THz pump/probe facility @ FLASH2

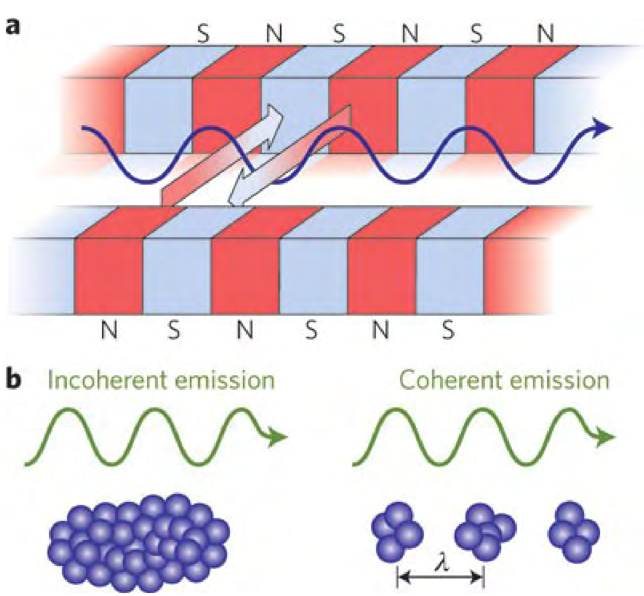
Nikola Stojanovic
New Science Opportunities at FLASH
Hamburg, 13.10.2011

HELMHOLTZ
ASSOCIATION

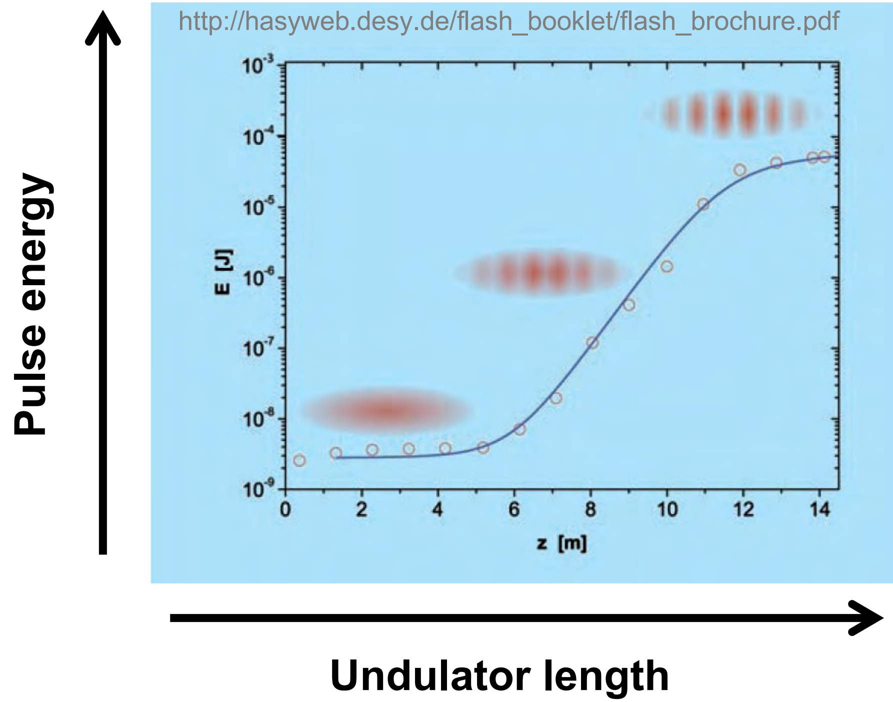
DESY

1.1 THz at FLASH

SASE – Self Amplified Spontaneous Emission



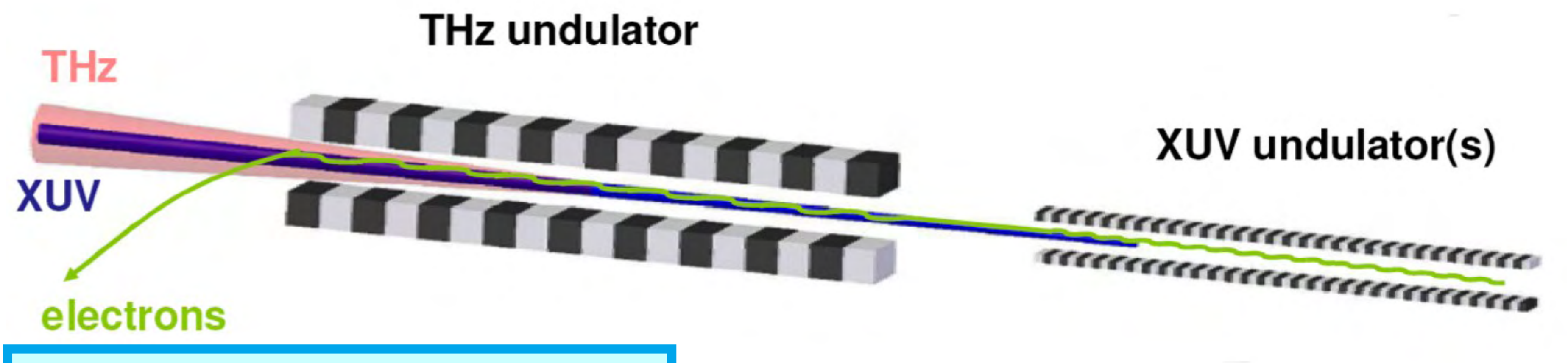
S. Jamison, *Nature Photonics* ***4*, 589 - 591 (2010)**



Electron beam requirements:

- High peak current – 10^3A
- Low emittance (low cross-section & divergence)
- Low energy spread (all electrons have same "velocity")

1.2 THz at FLASH – Source



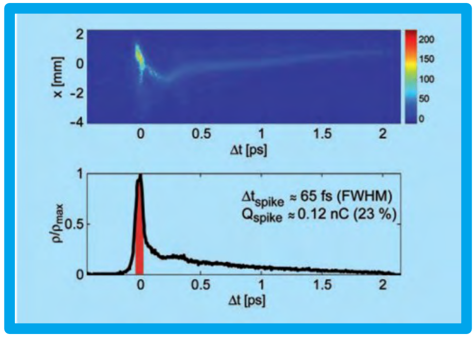
<u>Cascaded design</u>:

- Parasitic operation
- Synchronized to XUV pulse

<u>Short electron bunch</u>:

- Intensity ~ $\mathbf{N_e^2}$ **(up to 70uJ)**
- Coherent and CPE stable

<u>Tunable:</u> (10 – 230 um)

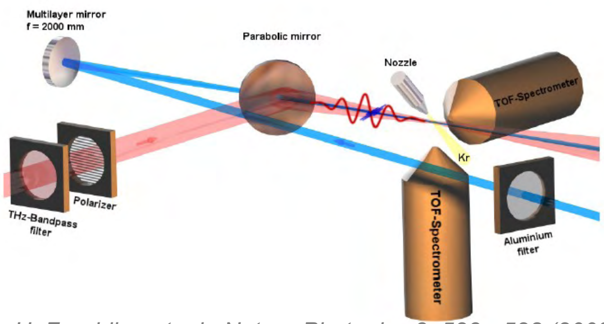


- B. Faatz et al., NIM A 475 (2001) 363.
- G. Geloni, E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov, Nucl. Instr. Method A 528 (2004) 184–188.
- Gensch, M. et al. New infrared undulator beamline at FLASH, Infrared Phys. Technol. 51, 423–425 (2008).

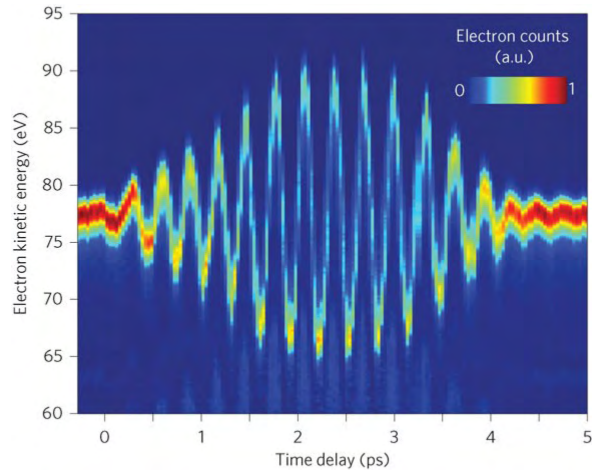
1.3 THz at FLASH – Coherence…

… and **C**arrier **E**nvelope **P**hase stability

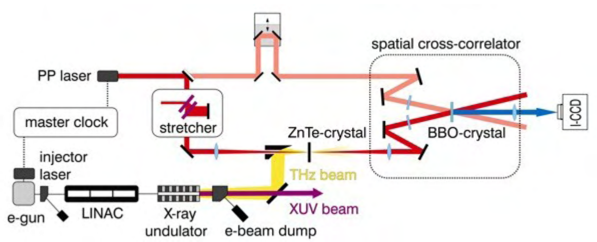
measured by streaking…



•*U. Fruehling et. al., Nature Photonics 3, 523 - 528 (2009)*

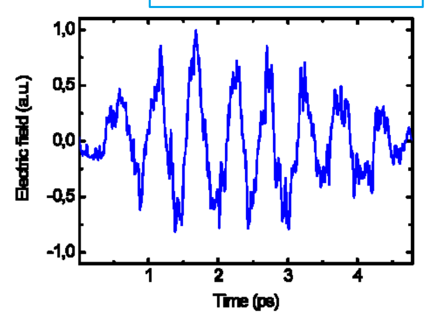


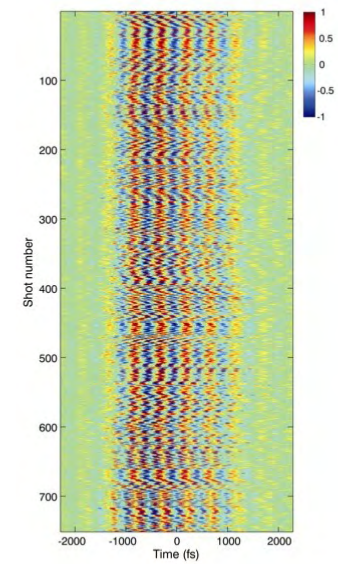
or **E**lectro **O**ptical **S**ampling …



F. Tavella, N. Stojanovic, G. Geloni, M. Gensch, Few fs synchronization at 4th generation light sources, *Nature Photon.* (2011).

