WP 4 Status: Femtosecond beamline at FLASH

Alaa Al-Shemmary
WP 4: Femtosecond beamline at FLASH
Hamburg, 16 December 2011

HELMHOLTZ ASSOCIATION

DESY

WP 4 Goals

- **WP4.1.1**: DESY will perform detail characterization of the FLASH edge radiation in collaboration with THz experts from Budker institute and FZB.
- **WP 4.1.2**: Modelling of the edge amplification: DESY, Budker institute, LITP and TUKL will develop physical model for generation of the edge radiation and calculate optimal parameters for its amplification (e.g. geometry, amplification medium, pump wavelength).
- **WP 4.1.3**: Test of edge radiation amplification using existing laser system at FLASH: experiment will be led by DESY in collaboration with THz experts from Budker institute and FZB as well as with parametric amplification experts from AG Cavalleri.
- **WP 4.1.4**: Upgrade of THz experimental station will be performed by DESY.
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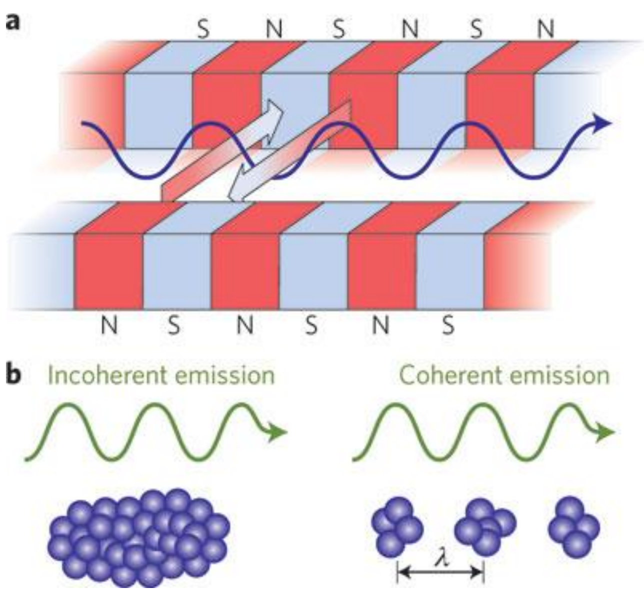
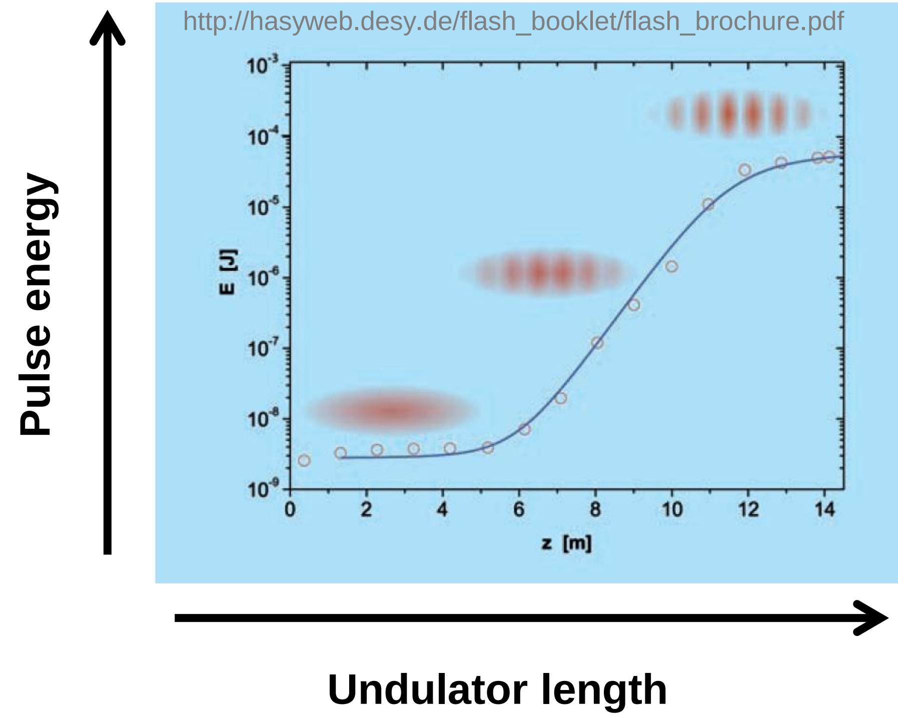
Overview: FLASH

SASE – Self Amplified Spontaneous Emission



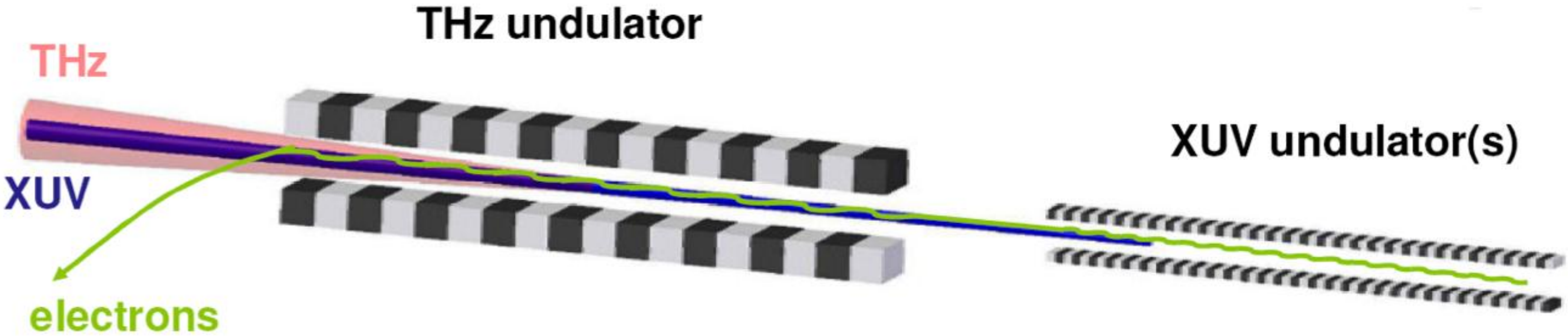
S. Jamison, *Nature Photonics* ***4*, 589 - 591 (2010)**



Electron beam requirements:

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

Overview: THz at FLASH - Source



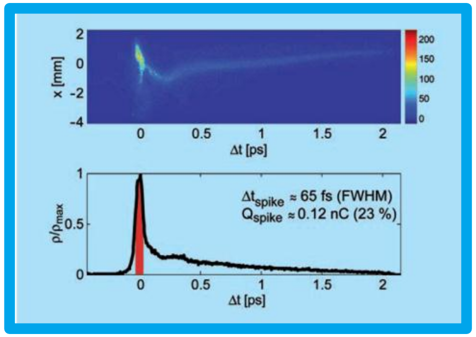
<u>Cascaded design</u>:

- Parasitic operation
- Synchronized to XUV pulse

<u>Short electron bunch</u>:

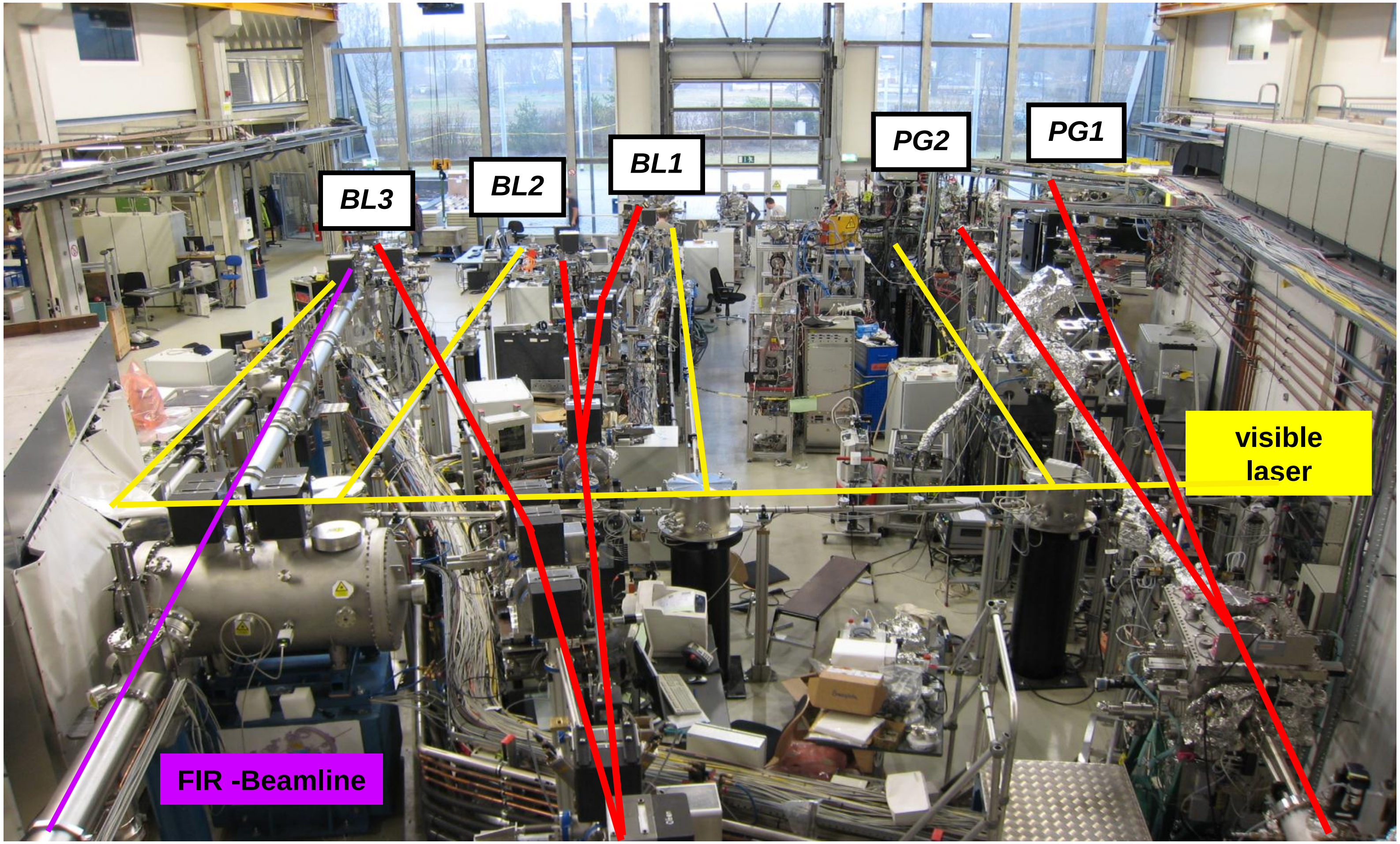
- Intensity ~ $\mathbf{N_e^2}$ **(up to 70uJ)**
- Coherent and CPE stable

