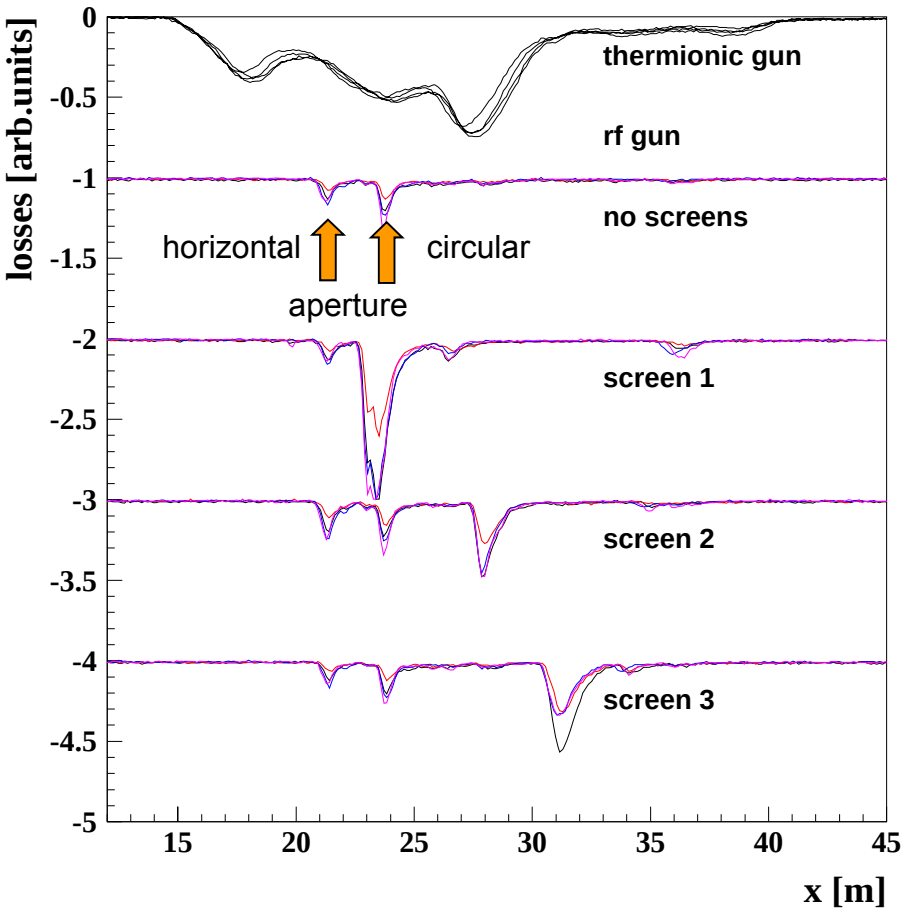
InSb bolometer
QMC Industruments Ltd.
100GHz – 1 THZ

THz signal used for bunch compression optimization

Ideal phase for compression 30
Optimized acceleration phase for
recirculating linac structure
8 off crest



Cherenkov Fibres



Non destructive
beam position monitor

4 Cherenkov signals give
x- and y- position
(not calibrated)

EPICS variables are logged

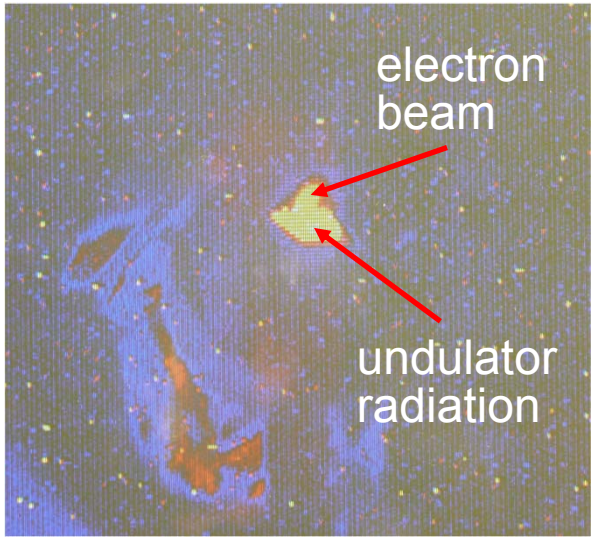
Walter Göttmann
Jochen Kuhnhenn et al.

Overlap of Seed Laser and Electron Beam

Transverse overlap

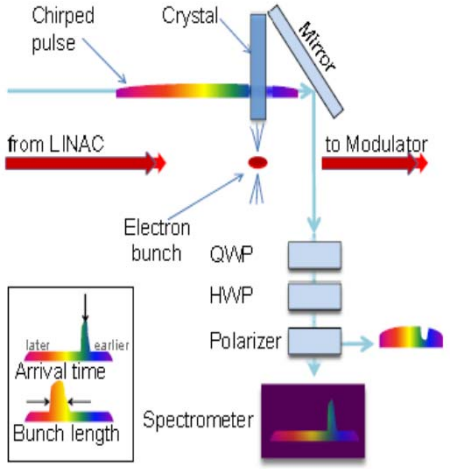
simultaneous detection
of electron beam and
seed laser position

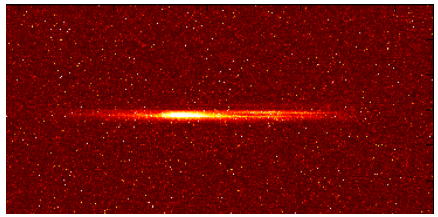
- Yag screens upstream and downstream of modulator
- CCD cameras