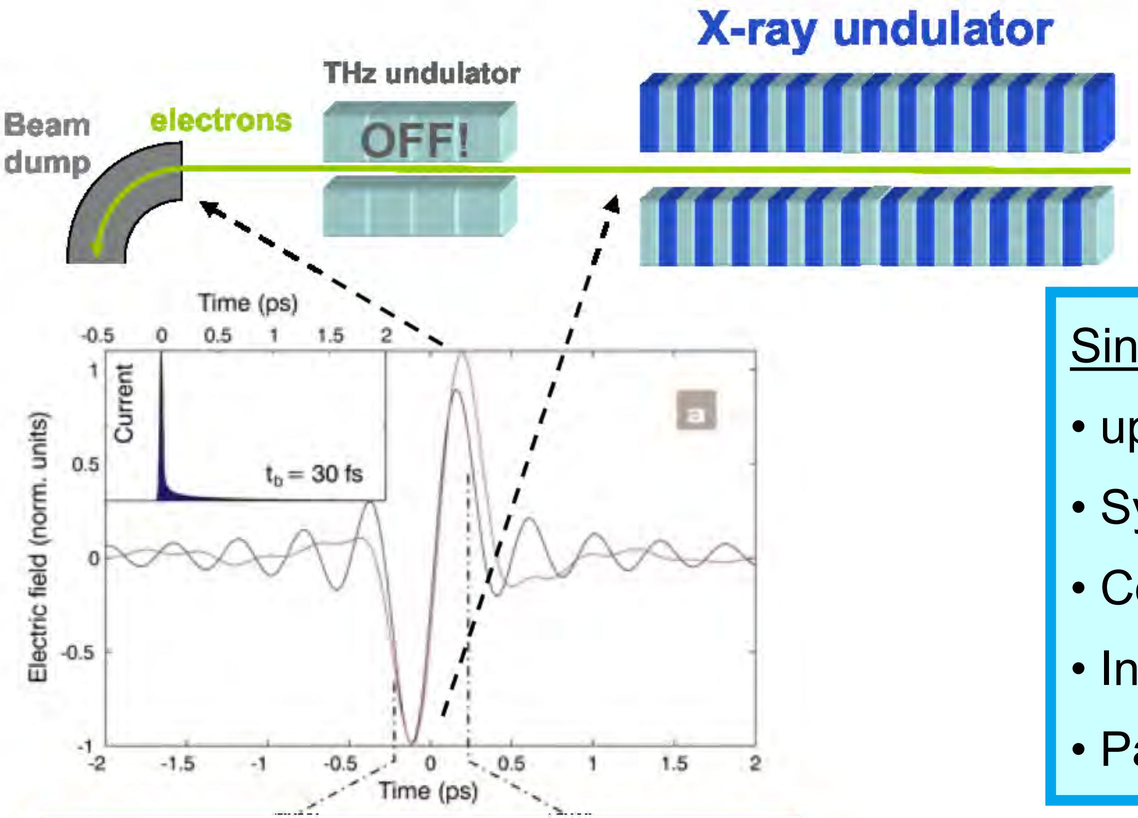
Single-shot





1.4 THz at FLASH – Single cycle

… for Free!



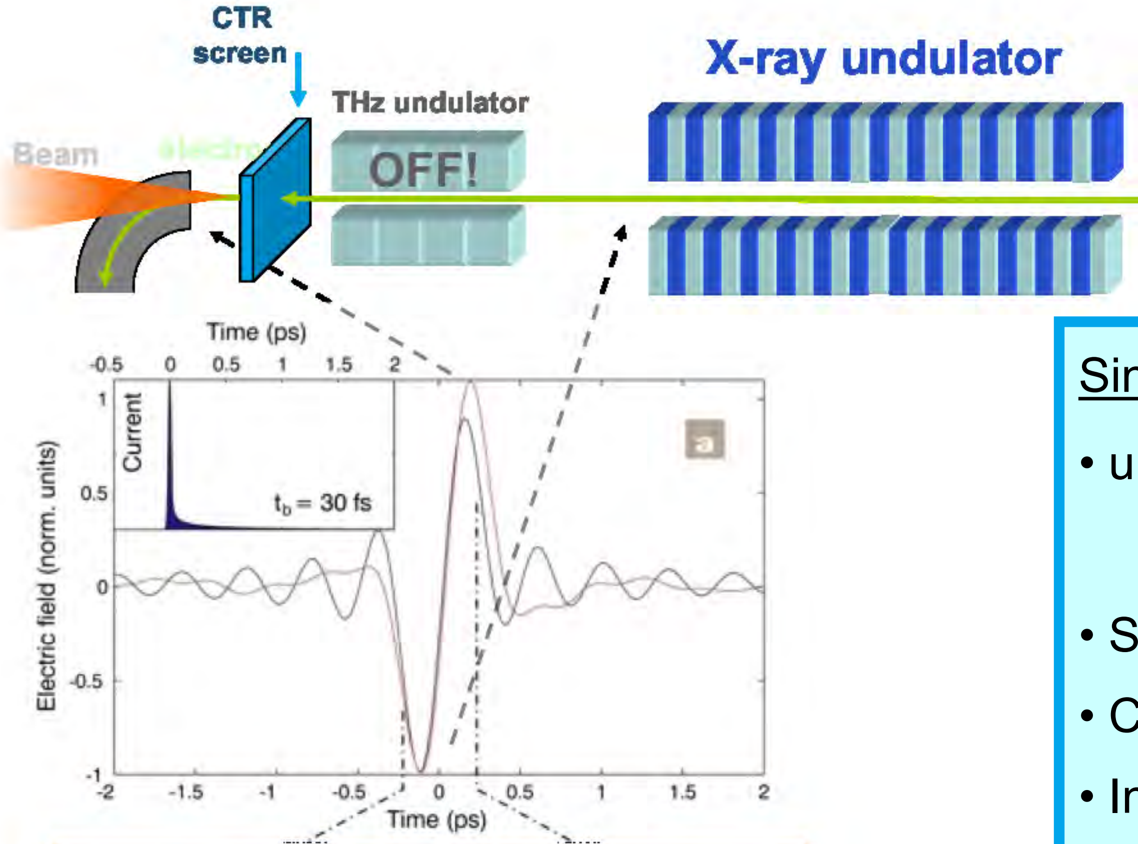
Calculation and measurement*

*F. Tavella, N. Stojanovic, G. Geloni, M. Gensch,
Few fs synchronization at 4th generation light sources, *Nature Photon.* (2011)

Single cycle (edge radiation):

- up to 10uJ
- Synchronized to XUV pulse
- Coherent and CPE stable
- Intensity ~ $\mathbf{N_e}^2$
- Parasitic

1.6 THz at FLASH – Single cycle (CTR)



Calculation and measurement*

*F. Tavella, N. Stojanovic, G. Geloni, M. Gensch,
Few fs synchronization at 4th generation light sources, *Nature Photon.* (2011)

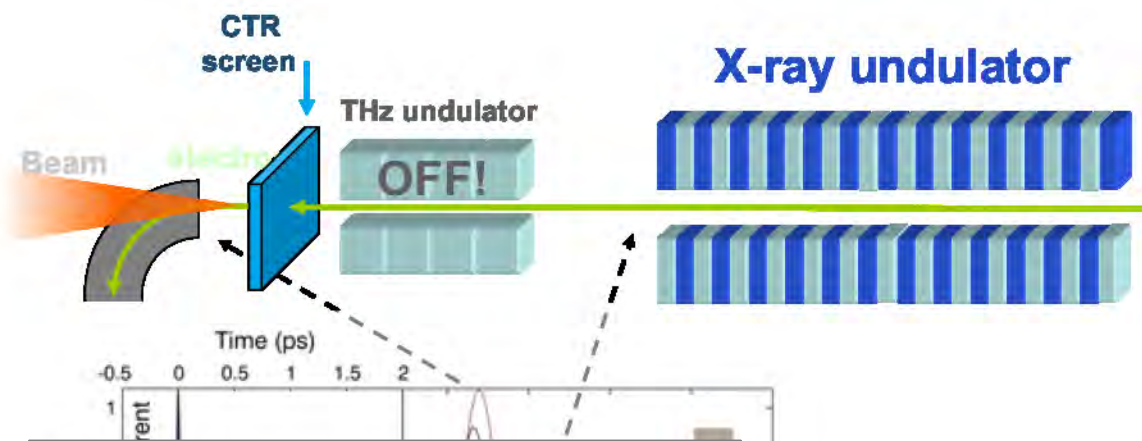
… for Free!

Single cycle (edge radiation):

- up to ~~10uJ~~ → **>100uJ !***
  - E≈1MV/m & B≈1T
- Synchronized to XUV pulse
- Coherent and CPE stable
- Intensity ~ $\mathbf{N_e}^2$
- Parasitic

M. C. Hoffmann** ***et al.**, Coherent single cycle pulses with MV/cm field strengths from a relativistic transition radiation light source, preprint** ***Optics Letters***

1.7 THz at FLASH – Single cycle (CTR)



… for Free!

...ngle cycle (edge radiation):

...p to ~~10uJ~~ → >100uJ !*

- E≈1MV/m & B≈1T

...ynchronized to XUV pulse

APS » Journals » Phys. Rev. ST Accel. Beams » Volume 12 » Issue 3

Phys. Rev. ST Accel. Beams 12, 030705 (2009) [13 pages]

Ultrabroadband terahertz source and beamline based on c...

2009@FLASH

Abstract | References | Citing Articles (7)

Download: PDF (1,357 kB), One-column PDF (1,372 kB) Export: BibTeX or EndNote (RIS)

S. Casalbuoni[1], B. Schmidt[2], P. Schmüser[2,3], V. Arsov[2], and S. Wesch[2]

[1]Institute for Synchrotron Radiation, Research Center Karlsruhe, P.O. Box 3640, D-76021 Karlsruhe, Germany
[2]Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22607 Hamburg, Germany
[3]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22607 Hamburg, Germany

Received 30 Oct...

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

2011@FLASH

Matthias C. Hoffmann[1,*], Sebastian Schulz[2], Stephan Wesch[2] ... Cavalleri[1,3] and Bernhard Schmi...

[1]Max Planck Research Department for Structural Dynamics, University of Hamburg - CFEL, Hamburg, Germany
[2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany
[3]Department of Physics, Clarendon Laboratory, University of Oxford, United Kingdom
*Corresponding author: matthias.c.hoffmann@mpsd.cfel.de

Received Month X, XXXX; revised Month X, XXXX; accepted Month X, XXXX; posted Month X, XXXX (Doc. ID XXXXX); published Month X, XXXX

Terahertz (THz) pulses with ... coherent transition radiation ... characterized in the time dom... 100 fs. High THz field streng... THz phenomena. © 2011 Op... OCIS Codes: 000.0000, 999...

Intense single-cycle THz pulses ... used to observe extreme nonlinear... high field strengths [1-3]. These pu...

C...

*F. Ta...

Few fs synchronization...

APPLIED PHYSICS LETTERS 99, 14111...