<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).

Overview: FLASH experimental Hall



Overview: Pump probe experiments

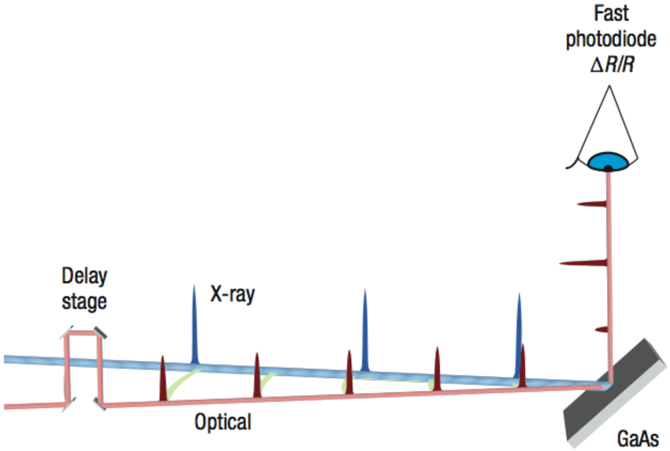
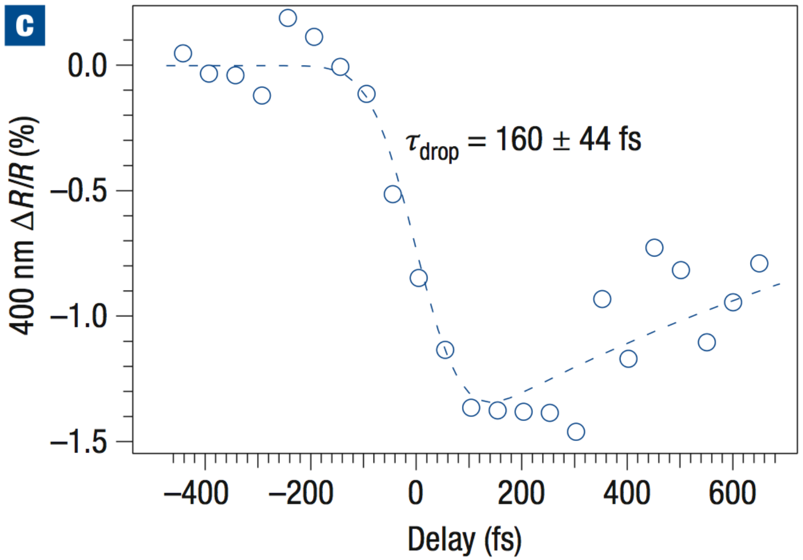
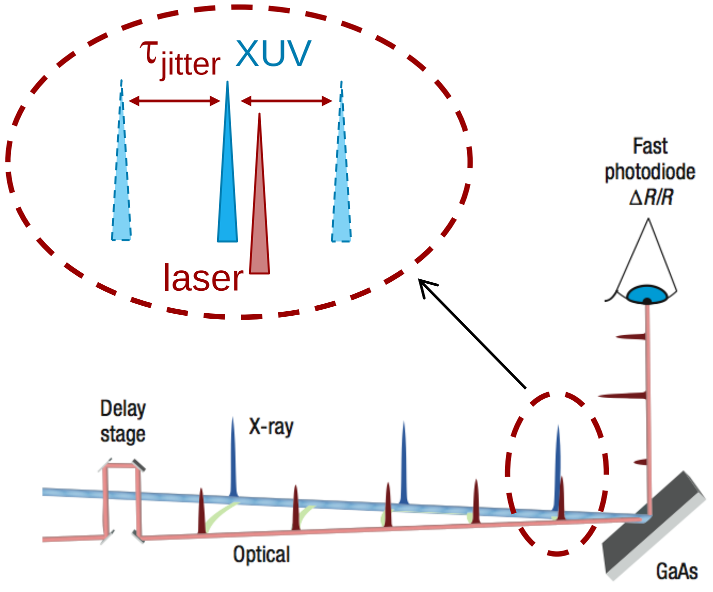


Figure 1 Transient X-ray-induced optical reflectivity ($\Delta R/R$) measurement: schematic overview. Extreme-UV FEL pulses (39.5 eV, <50 fs, <16 μJ)



Gahl, C. *et al. A femtosecond X-ray/optical cross-correlator. Nature Photon.* ***2, 165–169 (2008).***

Overview: Jitter in pump probe experiments



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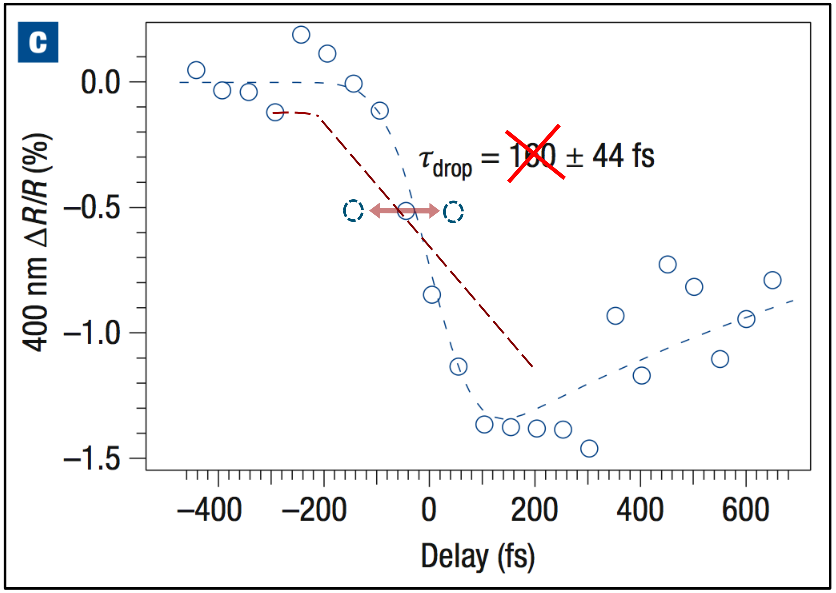

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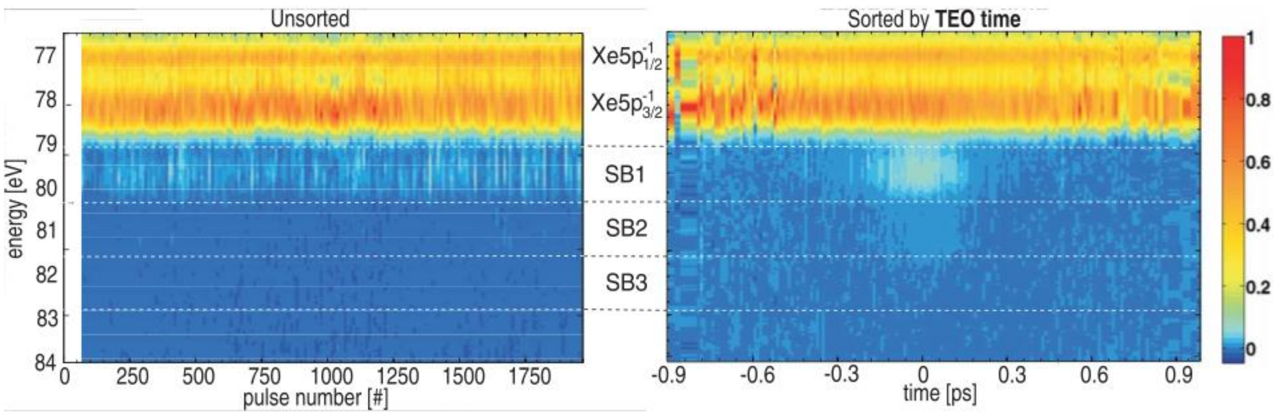
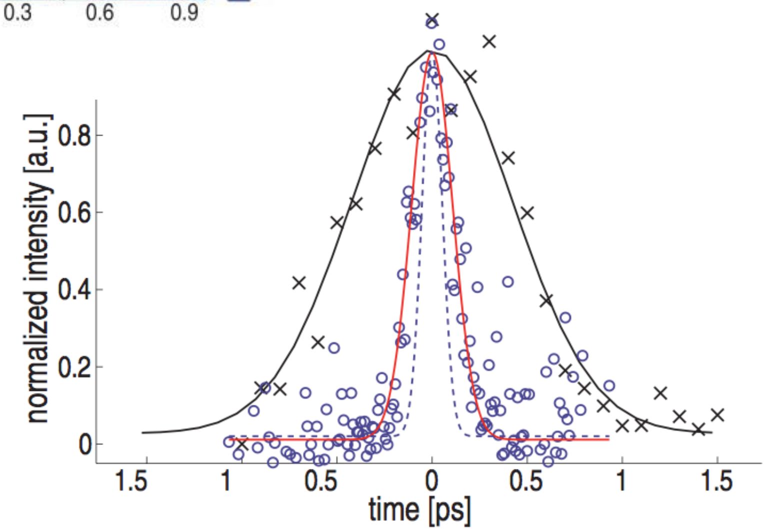
Overview: Jitter in pump probe experiments