Longitudinal overlap

Electro Optical Sampling
and Spectral Decoding

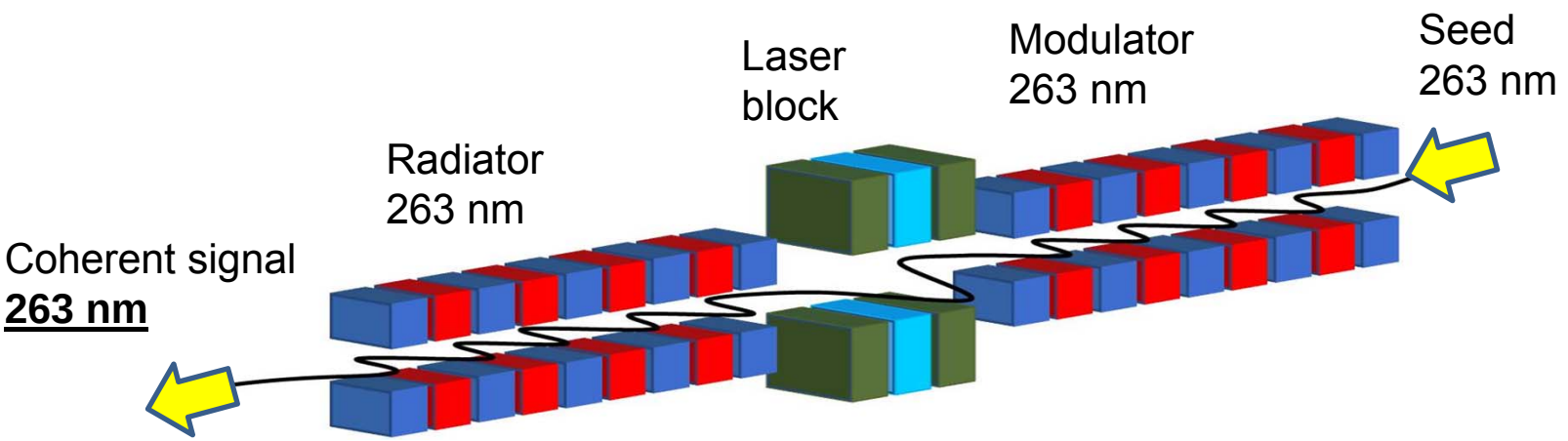


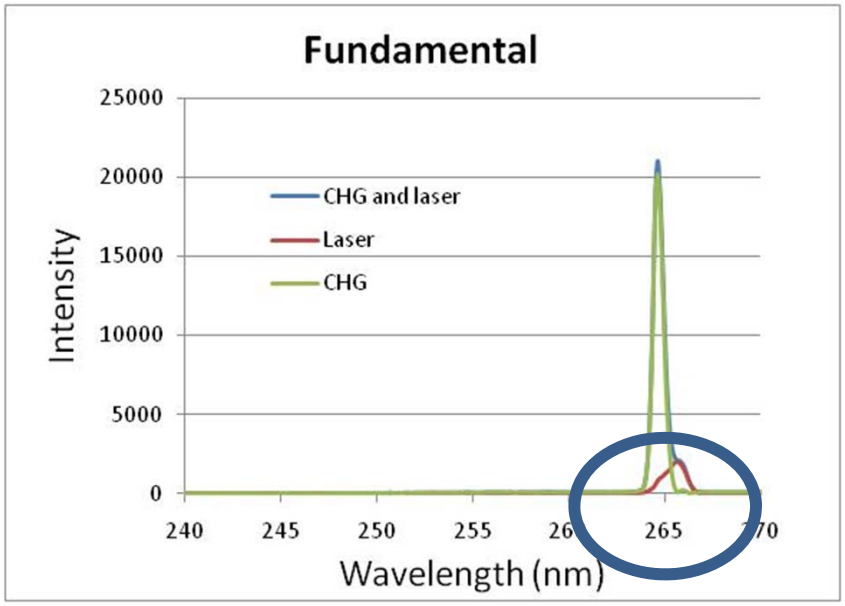


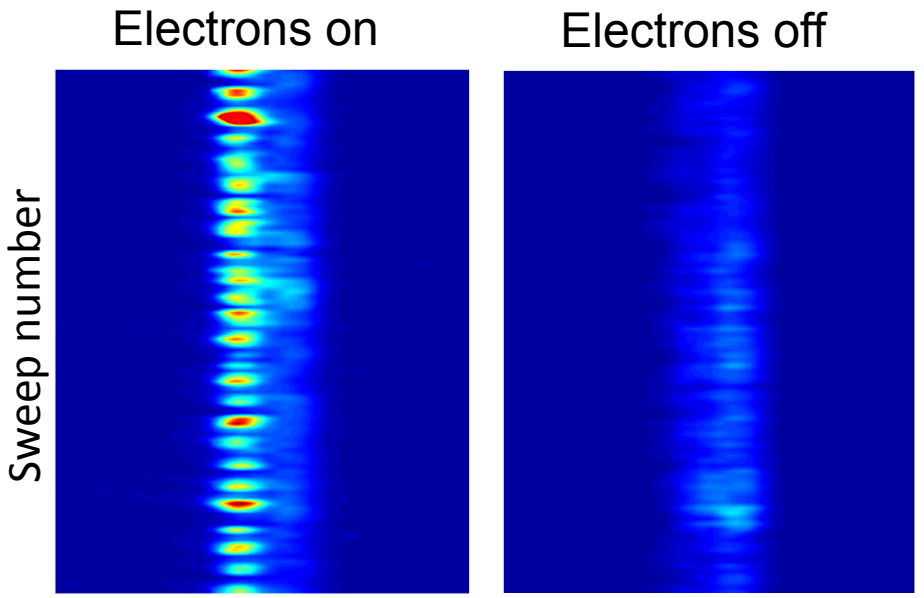
≈ 2 ps

Nino Cutic

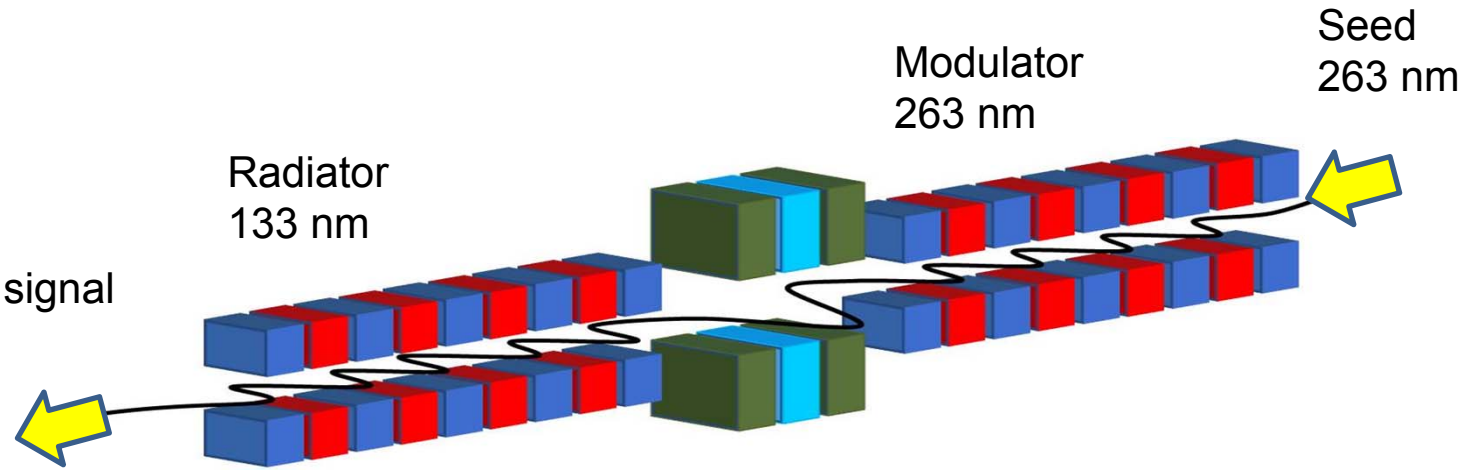