Single-cycle terahertz pulses with >0.2 V/Å field a... transition radiation

2011@LCLS

Dan Daranciang,[1,2] John Goodfellow,[3,4] Matthias Fuchs,[2] Haidan Wen,[5] Shambhu Ghimire,[2] David A. Reis,[2,4,6] Henrik Loos,[7] Alan S. Fisher,[7] and Aaron M. Lindenberg[2,3,4,a)]

[1]Department of Chemistry, Stanford University, Stanford, California 94305, USA
[2]PULSE Institute for Ultrafast Energy Science, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
[3]Department of Materials Science and Engineering, Stanford University, Stanford, California 94305, USA
[4]Stanford Institute for Materials and Energy Science, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
[5]Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois 60439, USA
[6]Department of Applied Physics, Stanford University, Stanford, California 94305, USA
[7]Linac Coherent Light Source, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA

(Received 26 July 2011; accepted 14 September 2011; published online 7 October 2011)

We demonstrate terahertz pulses with field amplitudes exceeding 0.2 V/Å generated by coherent transition radiation. Femtosecond, relativistic electron bunches generated at the Linac Coherent Light Source are passed through a beryllium foil, and the emitted radiation is characterized as a function of the bunch duration and charge. Broadband pulses centered at a frequency of 10 THz with energies of 140 μJ are measured. These far-below-bandgap pulses drive a nonlinear optical response in a silicon photodiode, with which we perform nonlinear autocorrelations that yield information regarding the terahertz temporal profile. Simulations of the spatiotemporal profile agree well with experimental results. © 2011 American Institute of Physics. [doi:10.1063/1.3646399]

FLASH @ 140 m – (B. Schmidt)

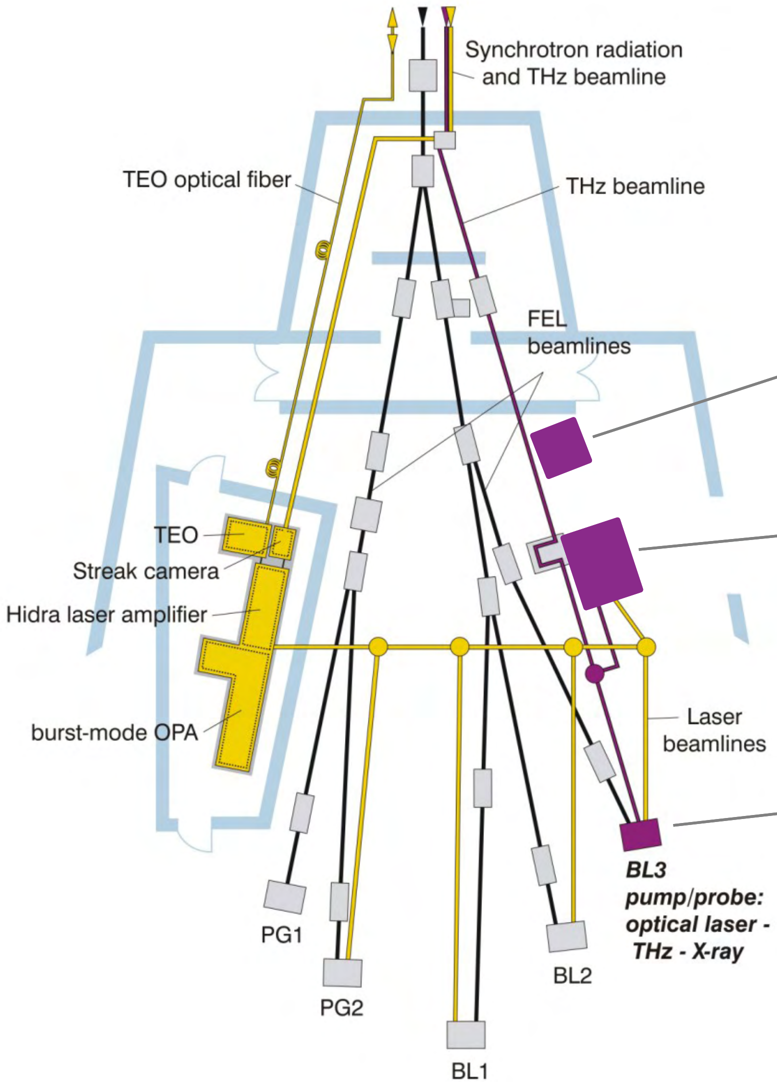
- el. bunch diagnostics
- EOS experiments

CTR - THz beamline @ HZDR

- already under construction
- collaboration w/ DESY

2.1 THz at FLASH – Beamline

… and THz ports



THz diagnostics port - THz only

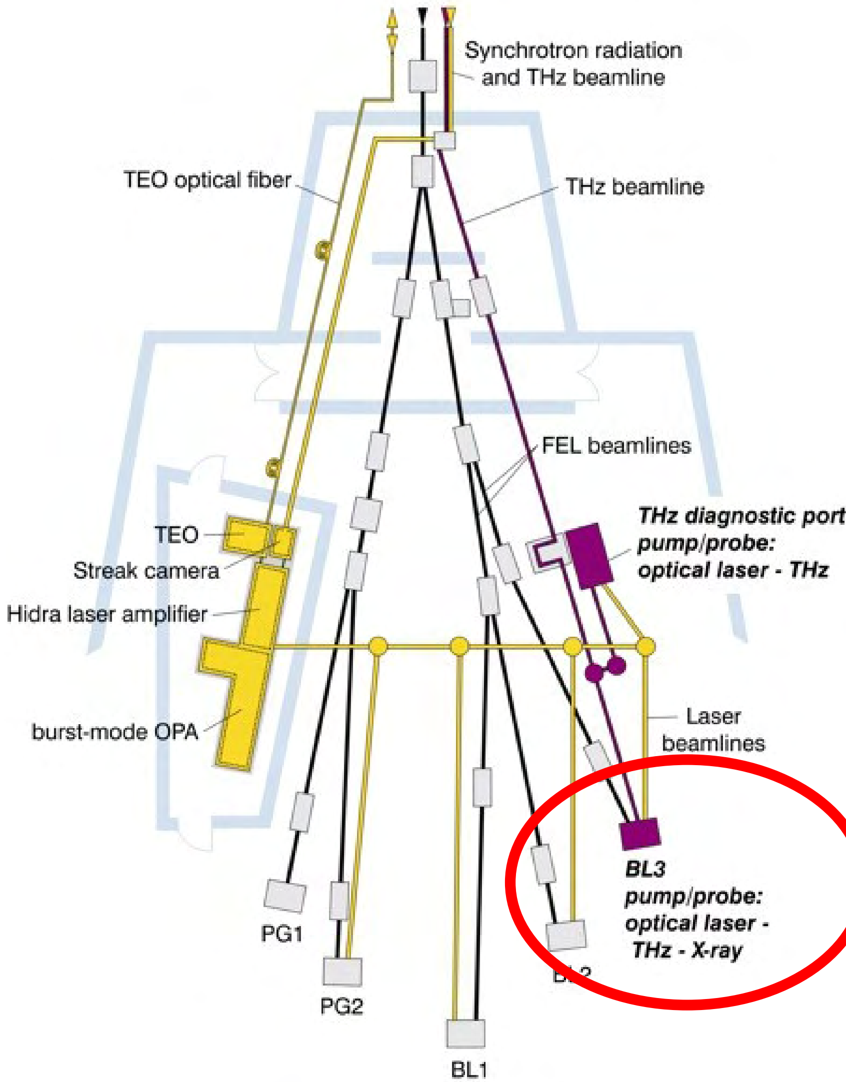
Pulse energy, spectrum …

THz pump/probe port - THz & VIS

Pulse duration, timing, experiments…

THz end station @BL3 - THz & VIS & XUV
User experiments …

2.2 THz at FLASH – User experiments



Resonant vibrational control in complex materials

1) *in strongly correlated oxides*

M. Gensch *(HZDR,Dresden)* + *CFEL …*

9 shifts

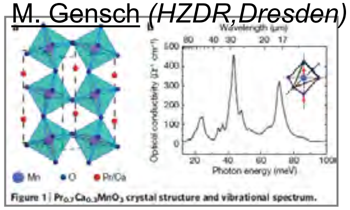
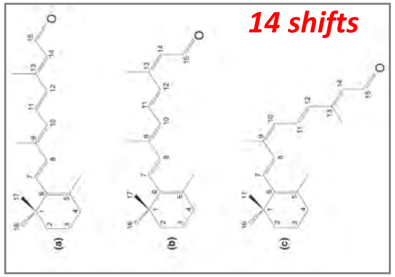


Figure 1 | $Pr_{0.7}Ca_{0.3}MnO_3$ crystal structure and vibrational spectrum.

2) of biomolecules

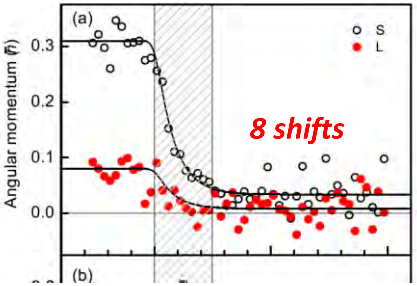
Dr. T. Laarmann (DESY) + …

14 shifts



3) Control of magnetization in ferromagnets

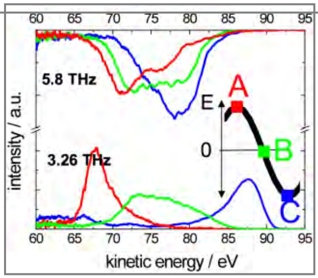
Dr. H. Duerr (SLAC) + CFEL + DESY + UNI HH…



8 shifts

4) Photoelectron Streaking

UNI-HH + DESY + …



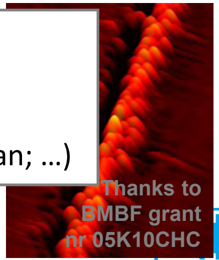
8 shifts

5) Pulse duration + *Timing*

20 shifts

DESY + users

(P. Johnsson; T. Laaeman; …)



Thanks to BMBF grant nr 05K10CHC

2.3 THz at FLASH – User experiments

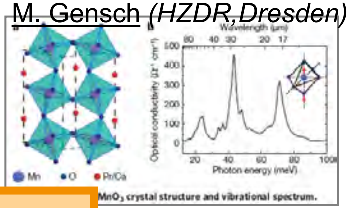
More than 700 hours of THz operation!