… monitoring and correcting





Azima, A. *et al. Time-resolved pump–probe experiments beyond the jitter limitations at FLASH. Appl. Phys. Lett.* ***94, 144102 (2009).***

FIG. 3. (Color online) An uncorrected pump-probe delay scan (x) of the normalized amplitude of the first order sideband is compared with the TEO sorted sideband amplitude (o) deduced from Fig. 2 and the expected optimal

Overview: Jitter in pump probe experiments

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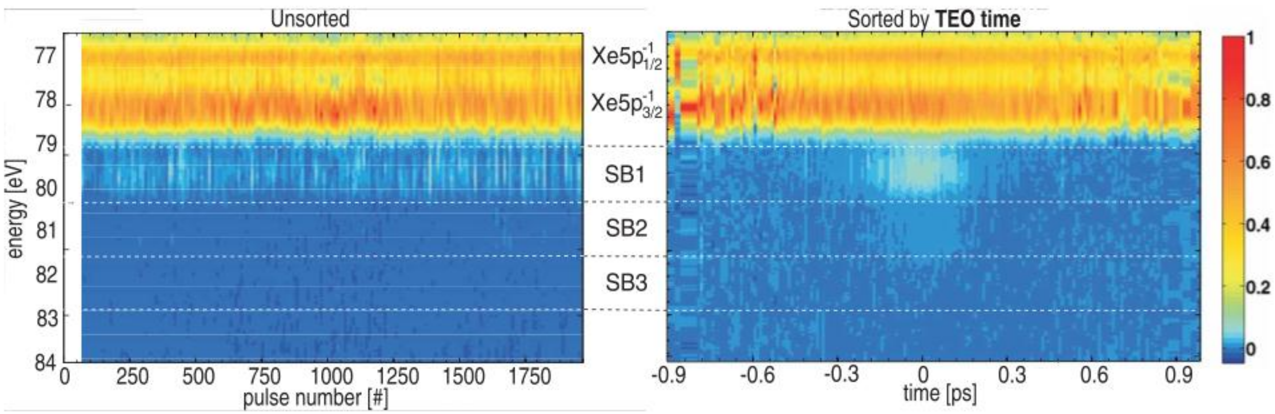
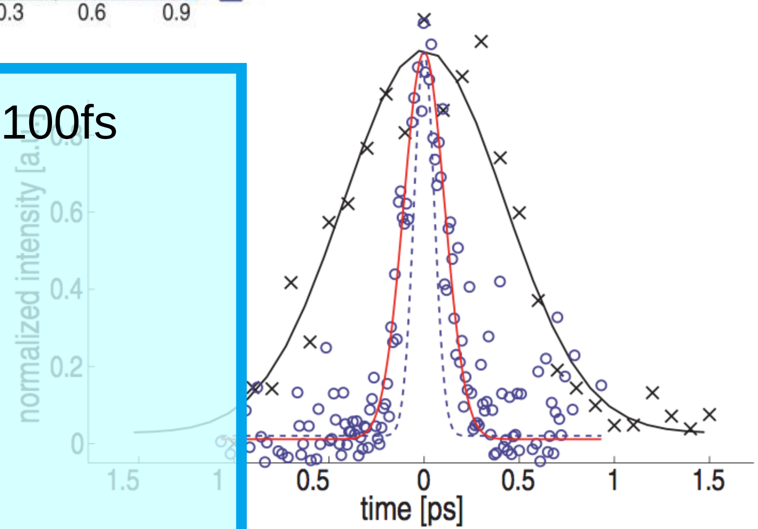


- TEO: timing by electro optical sampling ~ 100fs
- Antenna based arrival monitor
- Reflectivity XUV-VIS correletors:
    - Semiconductor >50fs
    - "Plasma switch" <10fs
- Laser based THz streaking ??? fs
- THz(from FLASH)/VIS correlation ~ 10fs
- ……



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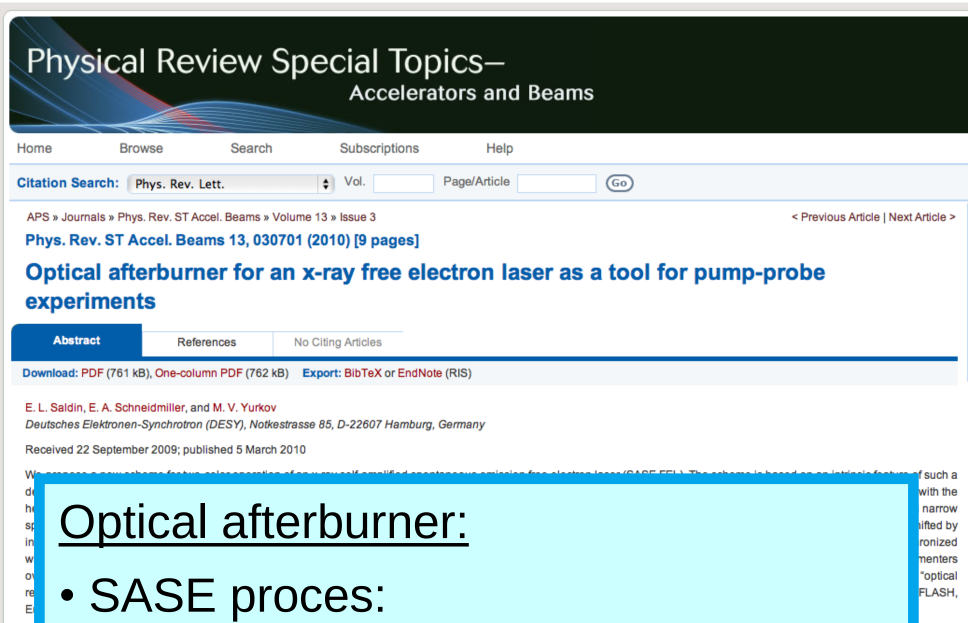
DESY

WP4.1.1: Optical afterburner - idea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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

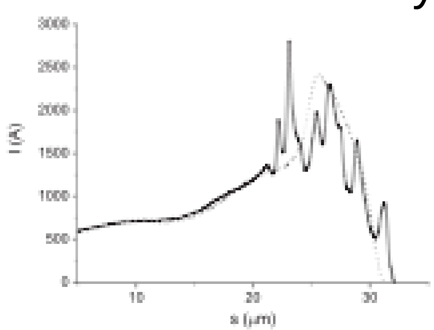
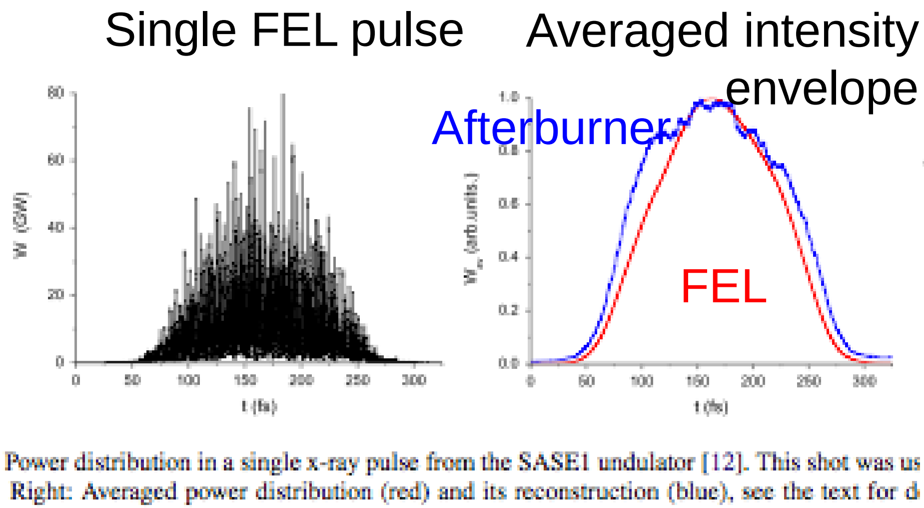
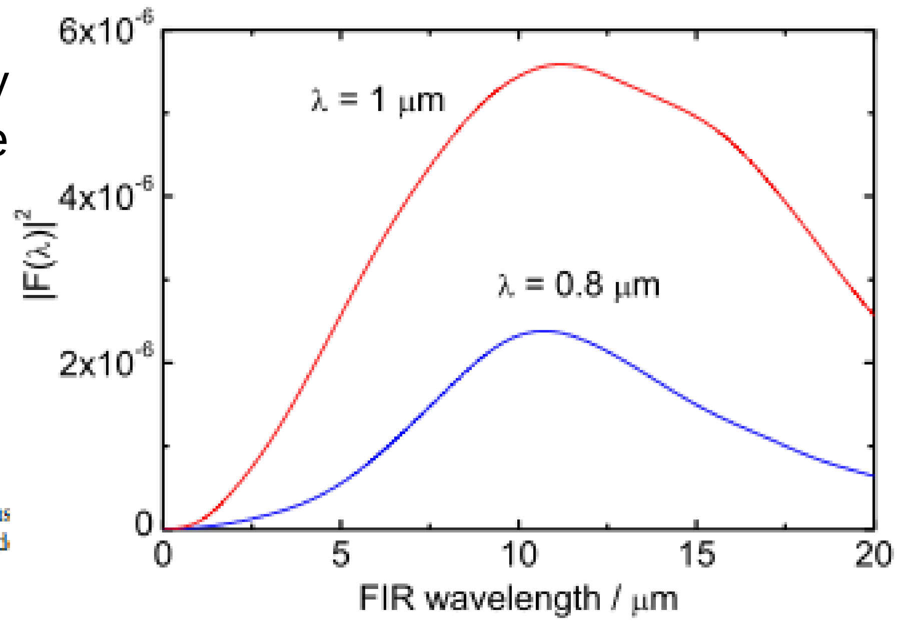