Coherent Radiation at Fundamental of 263nm

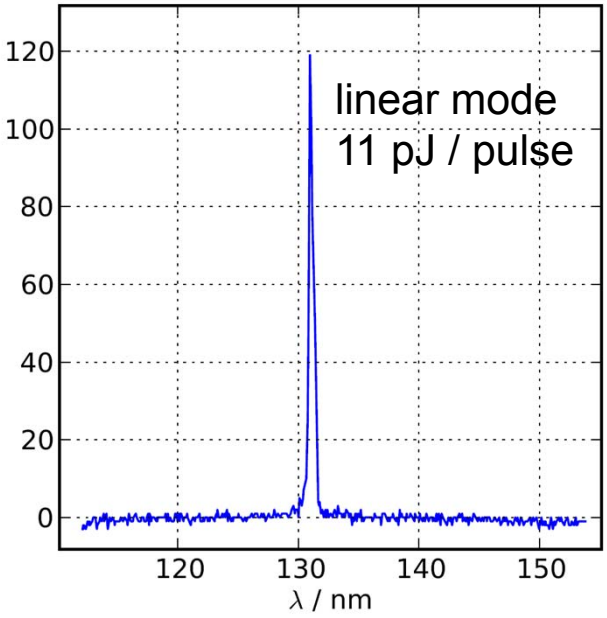






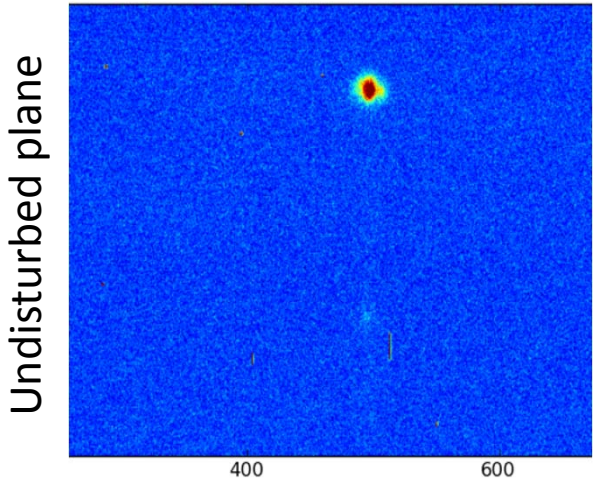
Coherent Radiation at 2nd Harmonic





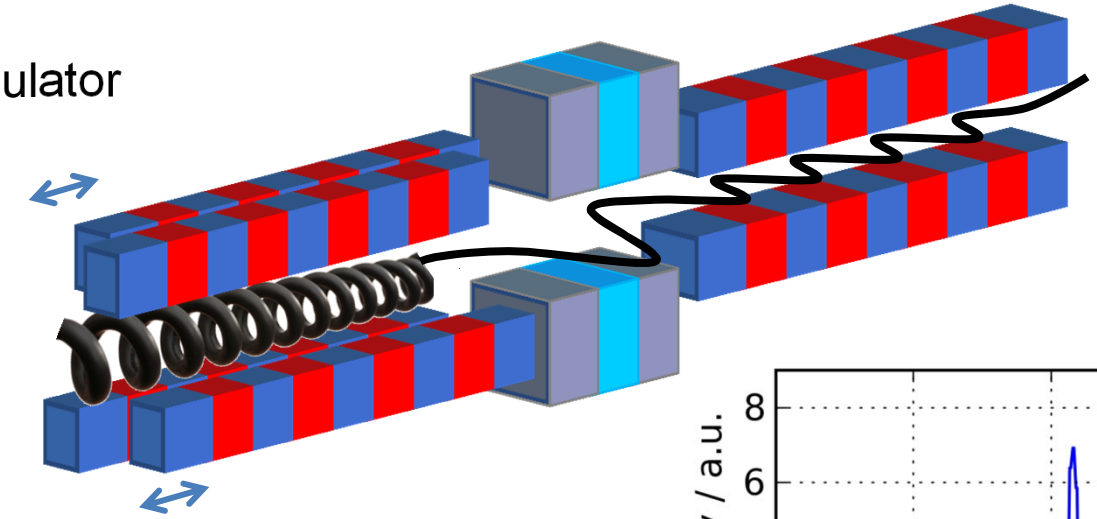
> 185 fs
< 0.24% spectr. BW
8e6 photons/pulse
0.2 mRad