Resonant vibrational control in complex materials

1) in strongly correlated oxides

M. Gensch *(HZDR,Dresden)* + *CFEL …*

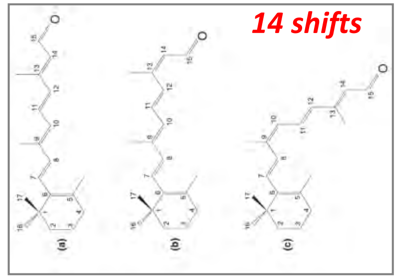
9 shifts



2) of biomolecules

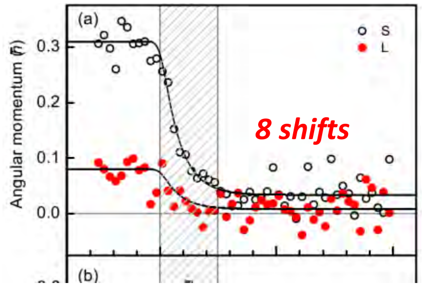
Dr. T. Laarmann (DESY) + …

14 shifts



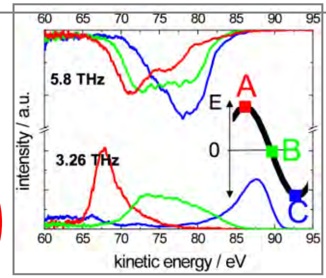
3) Control of magnetization in ferromagnets

Dr. H. Duerr (SLAC) + CFEL + DESY + UNI HH…



8 shifts

4) Photoelectron Streaking UNI-HH + DESY + …

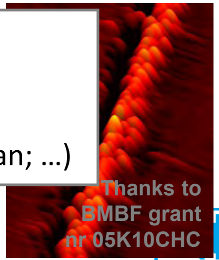


8 shifts

5) Pulse duration + ***Timing*** **20 shifts**

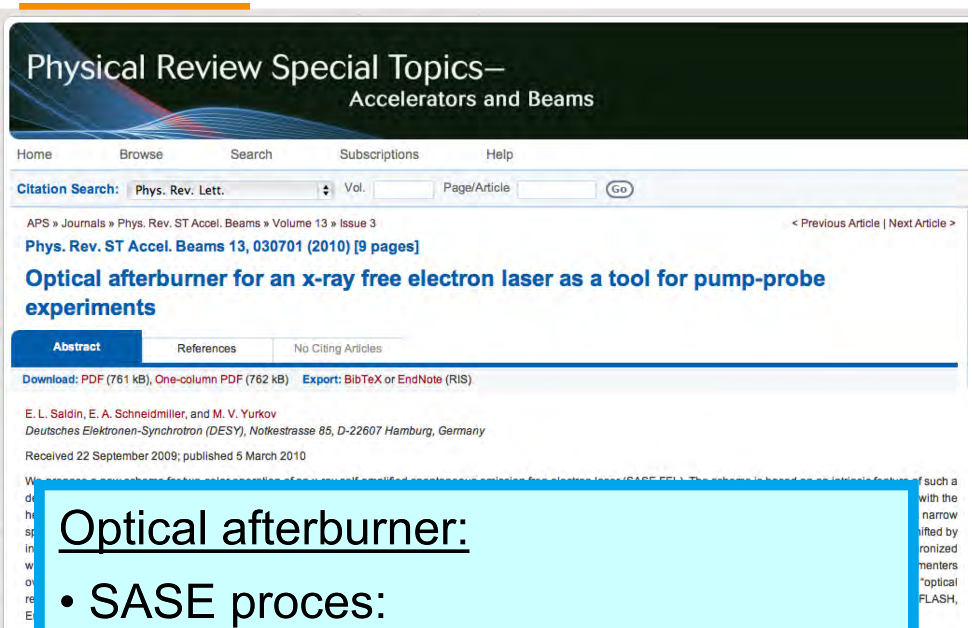
DESY + users

(P. Johnsson; T. Laaeman; …)



3.1 THz at FLASH – Optical afterburner

An idea



Physical Review Special Topics– Accelerators and Beams

Home Browse Search Subscriptions Help

Citation Search: Phys. Rev. Lett. Vol. Page/Article Go

APS » Journals » Phys. Rev. ST Accel. Beams » Volume 13 » Issue 3 < Previous Article | Next Article >

Phys. Rev. ST Accel. Beams 13, 030701 (2010) [9 pages]

Optical afterburner for an x-ray free electron laser as a tool for pump-probe experiments

Abstract References No Citing Articles

Download: PDF (761 kB), One-column PDF (762 kB) Export: BibTeX or EndNote (RIS)

E. L. Saldin, E. A. Schneidmiller, and M. V. Yurkov

Deutsches Elektronen-Synchrotron (DESY), Notkestrasse 85, D-22607 Hamburg, Germany

Received 22 September 2009; published 5 March 2010

FIG. 1. (Color) Scheme of the afterburner for pump-probe experiments at an x-ray FEL.

Optical afterburner:

- SASE proces:
  - modulations of the electron bunch energy (VIS/NIR scale)
- Dispersion section:
  - energy ➔ density modulations
- Radiator:

E.L. Saldin, E.A. Schneidmiller and M.V. Yurkov, *Phys. Rev. ST Accel. Beams 13, 030701 (2010)*

Modulated density profile

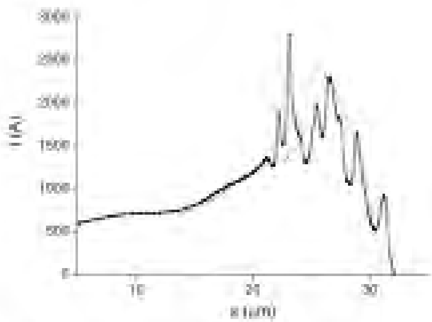


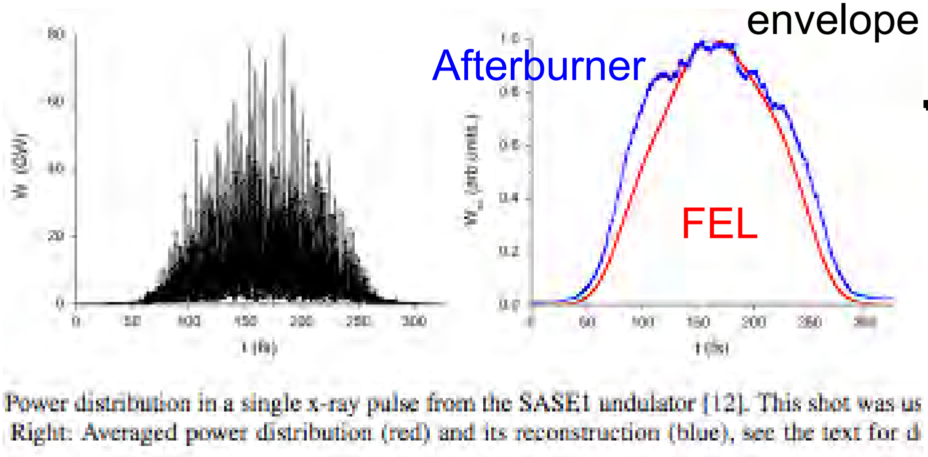
FIG. 8. Modulation of current in the head of electron bunch lasing at 7 nm in the VUV undulator of FLASH and passing FIR undulator with R_{56} equal to 250 μm (solid), and with $R_{56} = 0$ (dots). Only the small part of the bunch is shown; the bunch head is on the right.

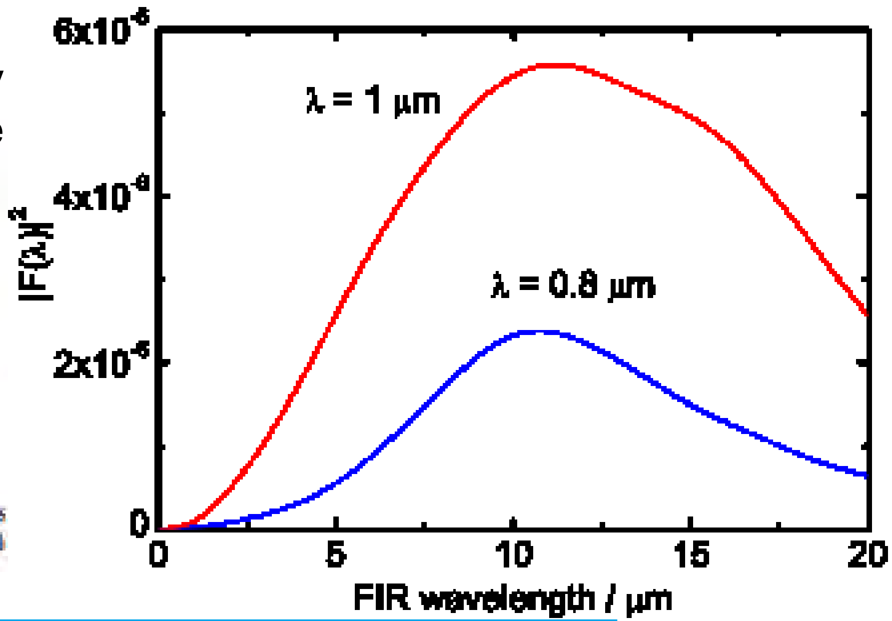
3.2 THz at FLASH – Optical afterburner

An idea

Single FEL pulse

Averaged intensity envelope





Optical afterburner - optical replica of SASE pulses:

- Pulse duration
- Time marker (for sync. with ext. sources)
- Synchronized VIS/NIR source
  - covers the gap from 0.6 - 30um

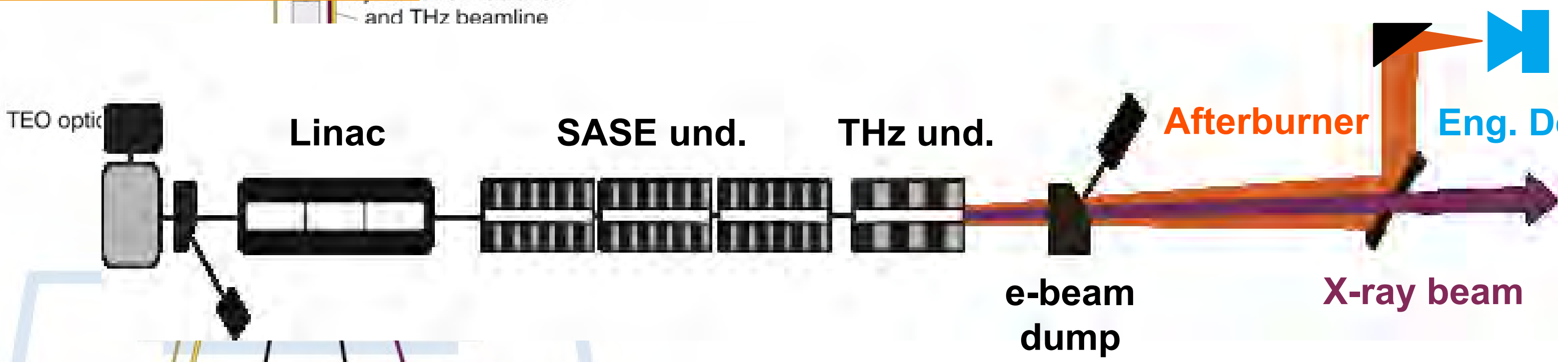
* E.L. Saldin, E.A. Schneidmiller and M.V. Yurkov, *Phys. Rev. ST Accel. Beams 13, 030701 (2010)*