FIG. 8. Modulation of current in the head of electron bunch lasing at 7 nm in the VUV undulator of FLASH and passing FIR undulator with R_{56} equal to 250 μm (solid), and with $R_{56} = 0$ (dots). Only the small part of the bunch is shown; the bunch head is on the right.

WP4.1.1: Optical afterburner - Characterization



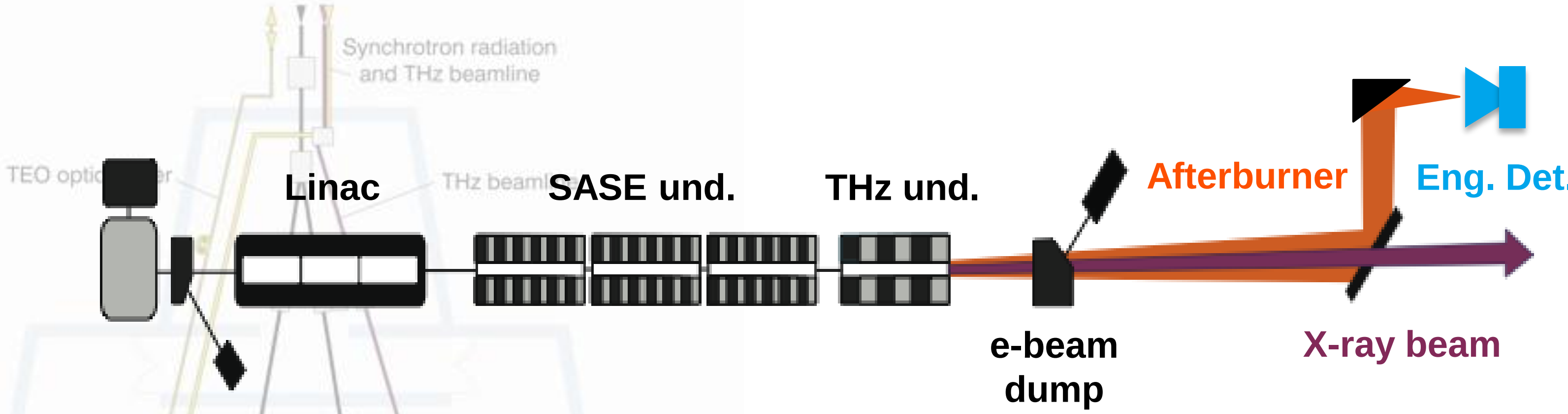


<u>Optical afterburner - optical replica of SASE pulses:</u>

- 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)*

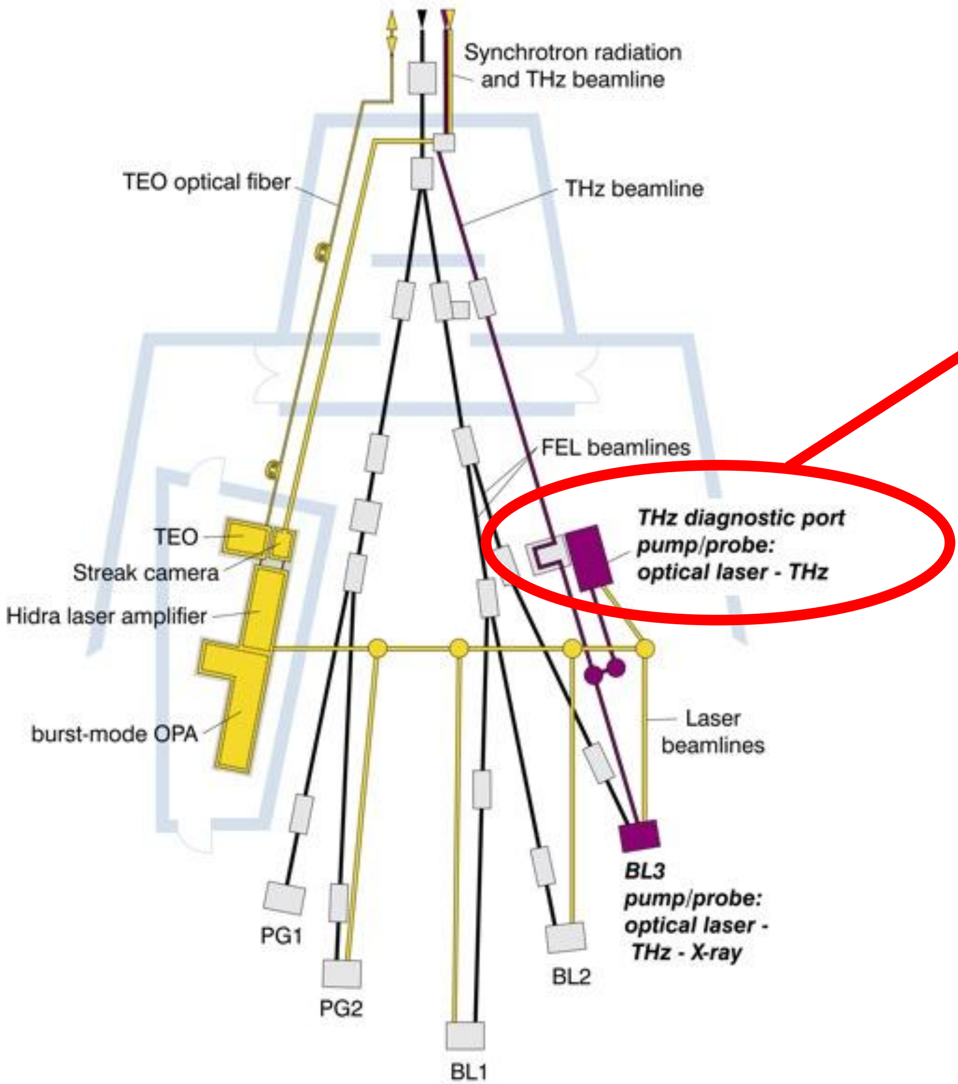
WP4.1.1: Optical afterburner – Proof of principle

