Terahertz Streaking @ DESY

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Hamburg, Nov 2013

HELMHOLTZ ASSOCIATION

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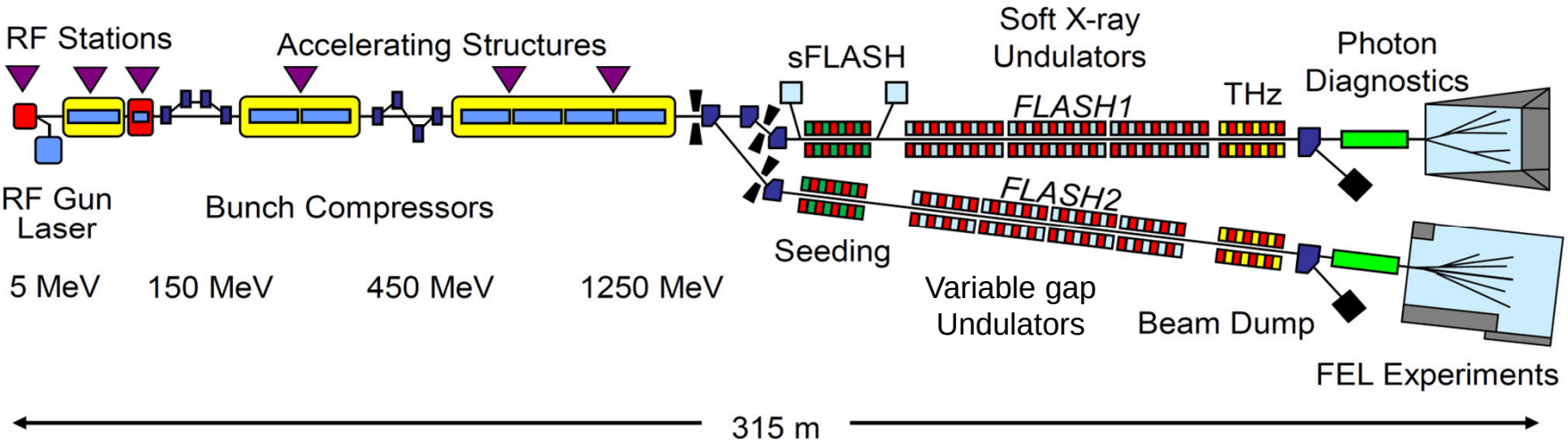
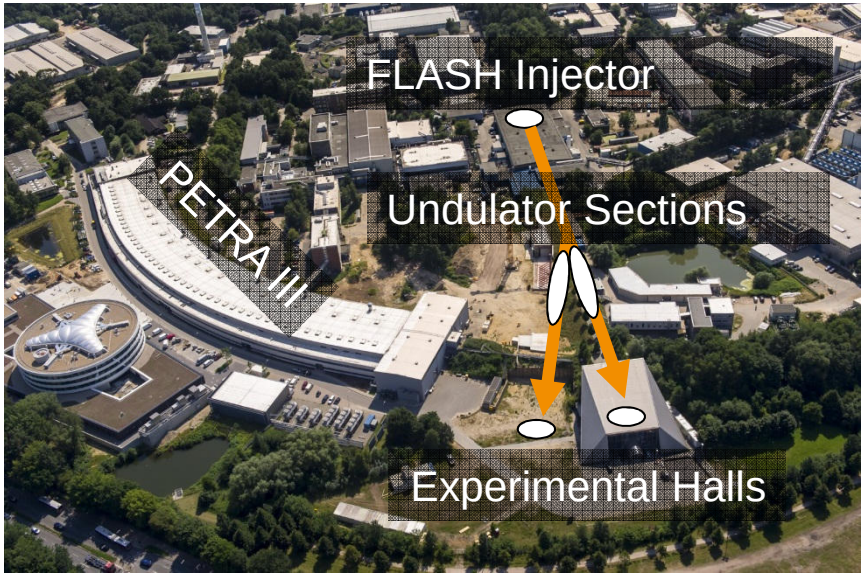
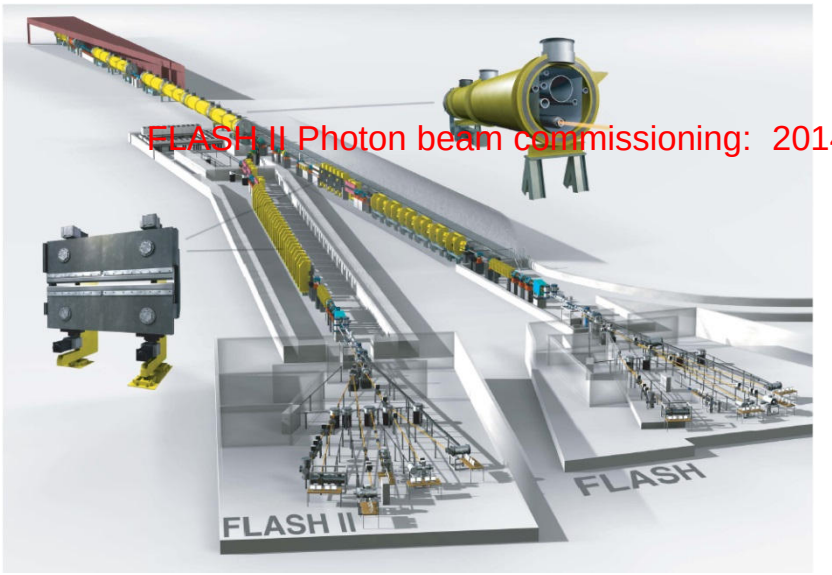
FLASH & FLASH II @ DESY