* THPC084, Proceedings of IPAC2011, San Sebastián, Spain

DESY

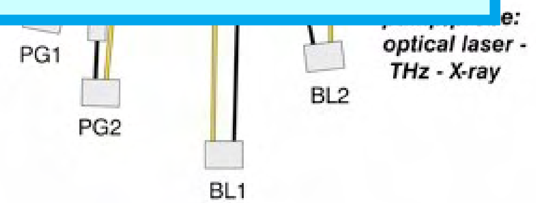
3.3 THz at FLASH – Optical afterburner

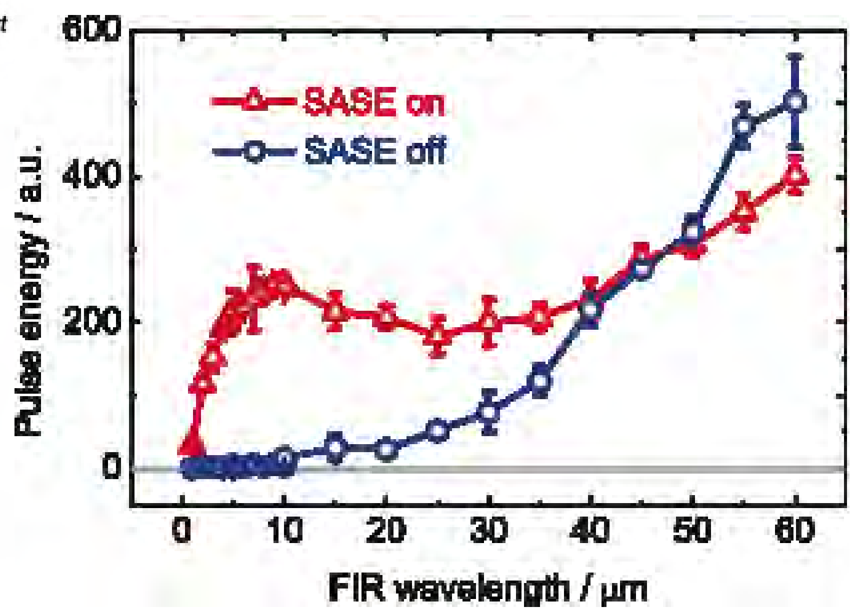
Proof of principle



THz undulator:

- Dispersion section + radiator
- SASE >100uJ @ 20nm
  - also @ 13.7nm, 7nm, 8nm, 5.9nm, 4.8nm, 4.3nm …

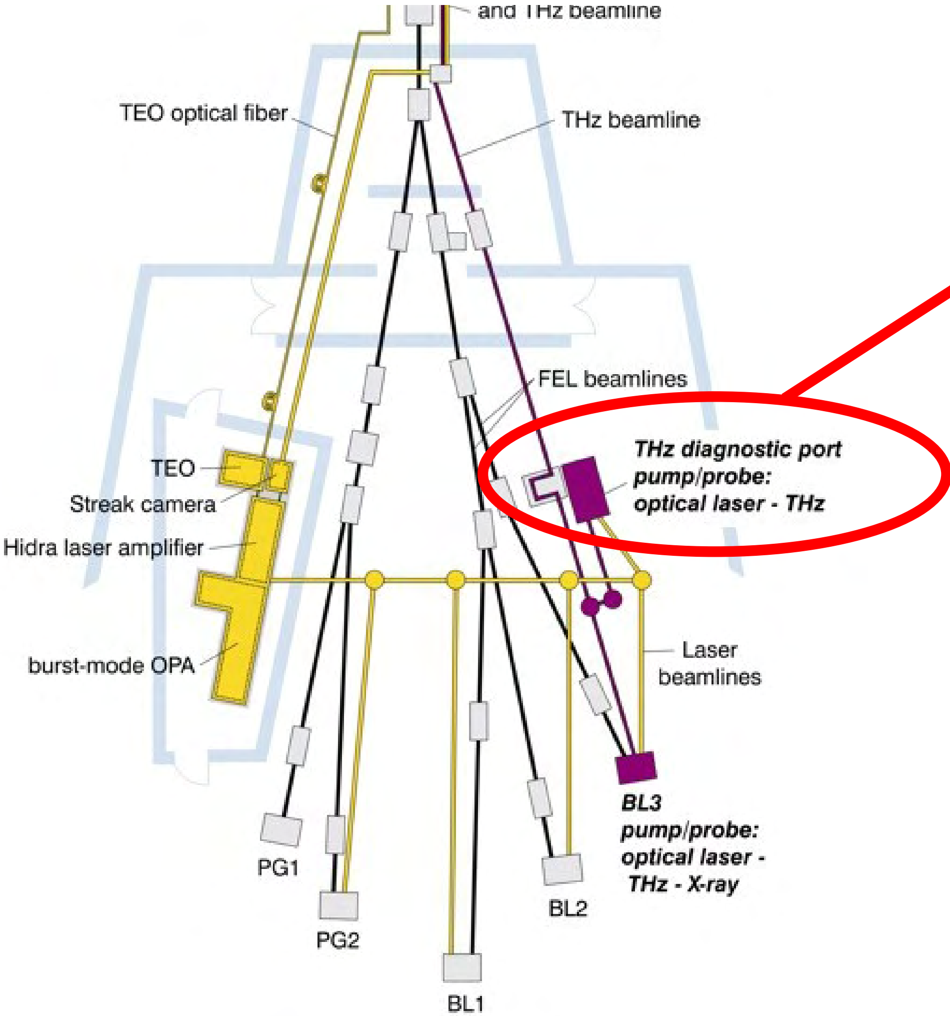


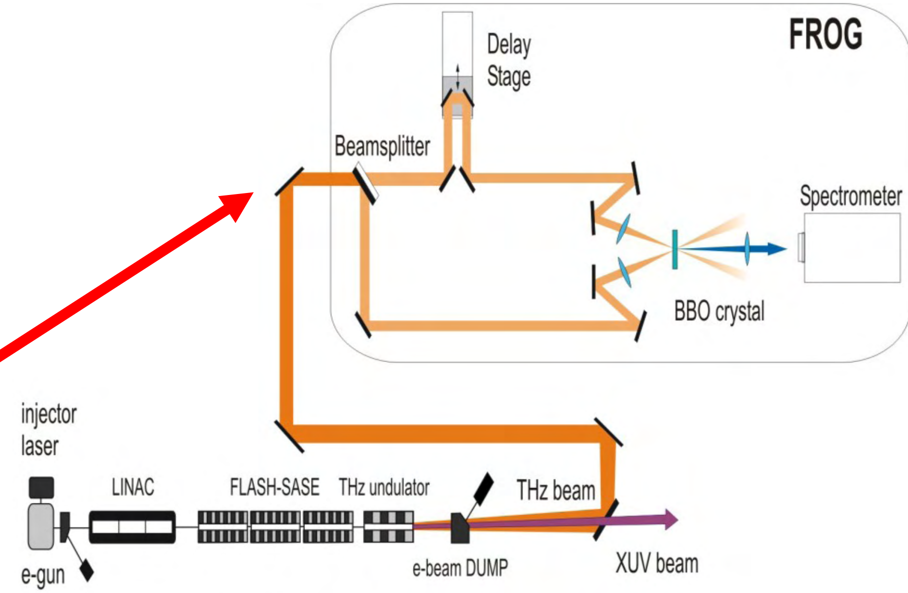


* THPC084, Proceedings of IPAC2011, San Sebastián, Spain

3.3 THz at FLASH – Optical afterburner

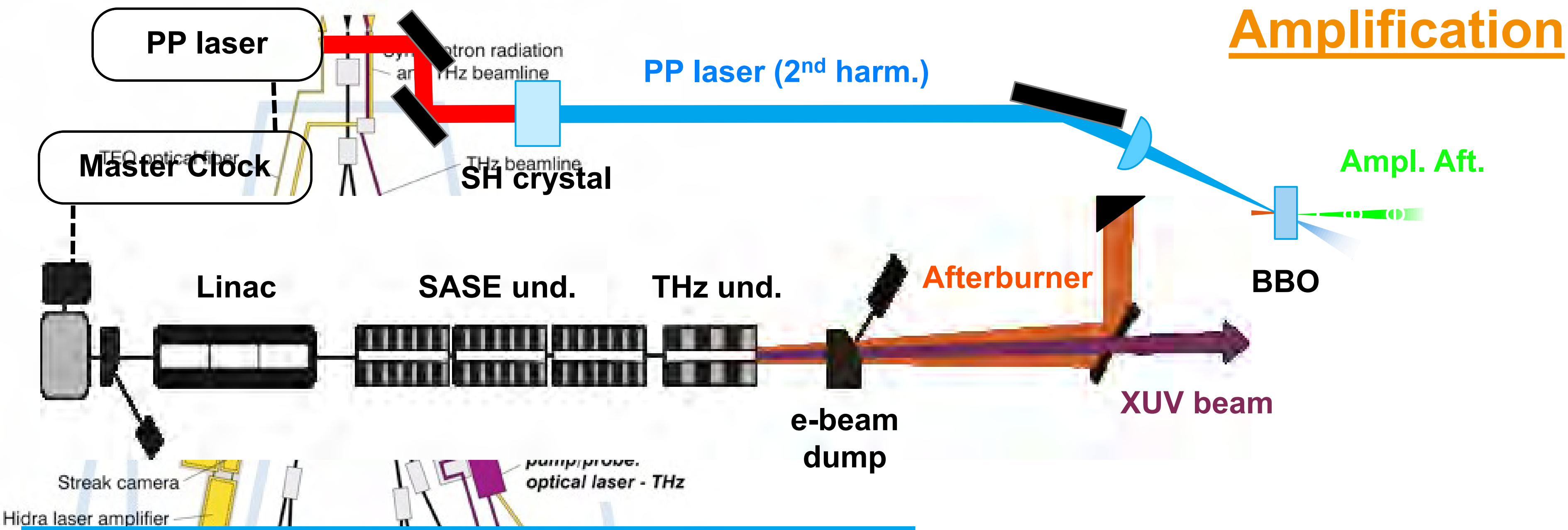
XUV pulse duration





This work is supported by the BMBF grant nr. 05K10CHC and a collaboration of DESY, HZDR, TUB, FUB.