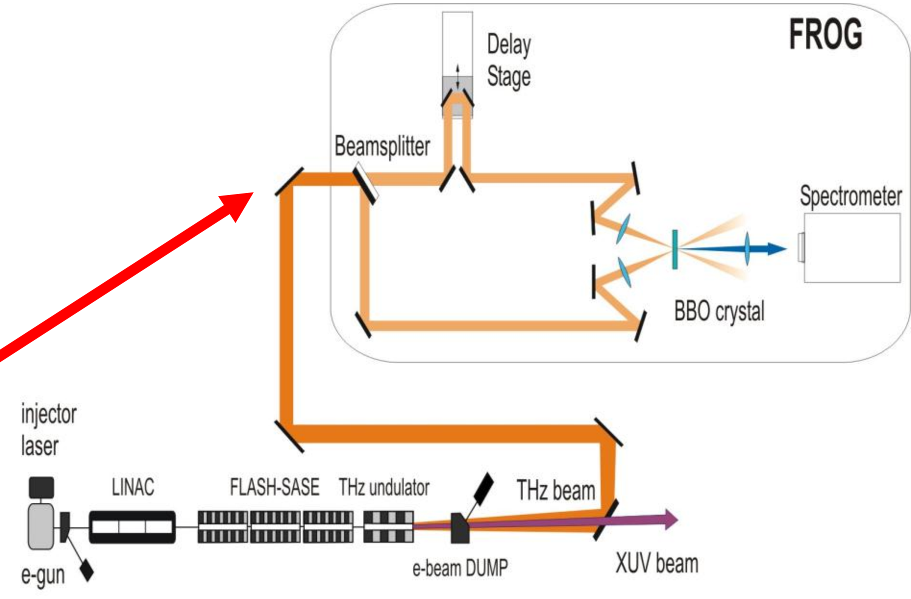


<u>THz undulator:</u>

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

WP4.1.1: Optical afterburner – pulse duration





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

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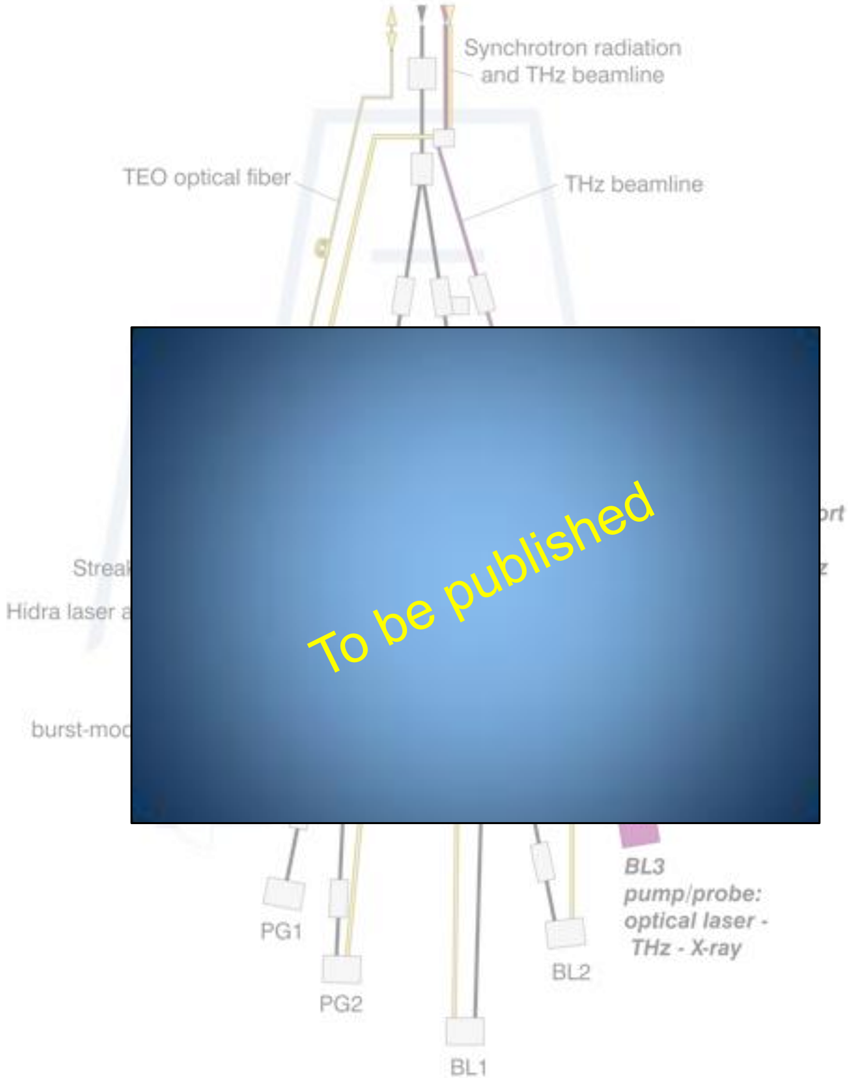
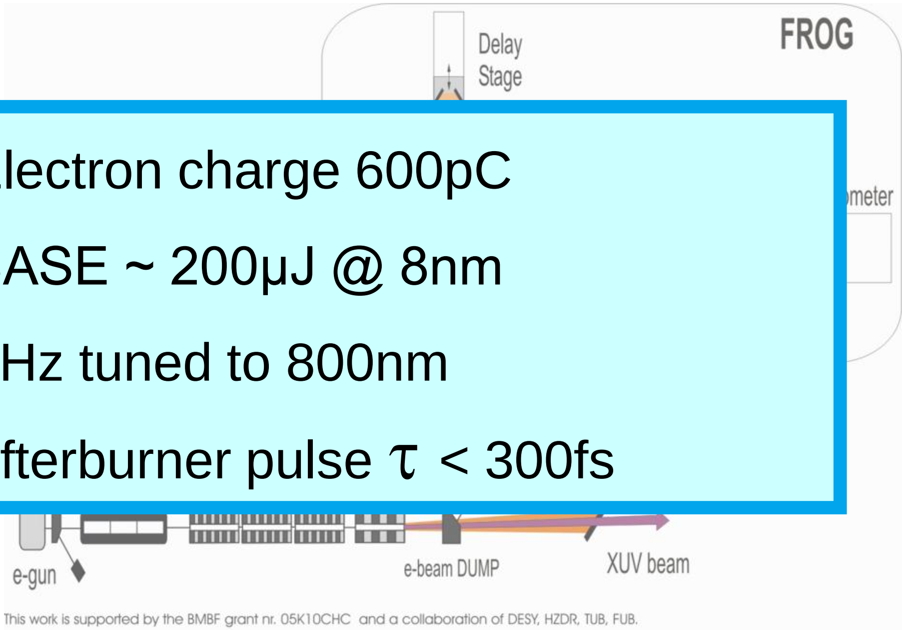
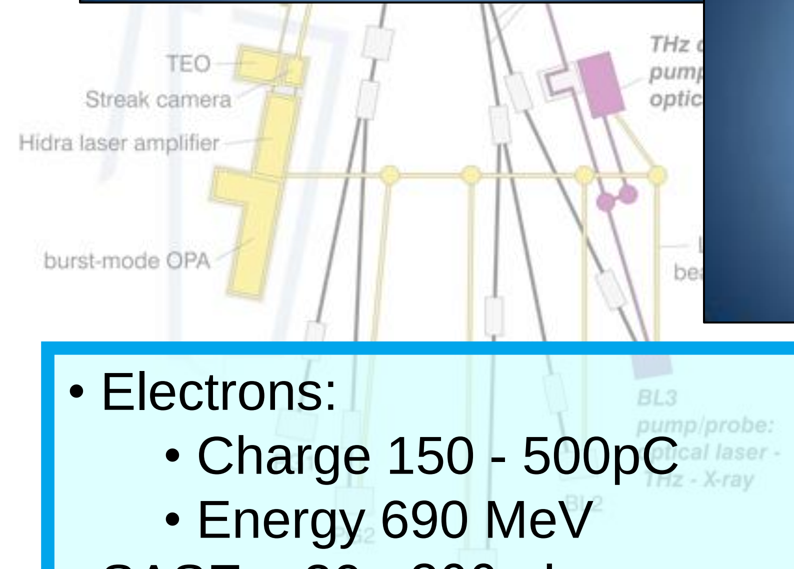
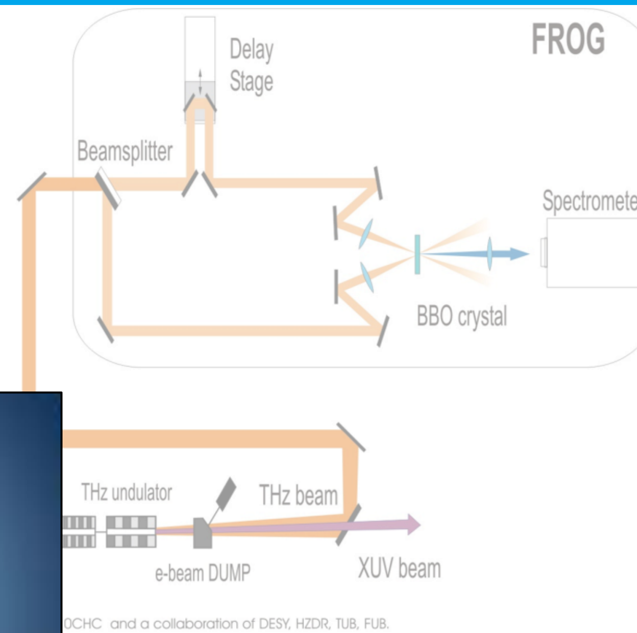




- Electron charge 600pC
- SASE ~ 200µJ @ 8nm
- THz tuned to 800nm
- Afterburner pulse τ < 300fs

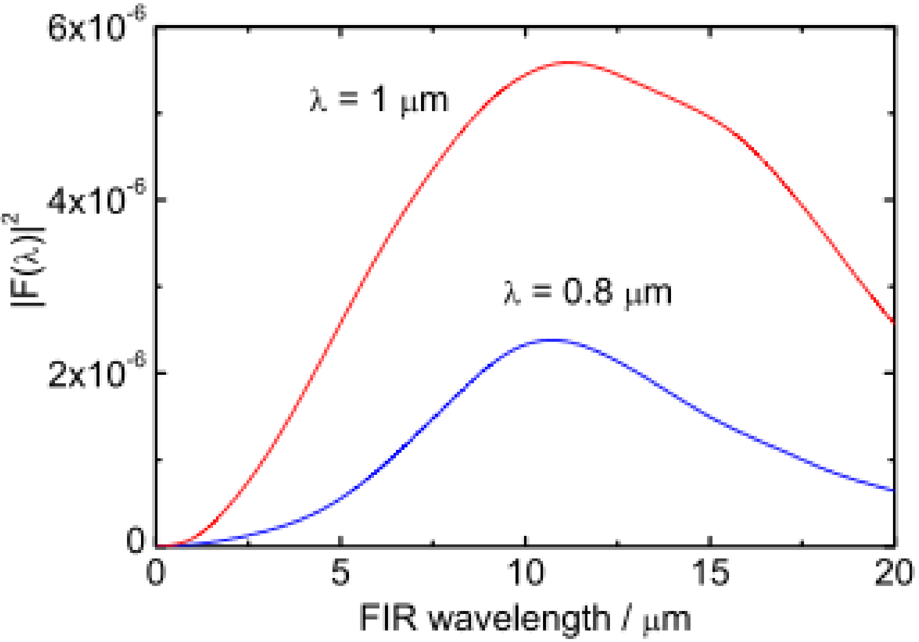
WP4.1.1: Optical afterburner – pulse duration