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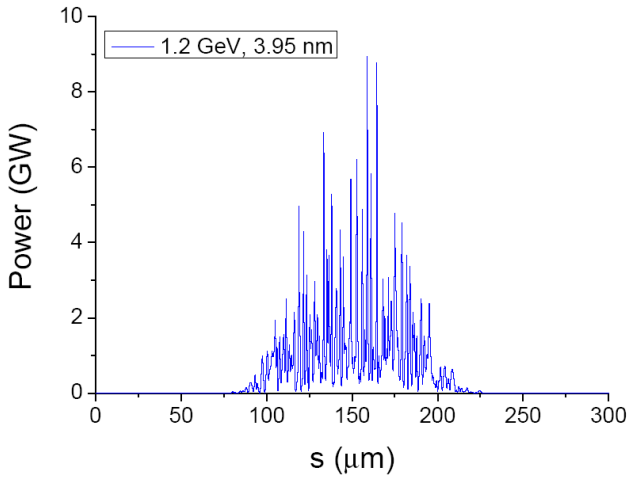
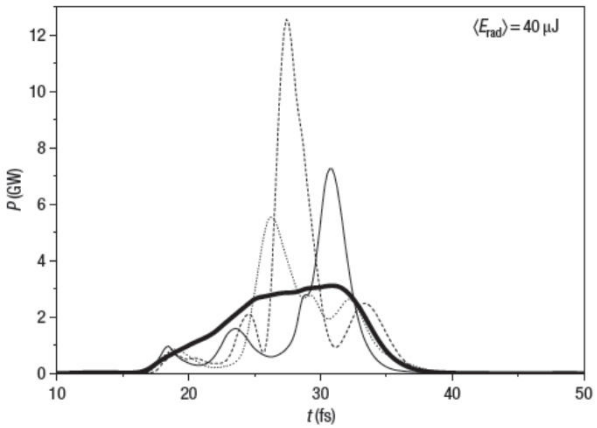
SASE FEP Pulse Characterization

Each shot different pulse profile
And different arrival time
(> pulse duration !)

Simulated pulse profiles





Technique needed:

- Wavelength independent (VUV to X-rays)
- High dynamic range (few fs to > 100 fs)
- SINGLE SHOT capability
- Parasitic / transparent