Full CCD chip
no trace of spontaneous signal
no laser stray light

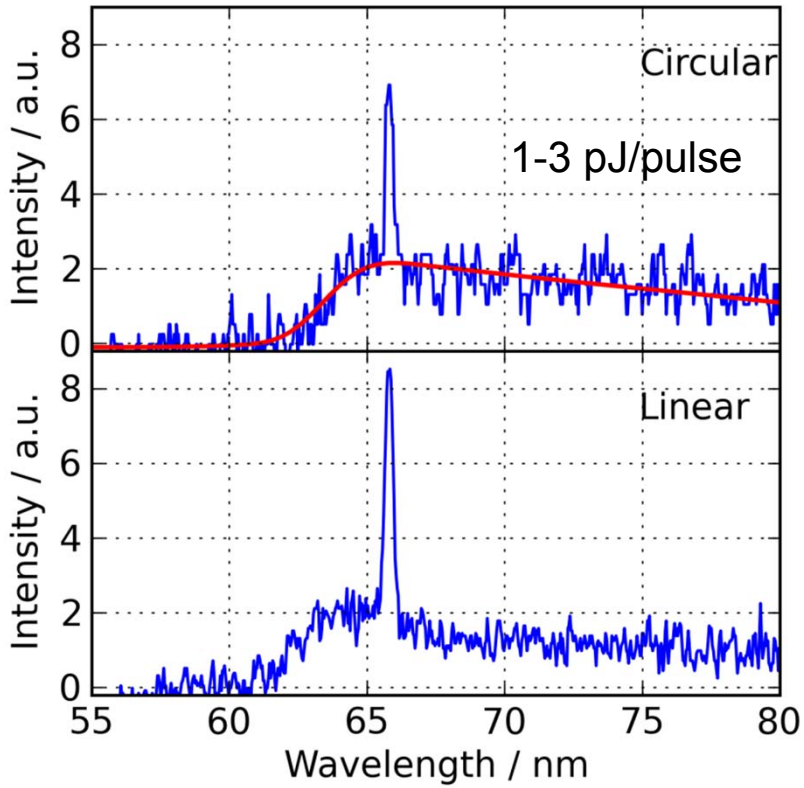


Coherent Radiation at 4th Harmonic
Variable Polarization

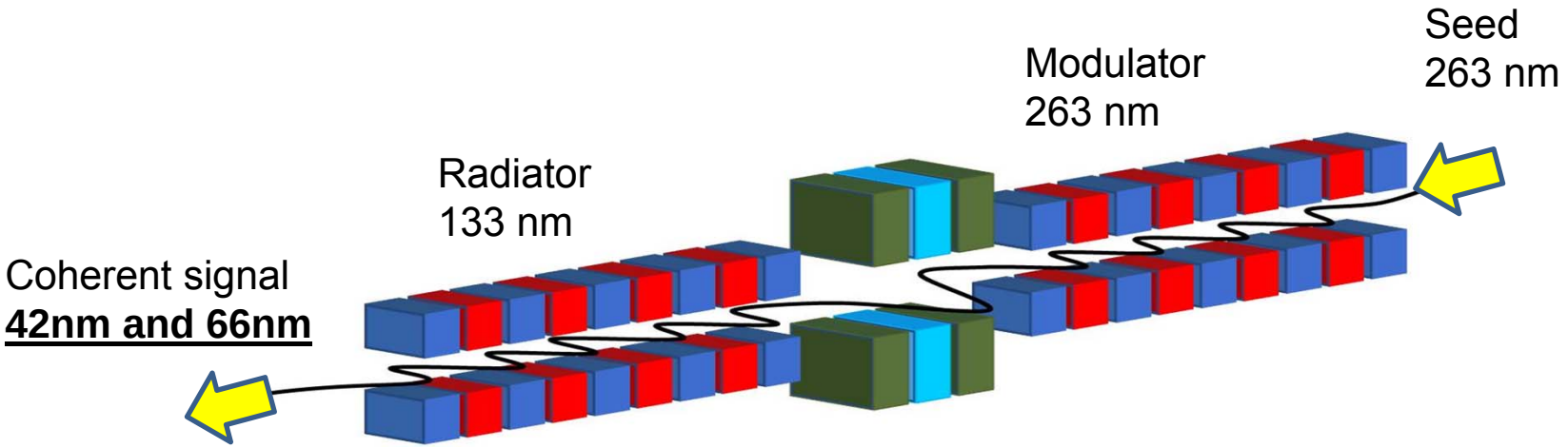
Apple II undulator
helical



66 nm

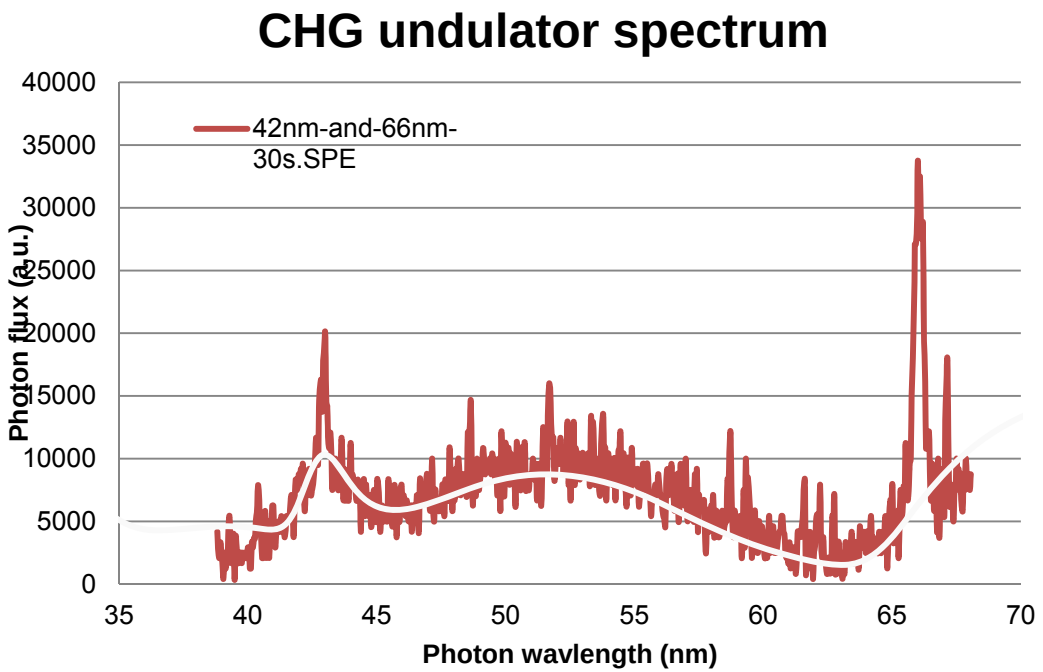