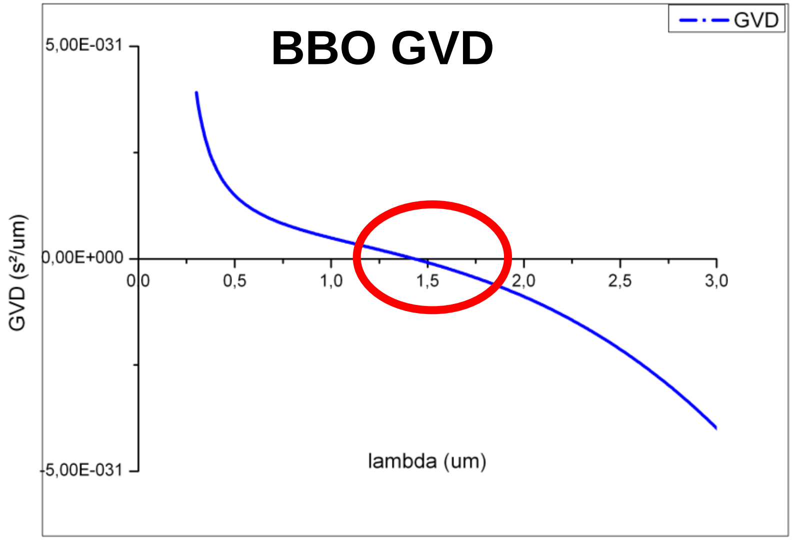


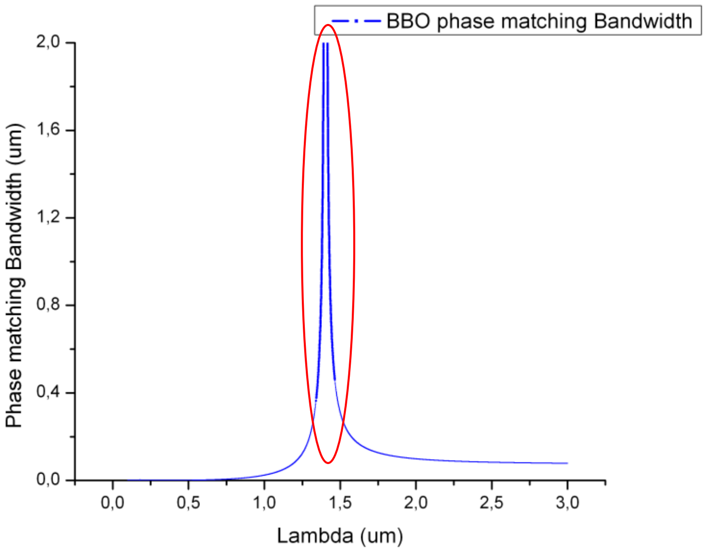


- Electrons:
    - Charge 150 - 500pC
    - Energy 690 MeV
- SASE ~ 30 - 200µJ
- THz tuned to 800nm

WP4.1.1: Optical afterburner characterization-Future work







- No pulse stretching @ 1.5 µm
- High SHG efficiency (Thick BBO crystal)
- High Phase matching Bandwidth
- Low dispersion in air

Dipl. Student: **Torsten Golz**

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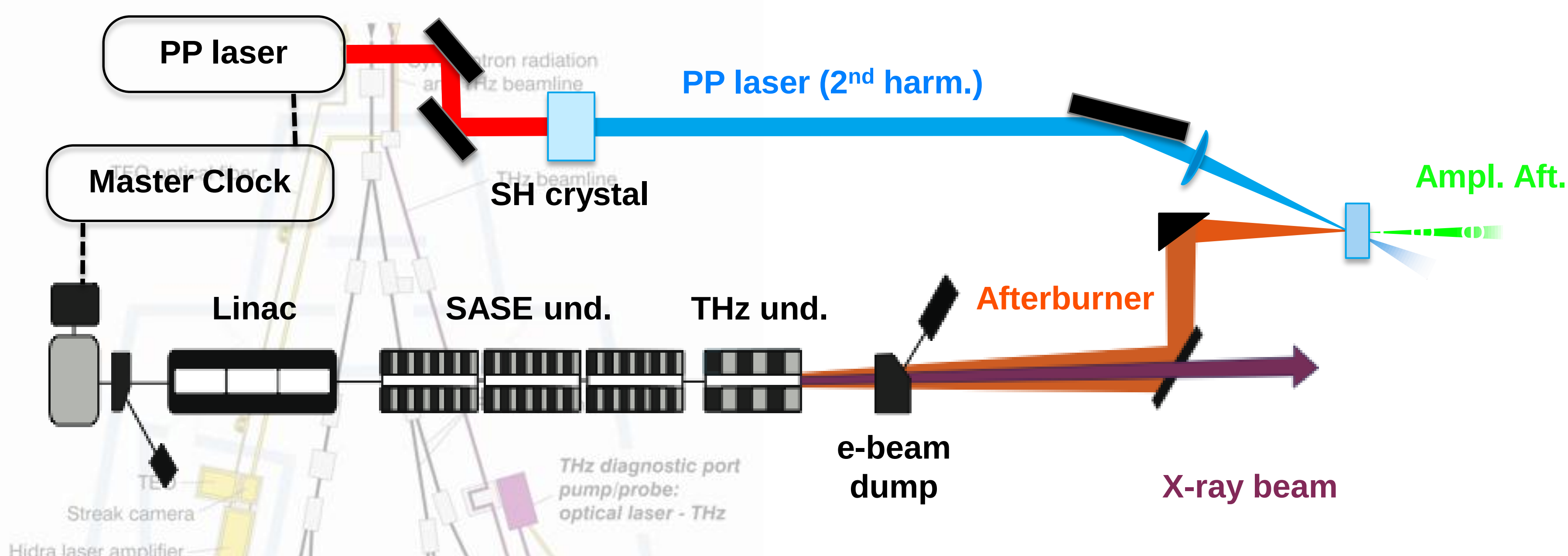
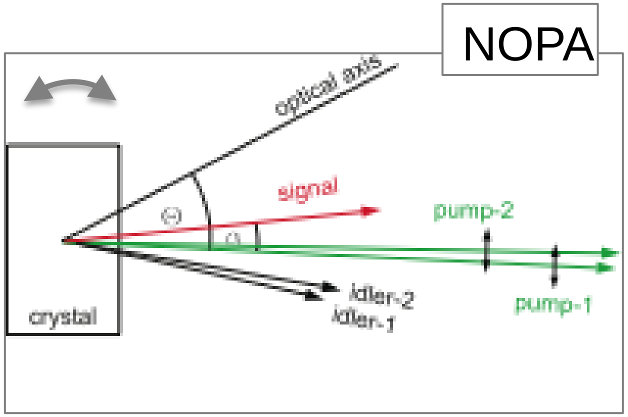
WP4.1.2: Optical afterburner – amplification



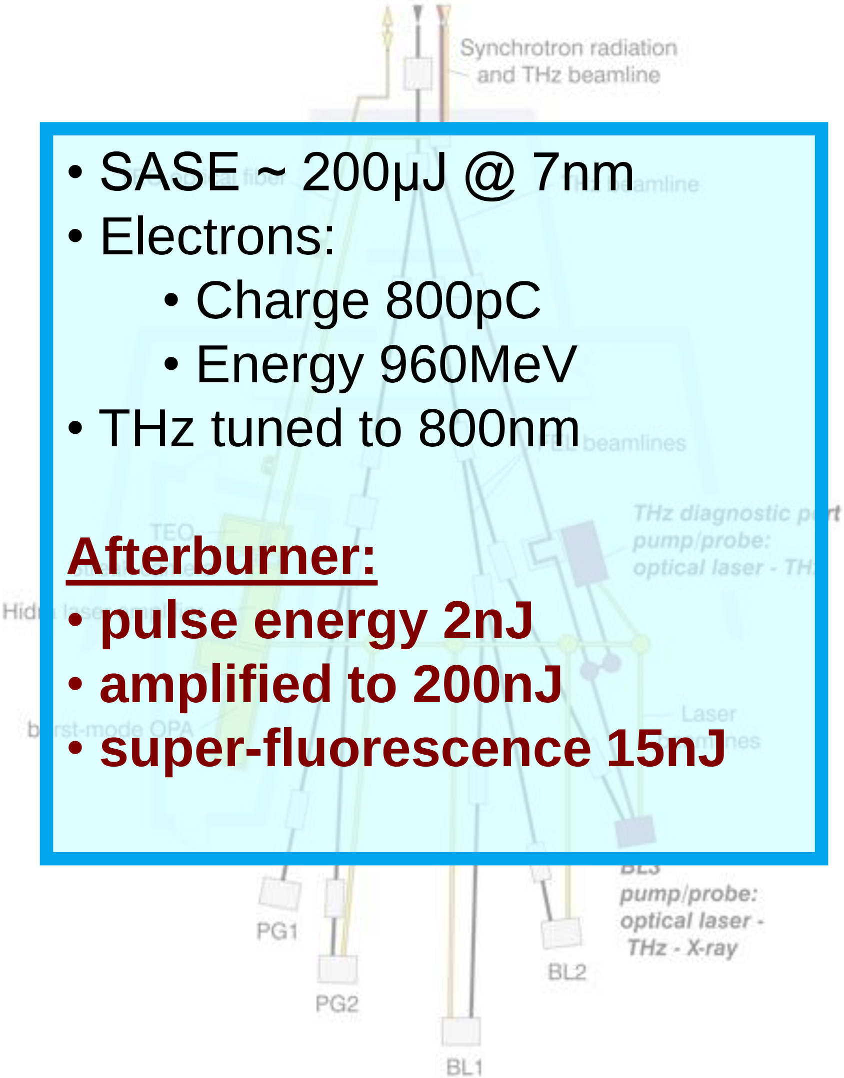
Non-colinear Optical Parametric Amplifier:

- 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)



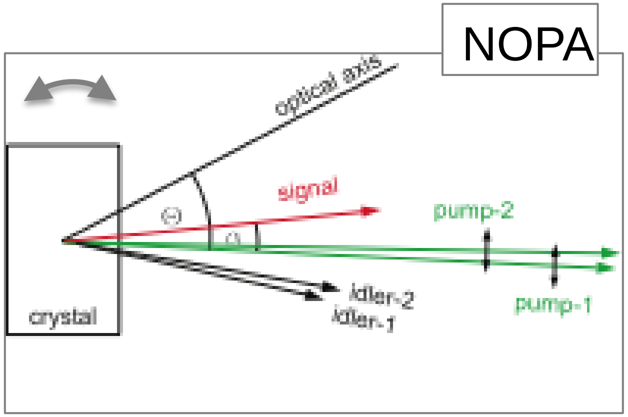
WP4.1.3 Optical afterburner – amplification



- SASE ~ 200µJ @ 7nm
- Electrons:
  - Charge 800pC
  - Energy 960MeV
- THz tuned to 800nm

Afterburner:

- **pulse energy 2nJ**
- **amplified to 200nJ**
- **super-fluorescence 15nJ**



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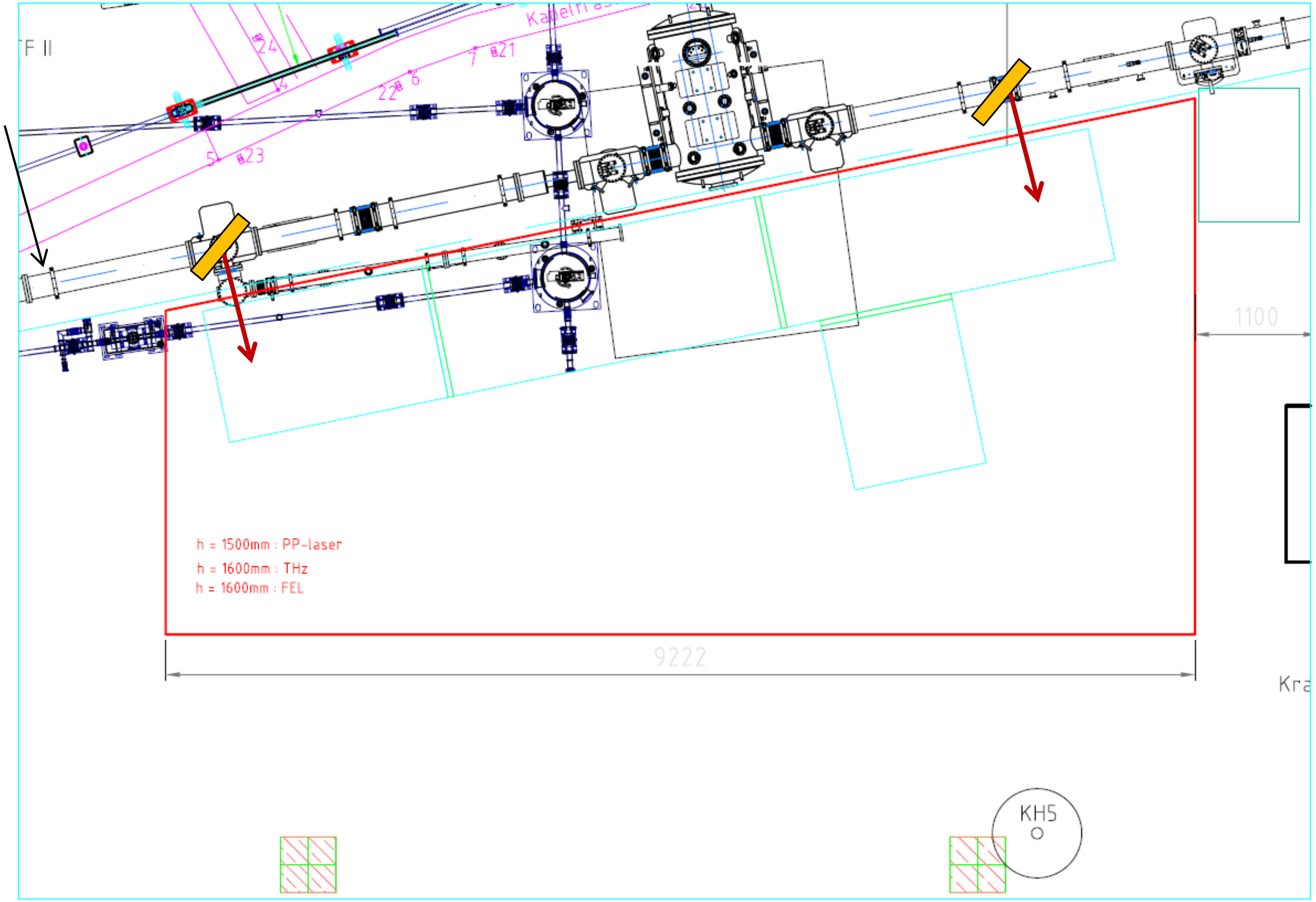

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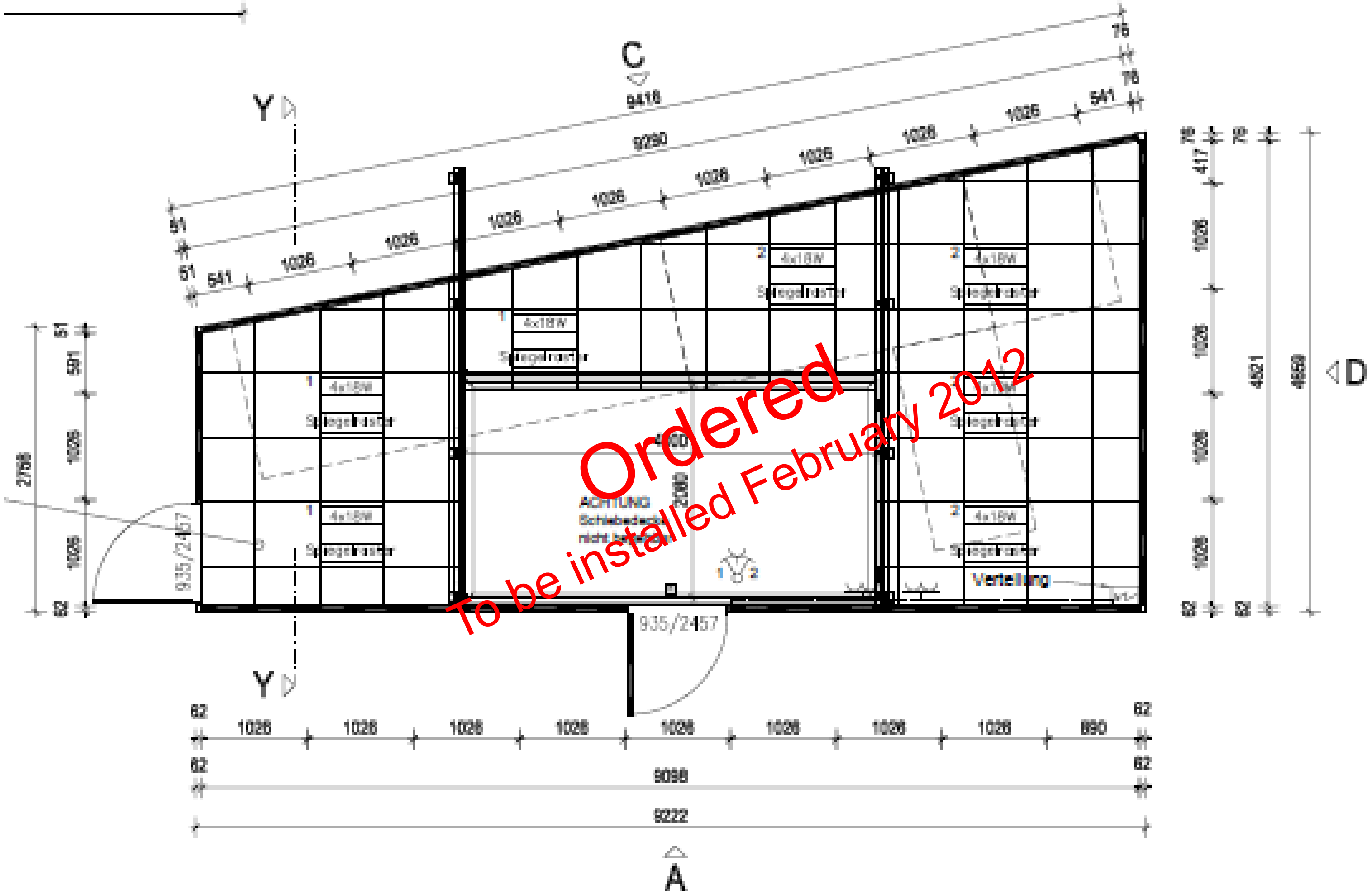