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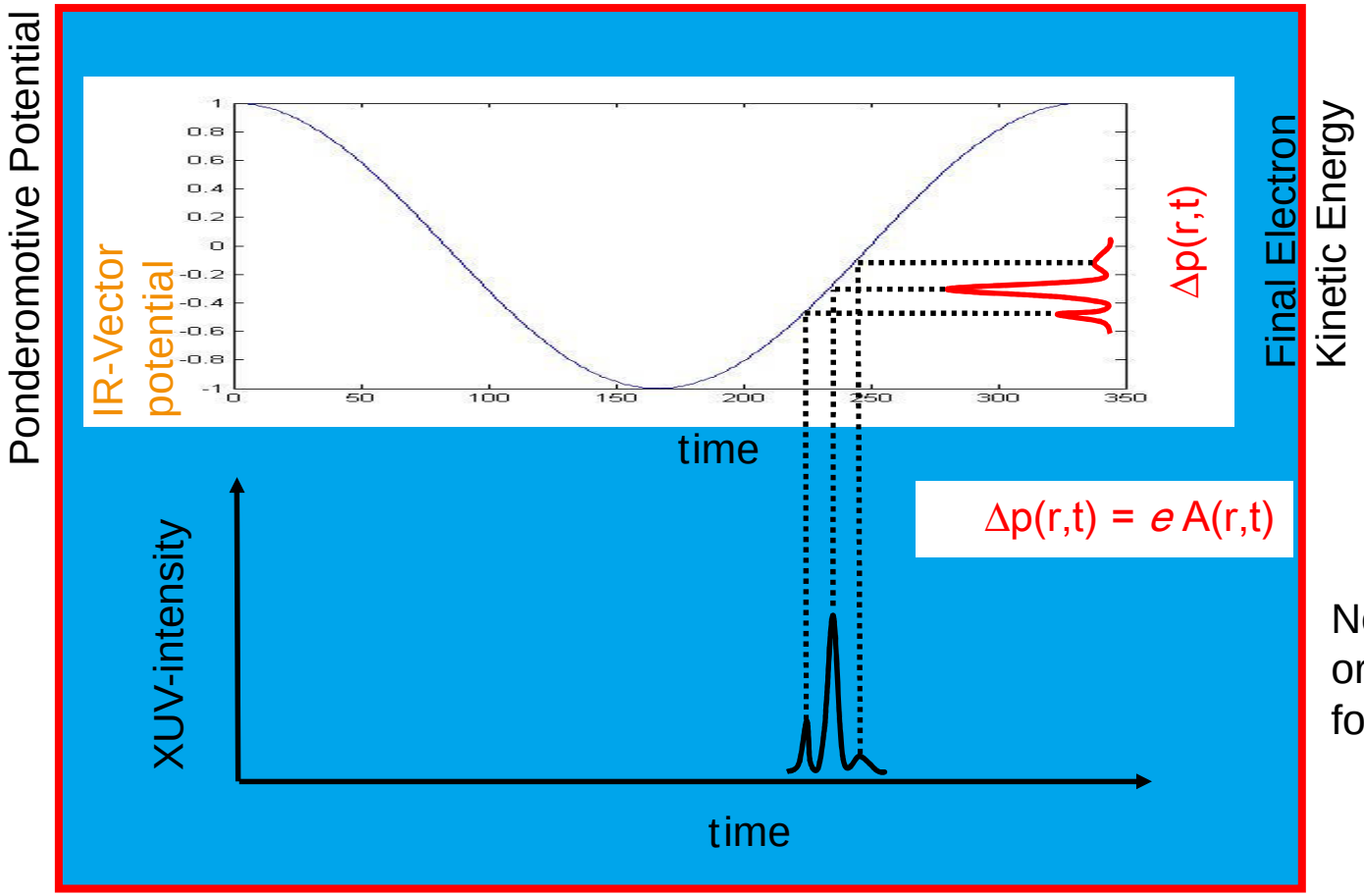
THz Streaking – Basic Principle

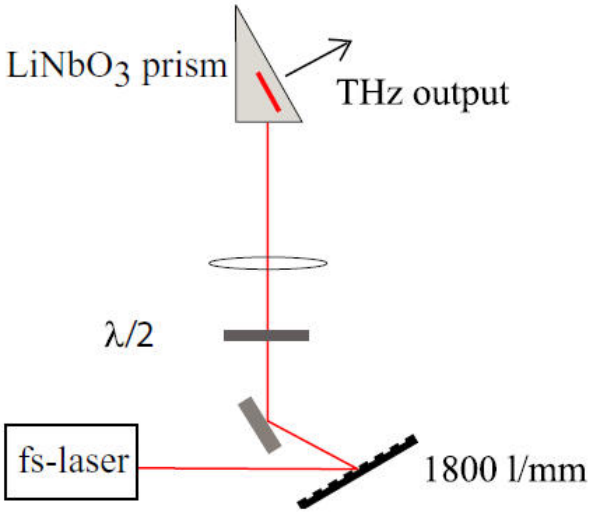
Nature Photonics 3, 523-528 (2009), Nature Photonics 6, 852-857 (2012))