Coherent Radiation at 2nd and 3rd Radiator Harmonic

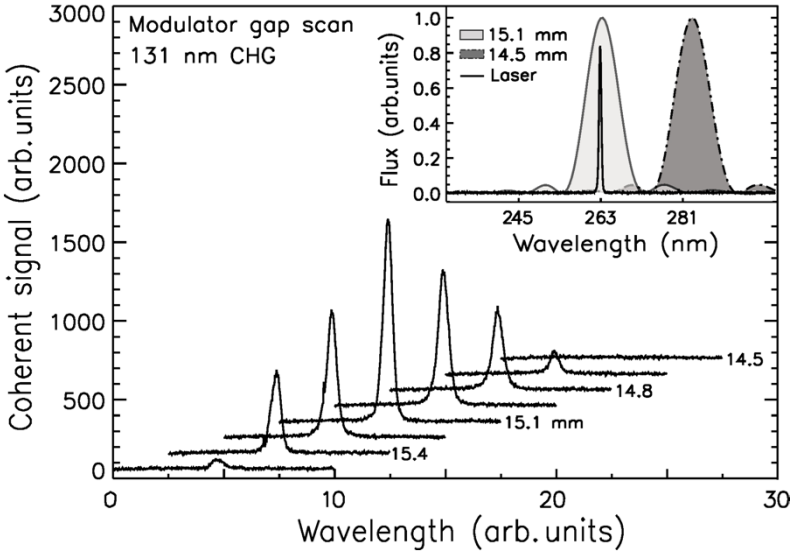


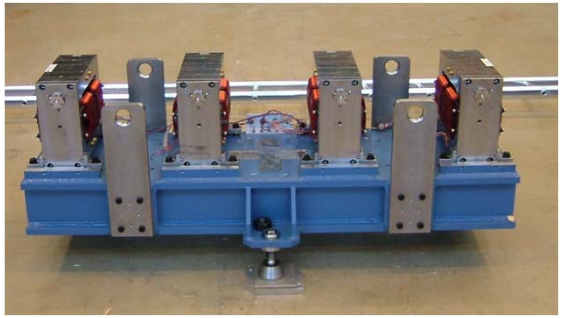
Higher undulator harmonics in linearly polarizing mode:

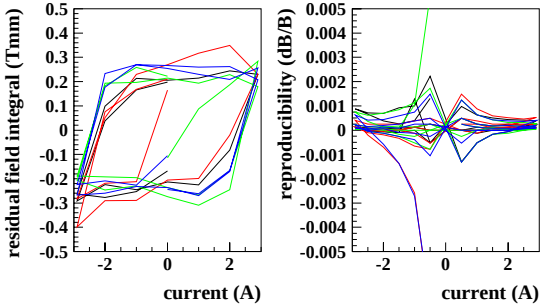
- 2nd harmonic off axis and
- 3rd harmonic on axis