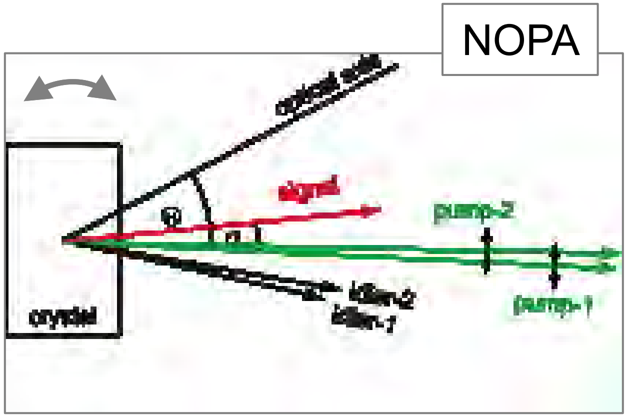
3.5 THz at FLASH – Optical afterburner



Non-colinear Optical Parametric Amplifier:

- broadband – short pulses
- tunable
- high gain

*E. Riedle et al., "Generation of 10 to 50 fs pulses tunable through all of the visible and the NIR"Appl. Phys. B, 71, 457-465, (2000)

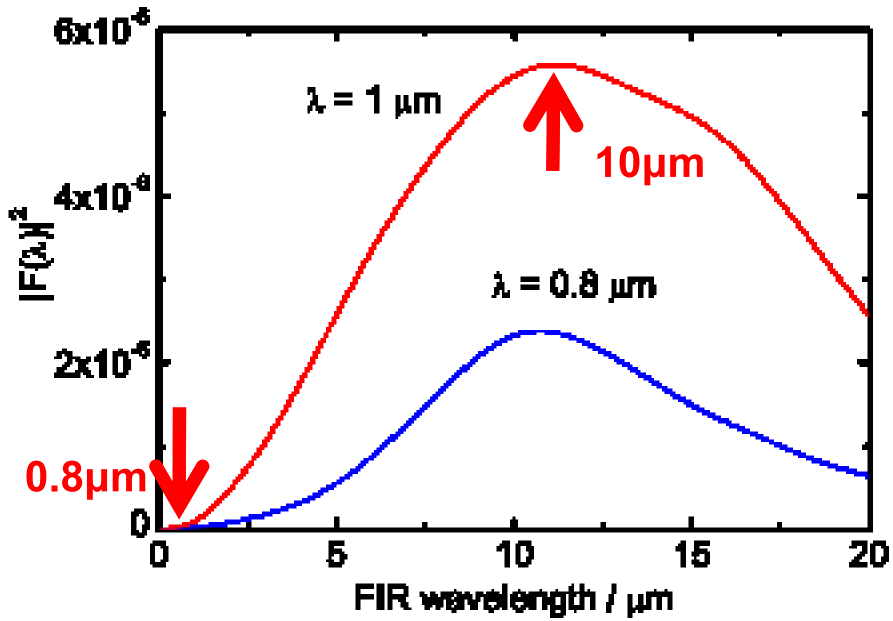


3.7 THz at FLASH – Optical afterburner

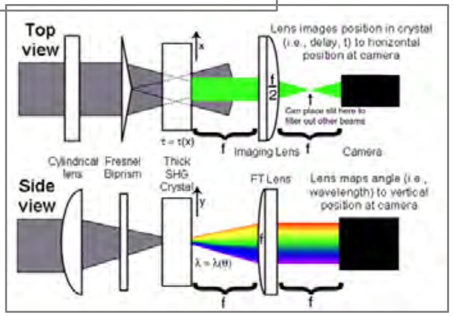
Single-shot pulse duration

FROG

➔ Single shot



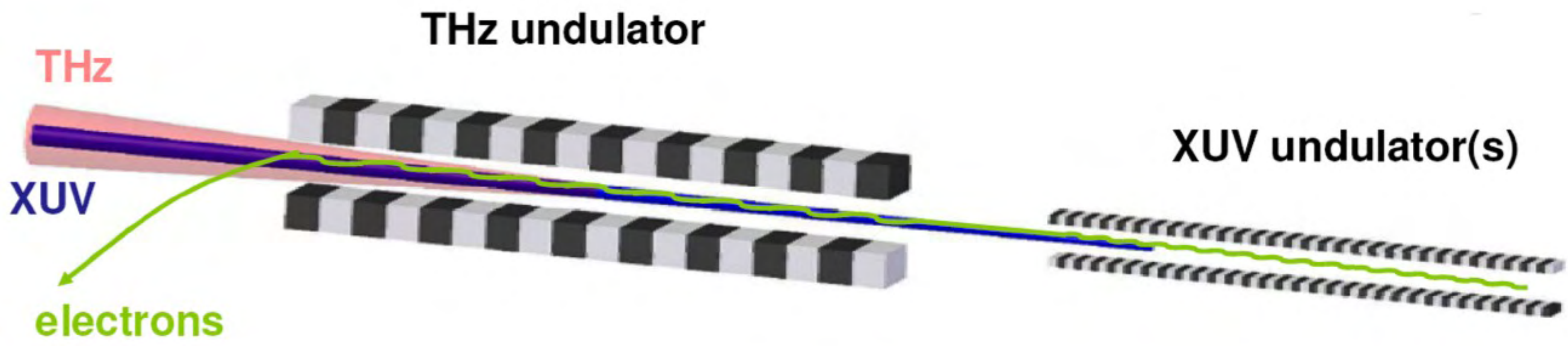
GRENOUILLE

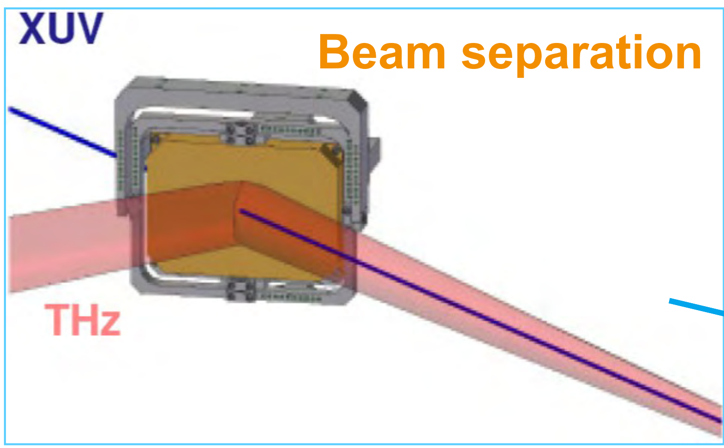


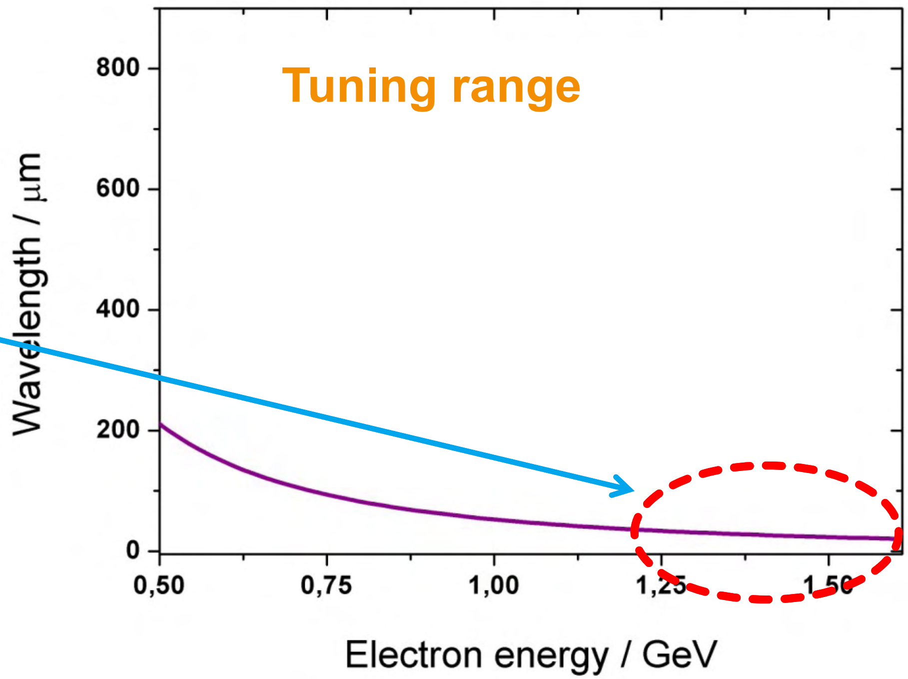
<u>Single-shot pulse duration:</u>

- Not enough intensity @ VIS
- Shifting to NIR-MIR
- Upgrade of detectors …

4.1 THz at FLASH – Existing design



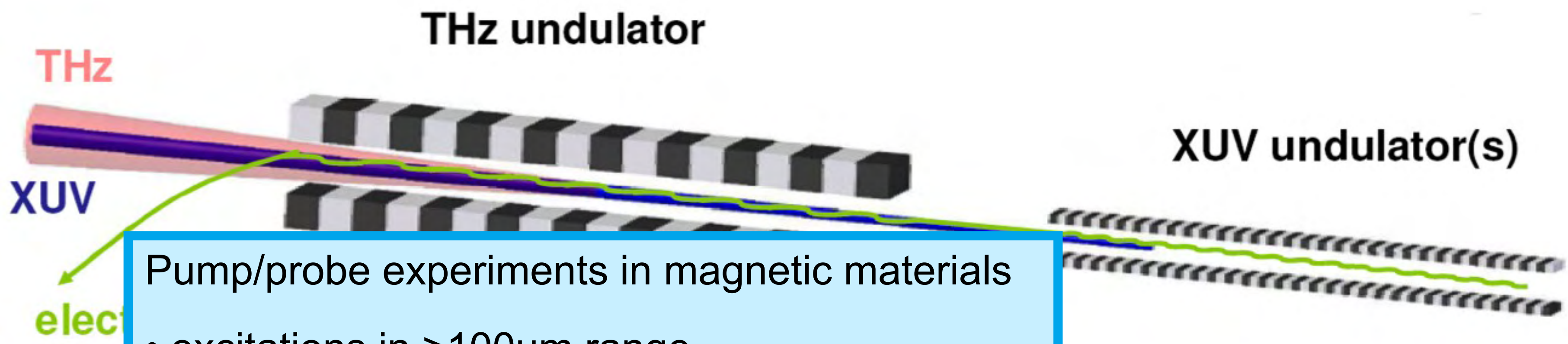




Peak Magnetic field 1.2T (K=44)

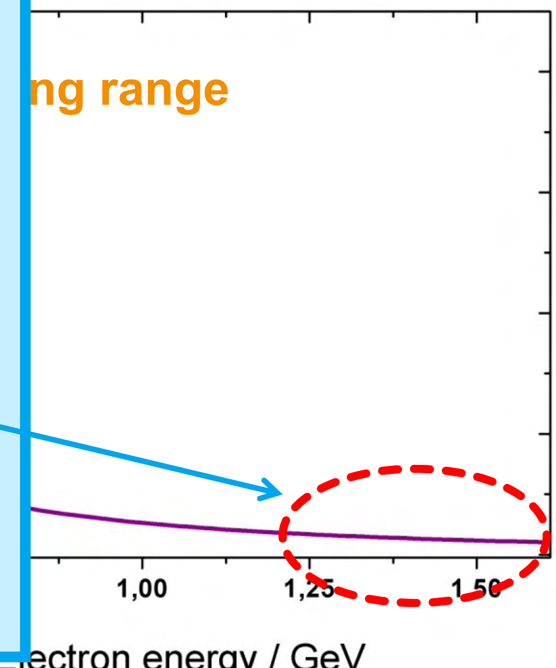
- B. Faatz et al., NIM A 475 (2001) 363.
- G. Geloni, E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov, Nucl. Instr.
- Gensch, M. et al. New infrared undulator beamline at FLASH, Infrared Phys. Technol. 51, 423–425 (2008).