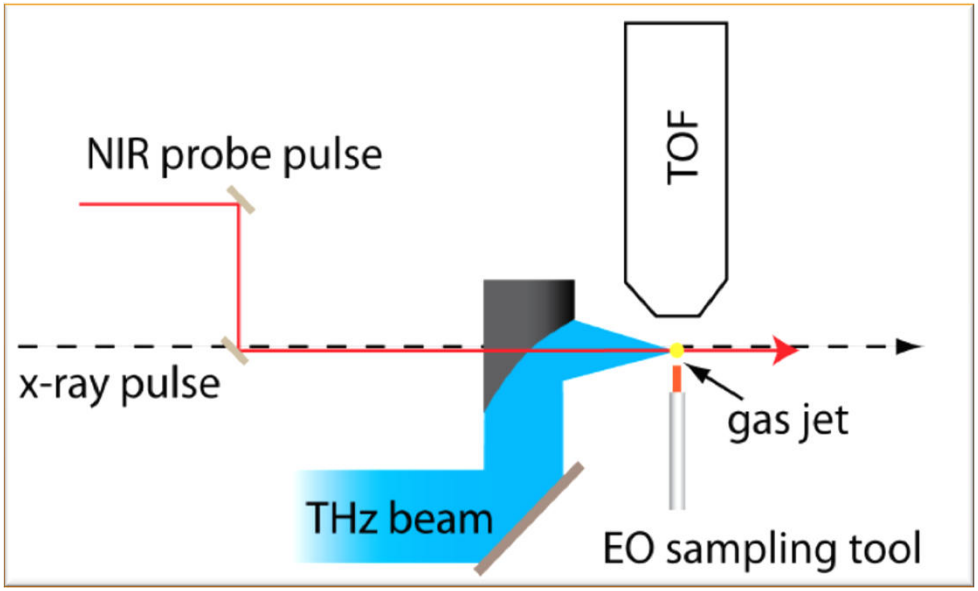


Needs either high fields or fast field rise times for good resolution

Laser Based THz Streaking

Few µJ single cycle



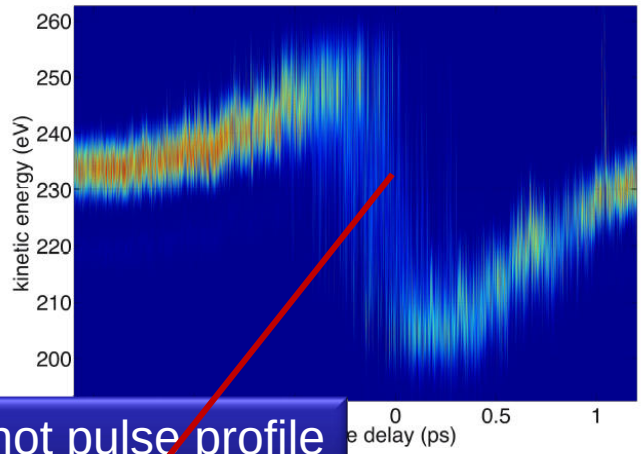


Hoffmann et al,
J. Phys. D: Appl. Phys. **44** (2011) 083001

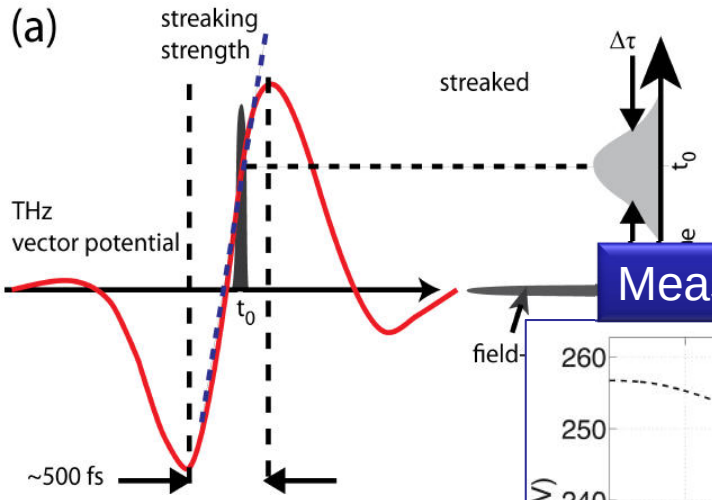
Grguras et al,
Nature Photonics **6,** 852-857 (2012)