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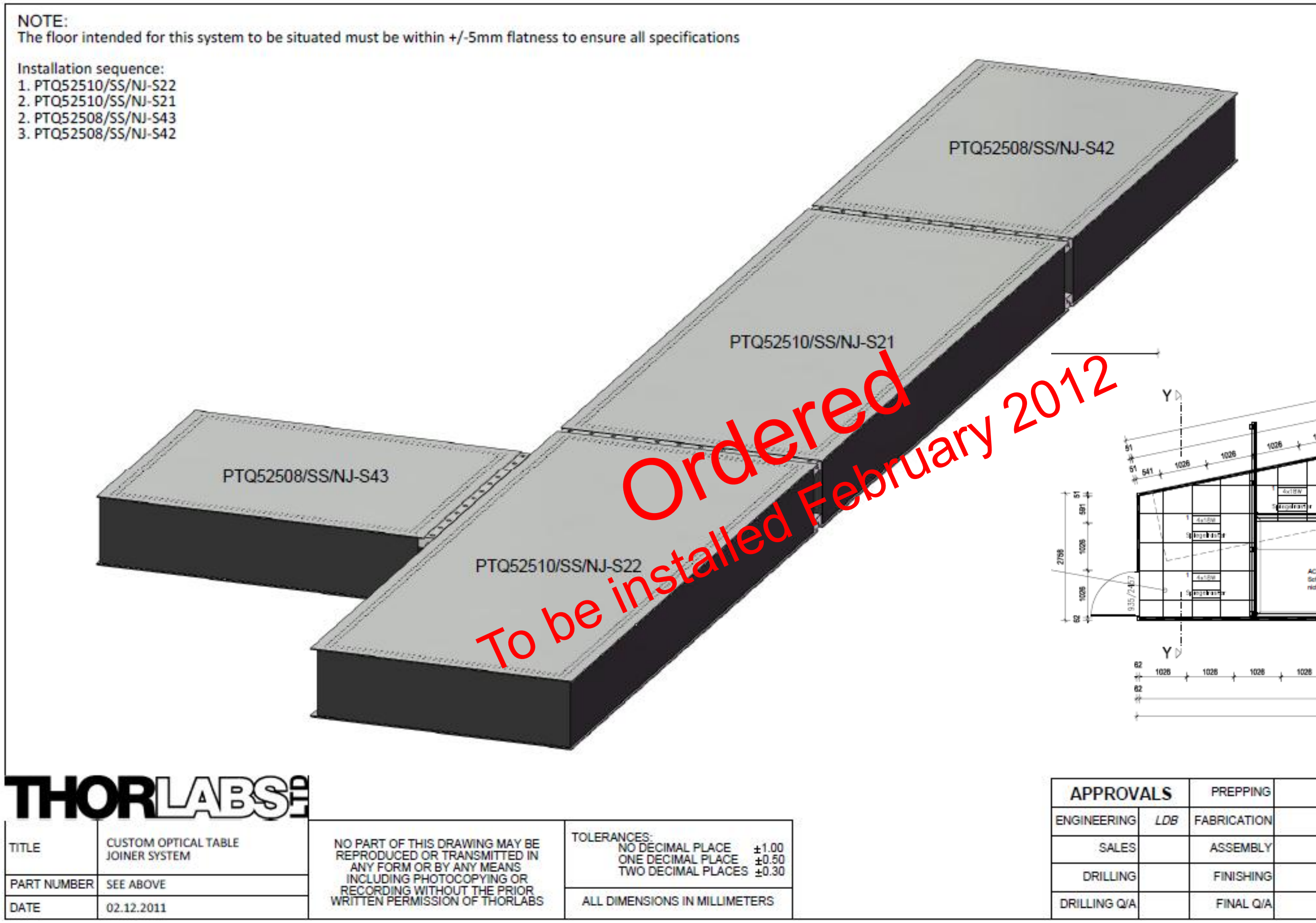

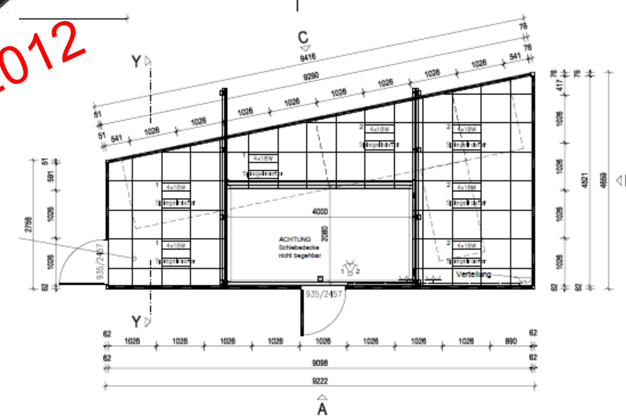

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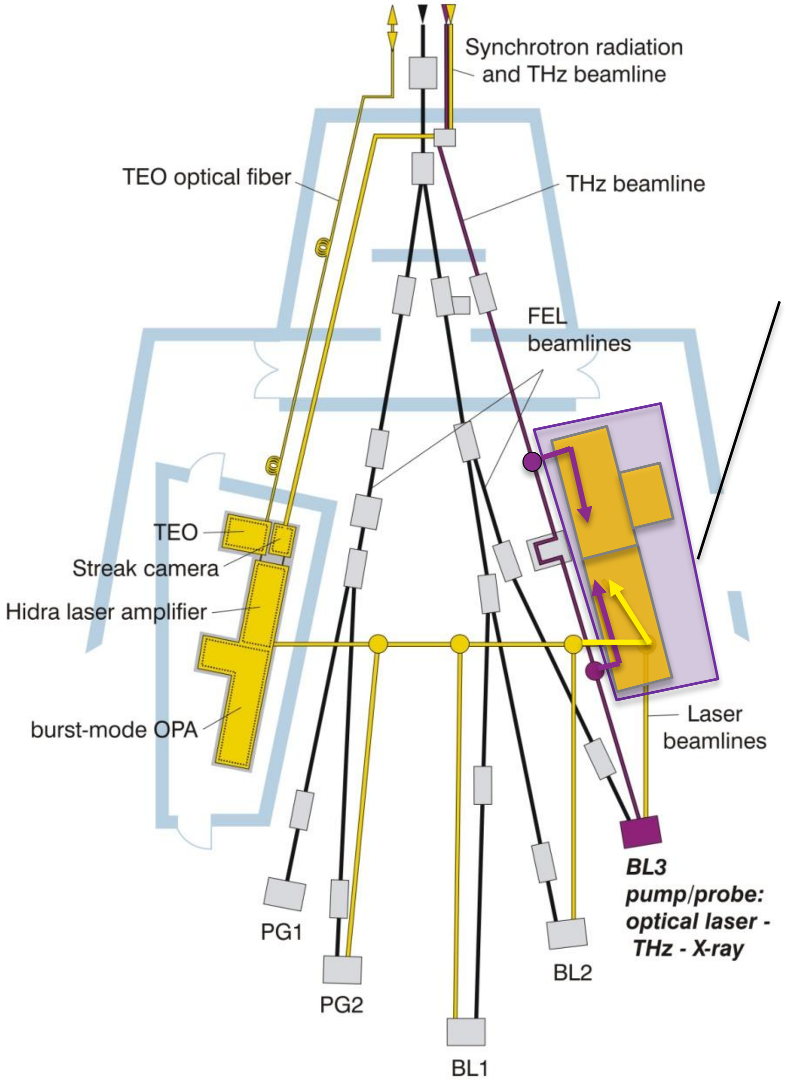
WP 4 Milestone planning

	1-Project year				2-Project year				3-Project year			
	1-Qt	2-Qt	3-Qt	4-Qt	1-Qt	2-Qt	3-Qt	4-Qt	1-Qt	2-Qt	3-Qt	4-Qt
Month	1-3	4-6	7-9	10-12	13-14	15-18	19-21	22-24	25-27	28-30	31-33	34-36
WP 4.1.1												
WP 4.1.2												
WP 4.1.3												
WP 4.1.4												
WP 4.1.5												
WP 4.1.6												
WP 4.2.1												
WP 4.2.2												
WP 4.2.3												
WP 4.2.4												

Thanks!

4.1 THz at FLASH - Upgrade



New THz diagnostic port
Pump/probe:
THz / optical laser

- Thermally isolated from FLASH hall
- Optically sealed
- Larger space on single optical table
    - Permanent diagnostics
    - Improved stability
    - Delayed & direct THz

To be published