4.2 THz at FLASH – Existing design



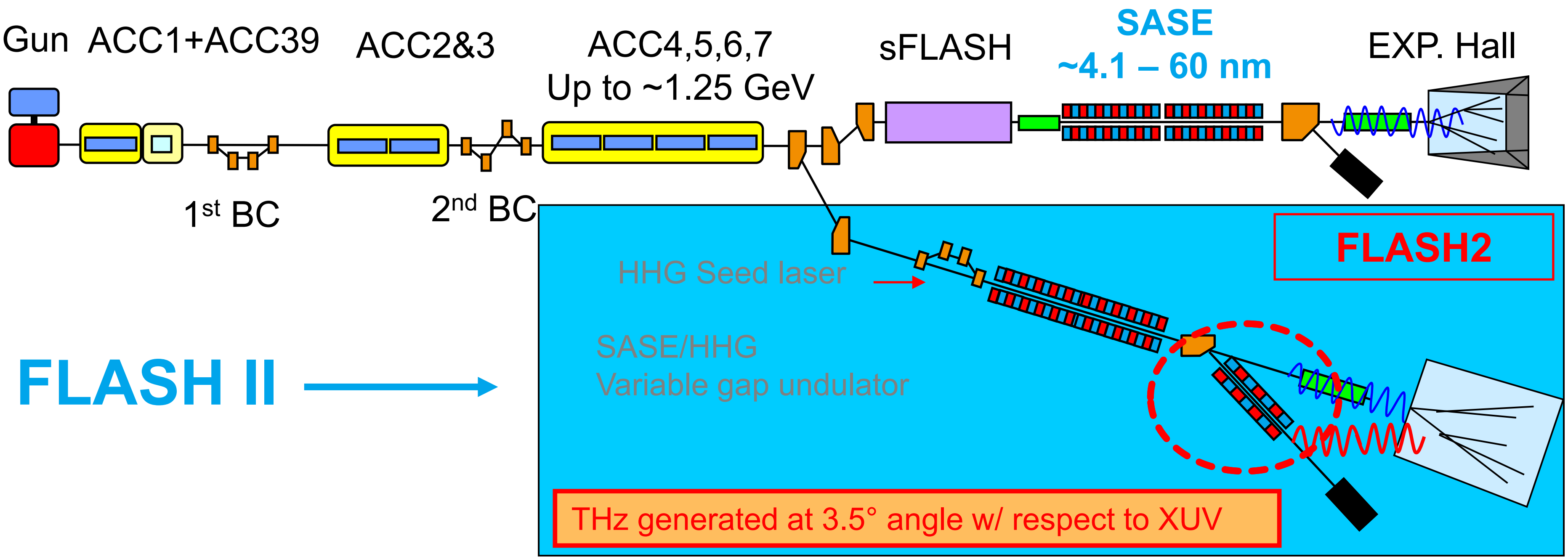
Pump/probe experiments in magnetic materials

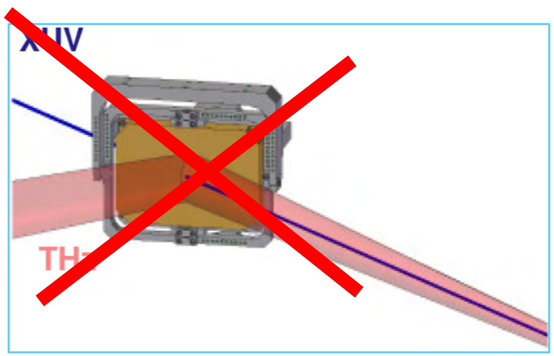
- excitations in >100um range
- short XUV wavelengths (<2nm)
- existing THz undulator at FLASH
  - 33um @ 1.25GeV
  - 21um @ 1.6GeV
  - **Solution:**
    - **Higher magnetic field**
    - **Longer undulator period**



• B. Faat…
• G. Geld…
• Gensch, M. et al. New infrared undulator beamline at FLASH, Infrared Phys. Technol. 51, 423–425 (2008).

4.3 THz at FLASH2

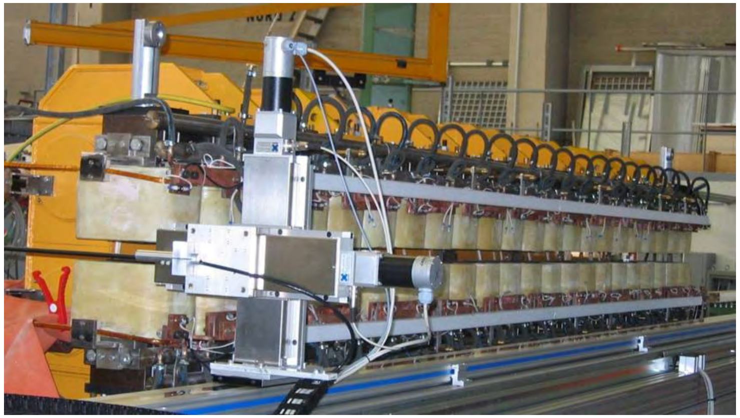




- Aperture-free optics:
  - reduced THz losses,
  - improved beam quality
  - prevents <u>unlikely</u> leakage of THz and VIS/NIR to X-ray beamlines

4.4 THz at FLASH2 - Source

Normal conducting

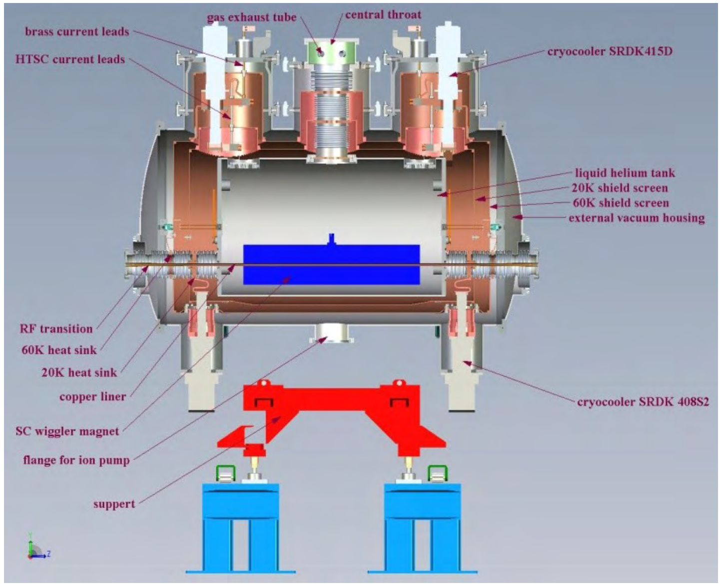


- Moderate field 1.2T (K = 44)
- Variable period
- ...

Available space <3.4m (length)

- Width <1m

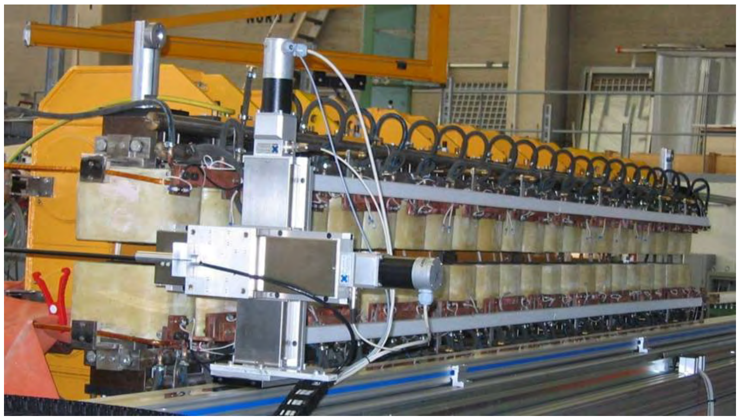
Superconducting



- Extremely high field (K>100)
- Low power consumption
- ...

4.5 THz at FLASH2 - Source

Normal conducting

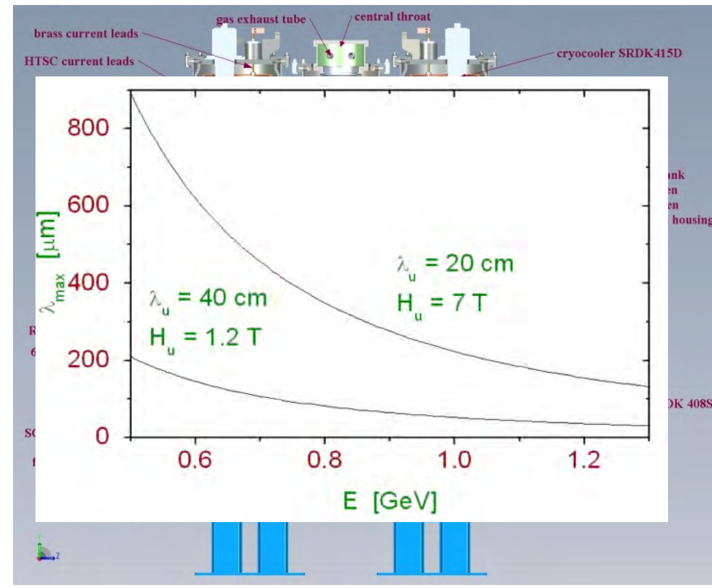


- Moderate field 1.2T (K = 44)
- Variable period
- ...