Dependence on Modulator Setting

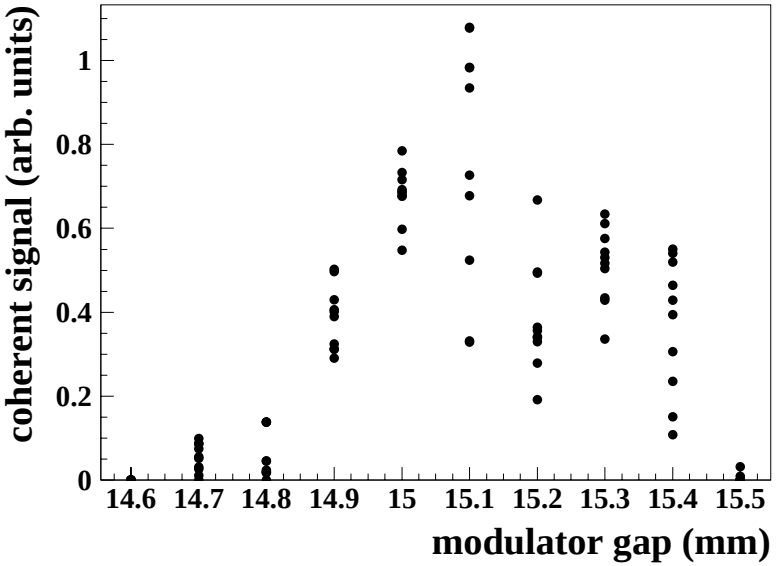






magnet chicane

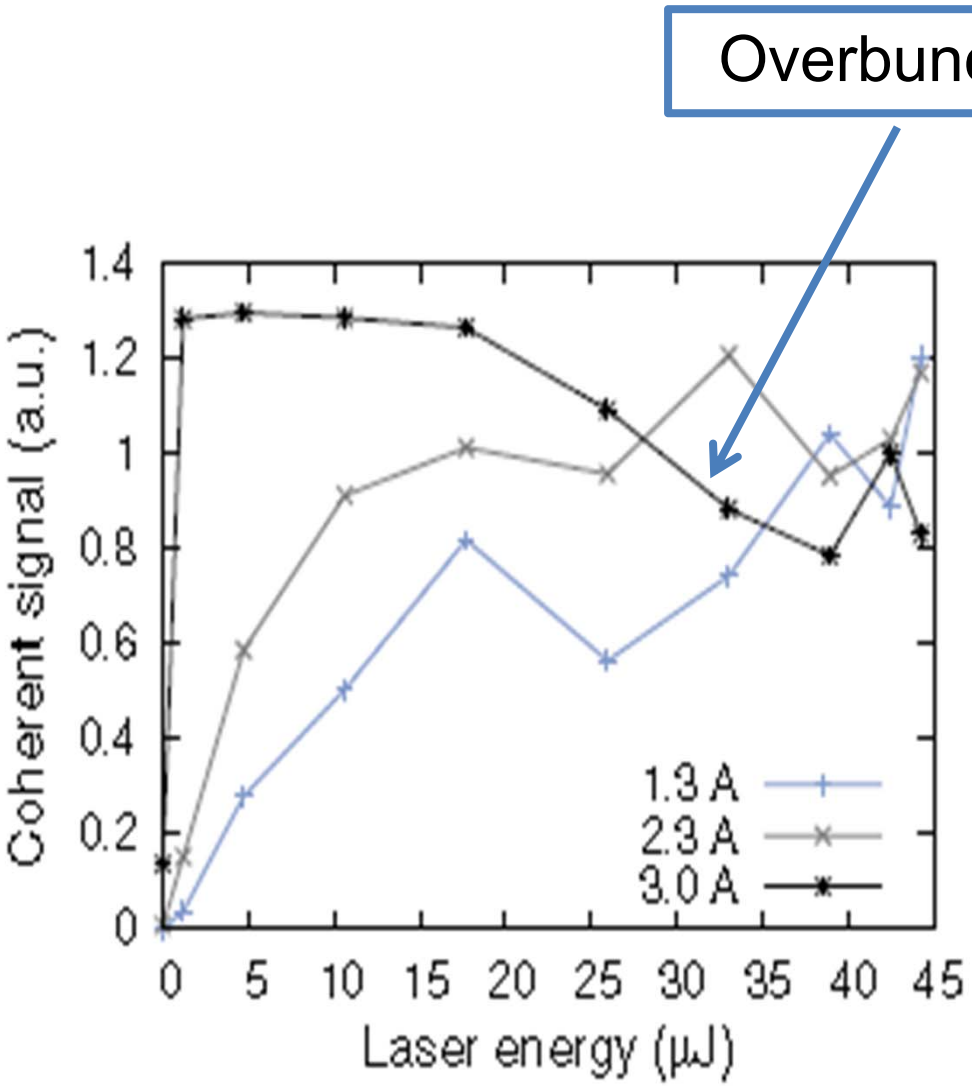
single magnet reproducibility



CHG-signal vs. modulator gap wider than expected from modulator line width:

- energy jitter
- shorter effective modulator length
  - short laser focus as compared to modulator length
  - misalignment of seed laser with respect to electron beam

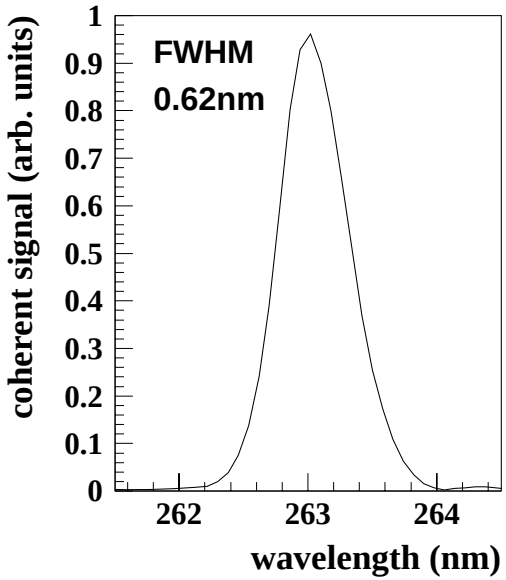
Dependence on Laser Energy and Chicane Setting

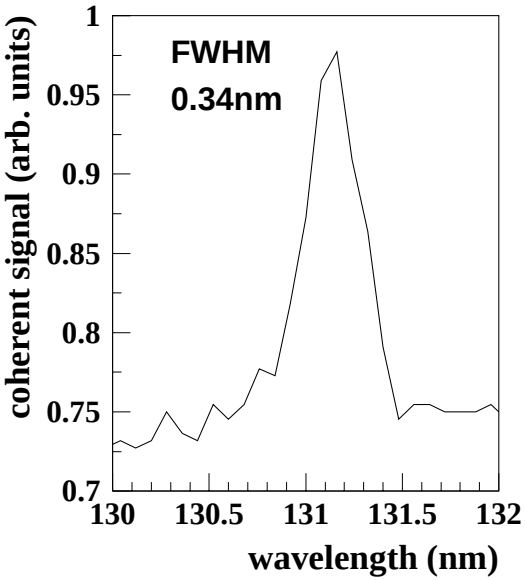


Bunching determined by:

- Laser energy
- R56 of chicane

Estimation of Pulse Length





simultaneous fit of both spectra

$$\Delta\lambda_{CHG} = \sqrt{\Delta\lambda^2_{meas.} - \Delta\lambda^2_{\mathrm{det.}}}$$