Available space <3.4m (length)

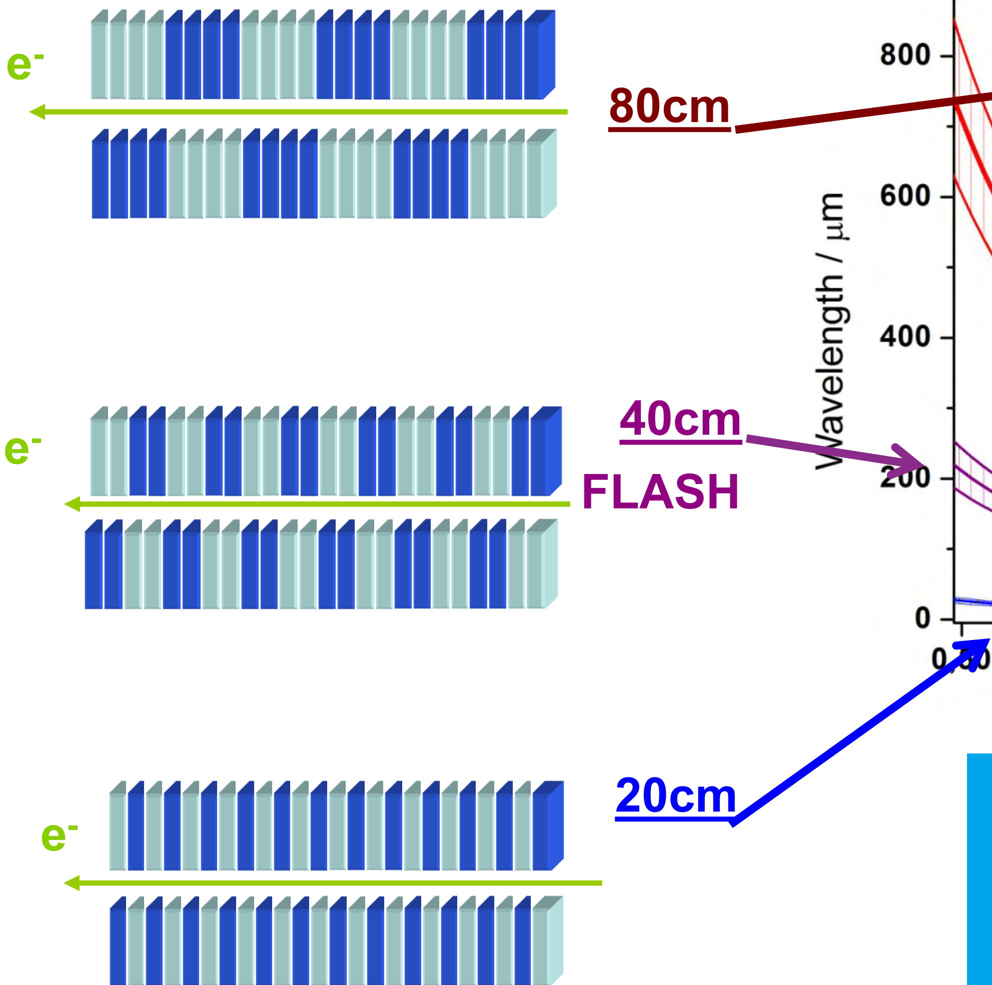
- Width <1m

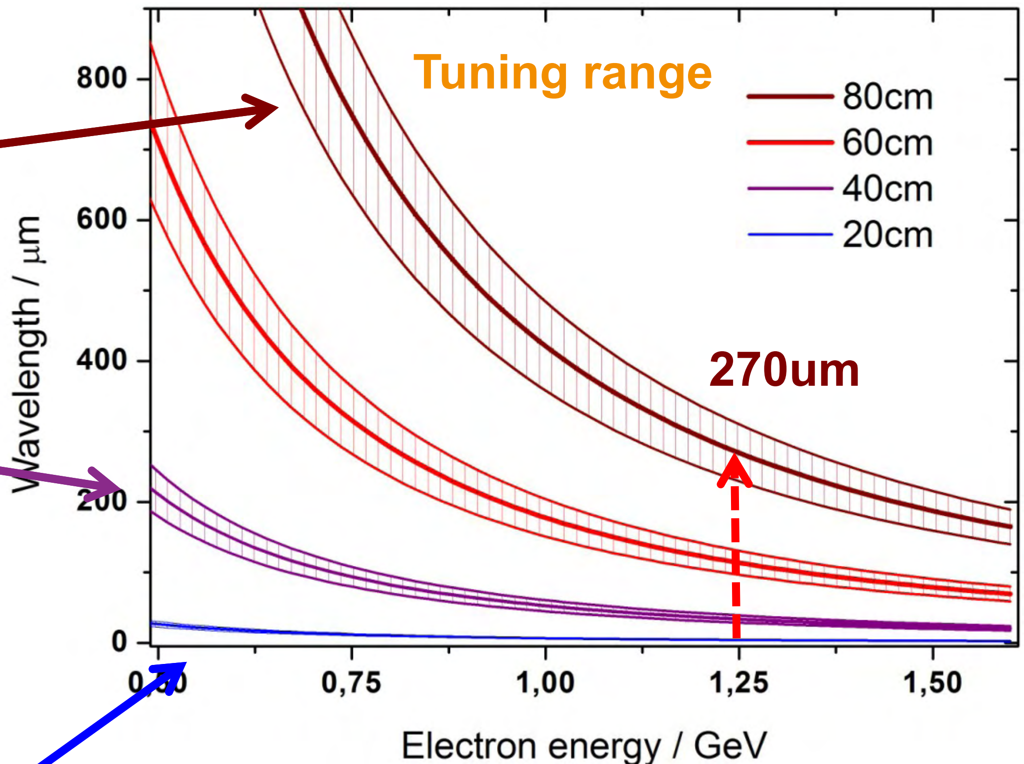
Superconducting



- Extremely high field (K>100)
- Low power consumption
- ...

4.6 THz at FLASH2 - Source



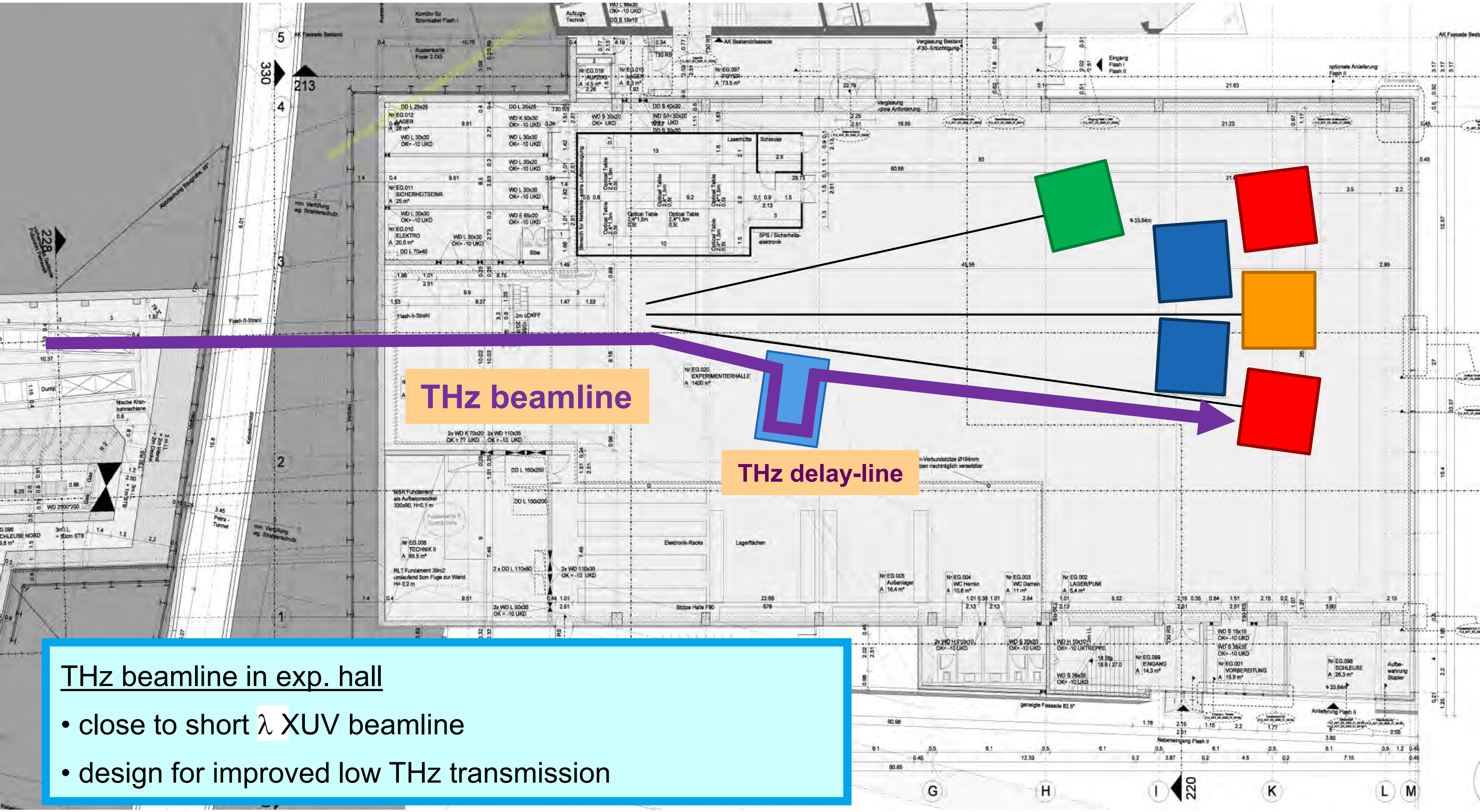


Peak magnetic field 1.2T

Variable undulator period:

- Extremely wide tuning range
- Spectral bandwidth control
  - (8%-30%)

4.7 THz at FLASH2 - Beamline



THz beamline in exp. hall

- close to short λ XUV beamline
- design for improved low THz transmission

4.8 THz at FLASH2 - Summary

THz pump probe facility at FLASH2

- There is motivation behind great THz success at FLASH
- Two potential designs
- No have funding yet (but might be there soon ...)
- DESY, HZDR, BINP (Novosibirsk)
- Use reserved space of 3.4m length in FLASH2 tunnel
- Electrical and cooling installations (100kW in case of NC)
- Earliest installation on 2013
    - Installation preparation before is already taking place
- THz installation would hugely benefit from 2nd harmonic XUV afterburner (magnetization dynamics experiments)

THz at FLASH - who's behind it?

N. Stojanovic, A. Al-Shemmary,
B. Faatz, T. Laarmann,
M. Yurkov, E. Schneidmiller,
G. Geloni, V. Kocharyan, E. Saldin,
M. Tischer, J. Feldhaus (DESY)
and of course FLASH team

M. Gensch, W. Seidel (HZDR)

M. Foerst, (MPSD-CFEL)

R. Riedel, F. Tavella, Helmholtz-Institut-Jena,

Budker Institute for Nuclear Physics

and through the PIDID Proposal
BMBF grant no 05K10CHC +
BMBF grant no 05K10KEB

Thanks!