$\Delta\lambda_{CHG}$ line width of coherent pulse

$\Delta\lambda_{\mathrm{det.}}$ detection line width (fitted to 0.28nm)

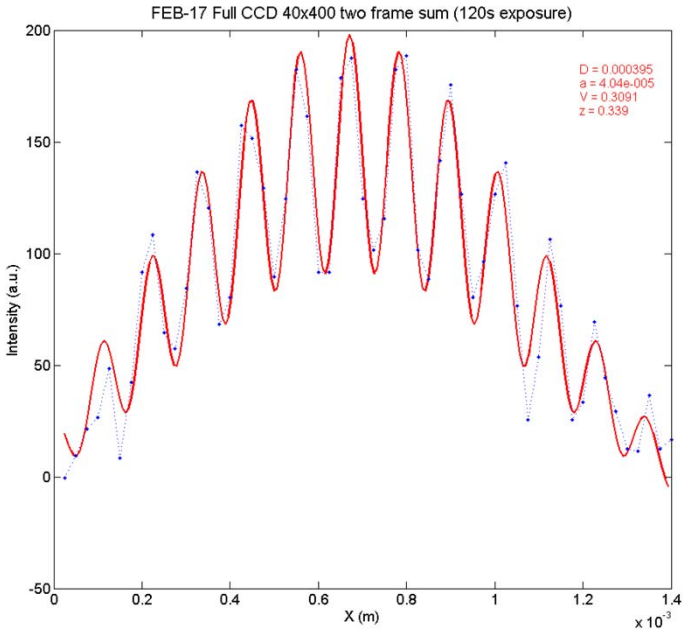
$\Delta\lambda_{meas.}$ measured line width

No significant variation of $\Delta\lambda_{\mathrm{det.}}$ between 263 and 133nm

$$\Delta\tau_{CHG} = \frac{0.44 \cdot \lambda^2}{c \cdot \Delta\lambda_{CHG}}$$

185 fs

Transverse Coherence



double slit experiment
double slit 1m upstream of spectrometer
wavelength 133nm

→ coherent radiation dominates spontaneous radiation

Jörg Schwenke

$$I(x) = I_0 \left(\frac{sin(\frac{ka}{2z}(x - x_0))}{\frac{ka}{2z}(x - x_0)} \right)^2 \left(1 + V cos \left(\frac{kD}{z}(x - x_0) \right) \right) + I_b$$

a = slit width

D = slit separation

z = distance to image plane

v = fringe visibility

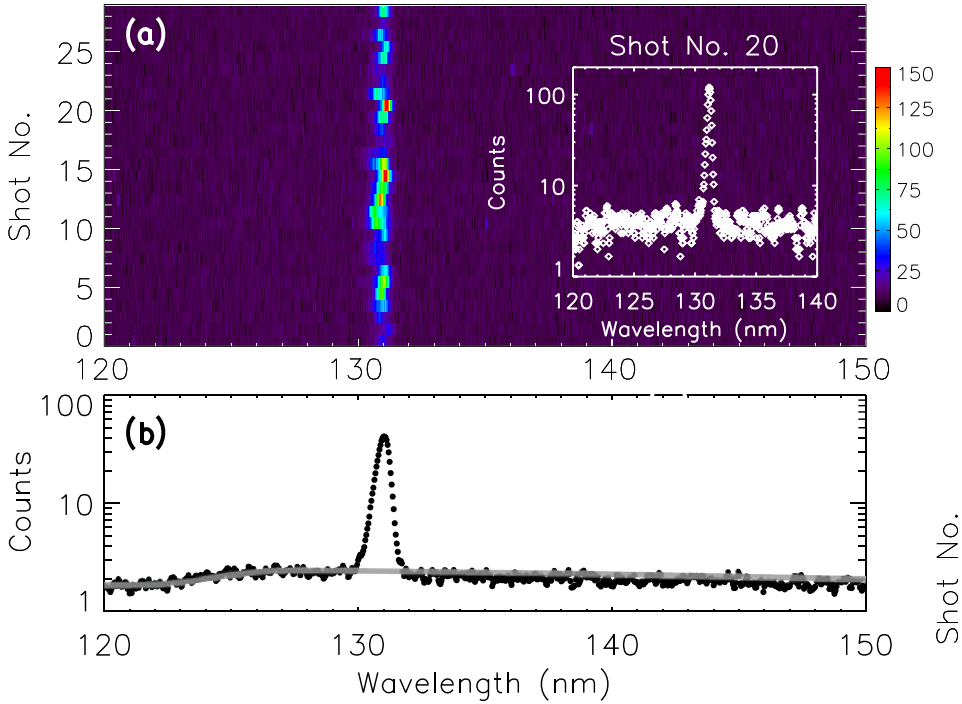
v = 0.3

work in progress:

separation of source size

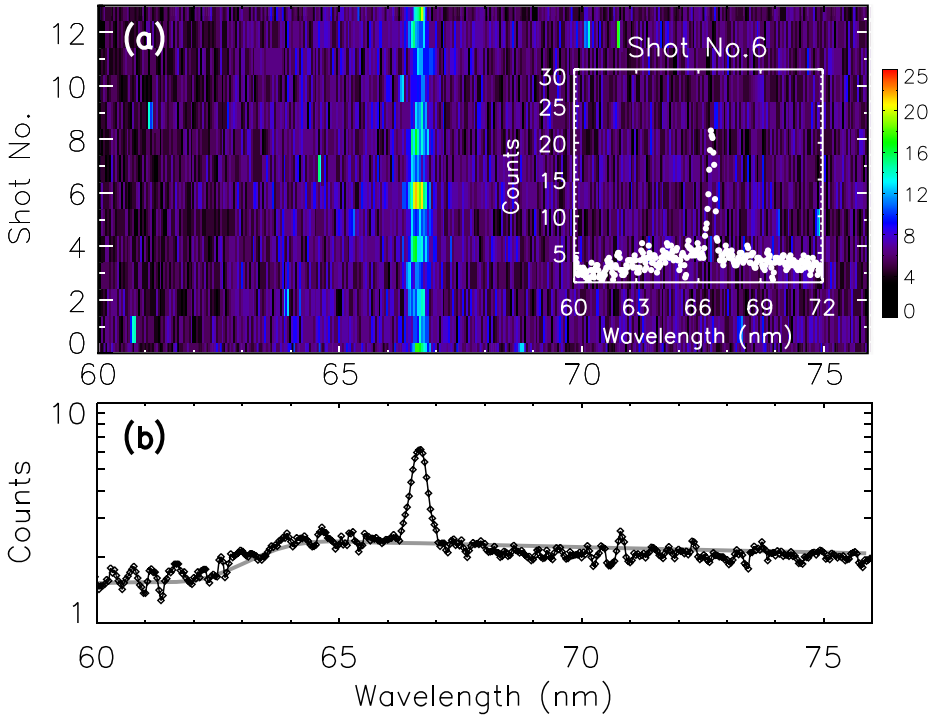
and partial coherence

Signal Averaging



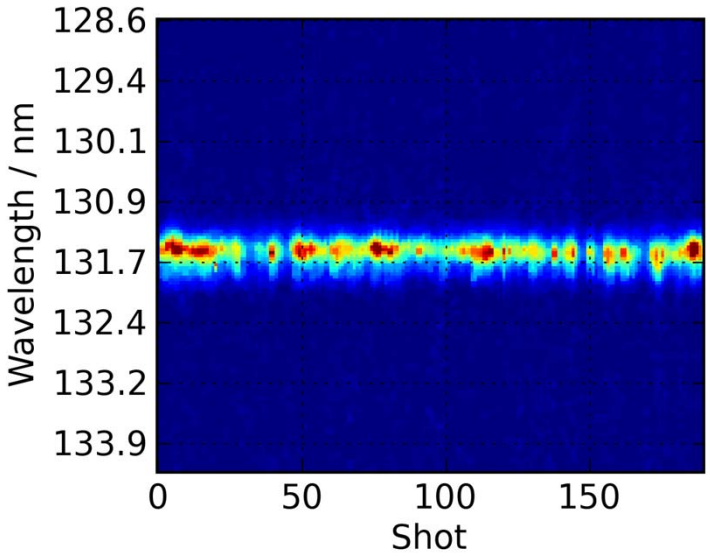
CHG at 2nd harmonic

CHG at 4th harmonic



Averaged spectra are broader than single shot spectra, higher stability required

Stability Issues

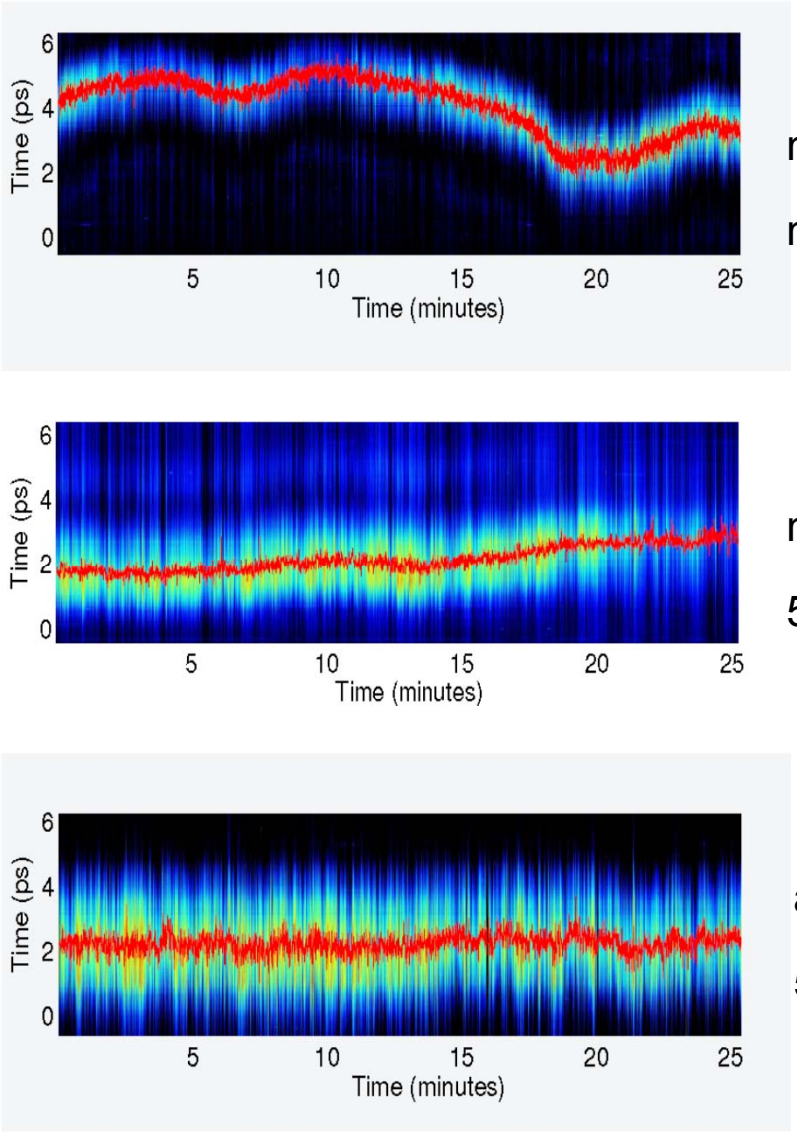


Reasons for signal fluctuation:

- jitter of bunch arrival time
- jitter of bunch transverse position

Stabilization via:

- EOS based arrival time stabilization
- (movement of optical delay stage)
- klystron modulators lock to 50 Hz
- still to be done:
  jitter gun-linac klystron



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