First Results @ FLASH

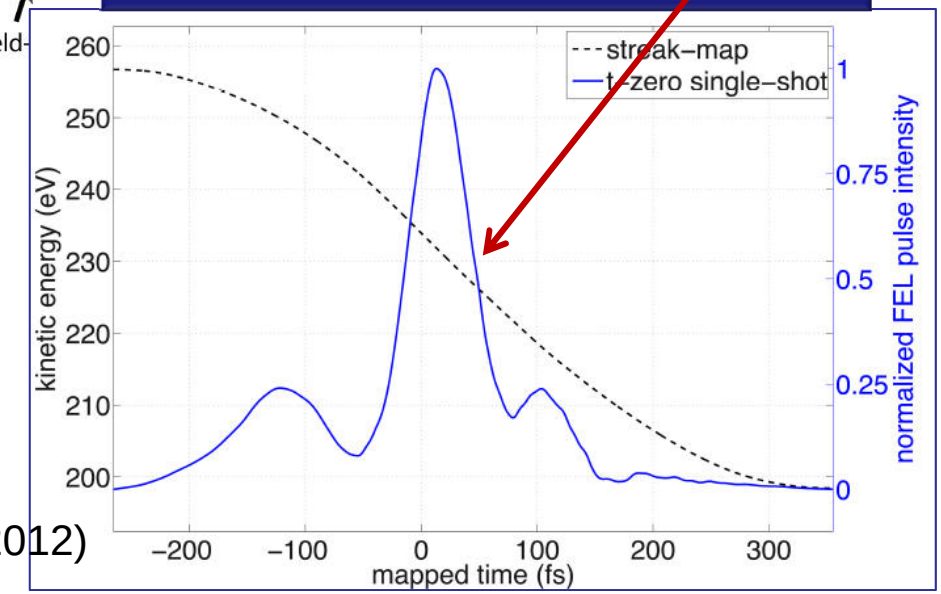
Time scan with few 1000 single shots



Generated THz single cycle



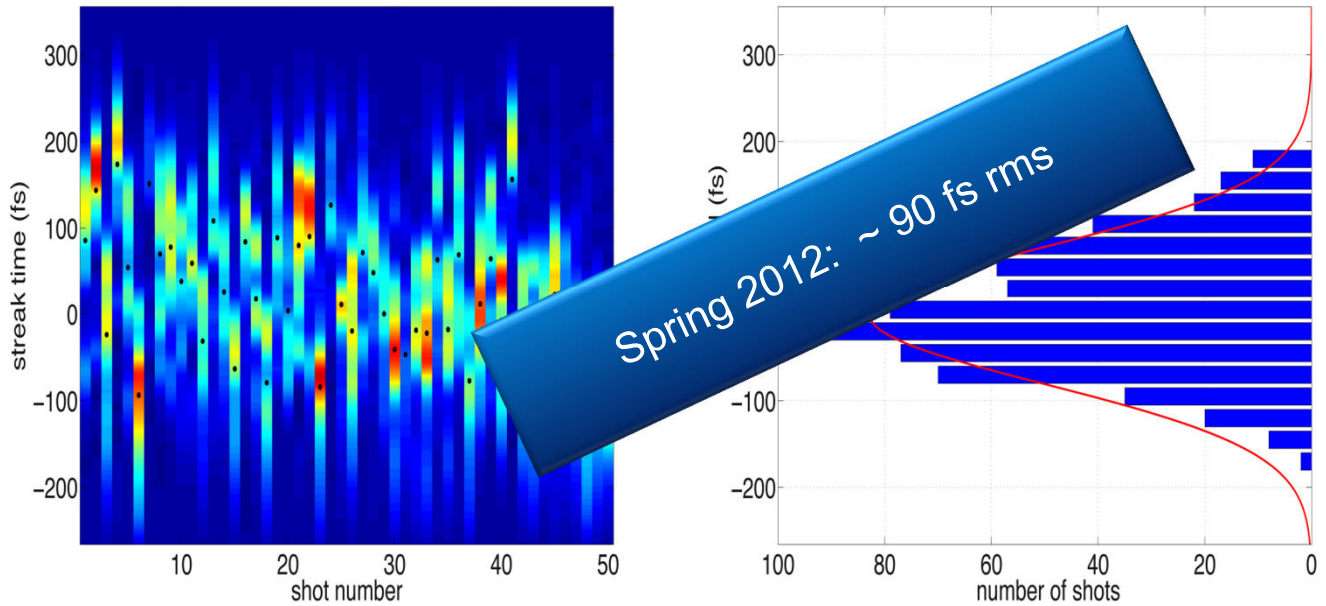
Measured single shot pulse profile



Grguras et al,
Nature Photonics **6,** 852-857 (2012)

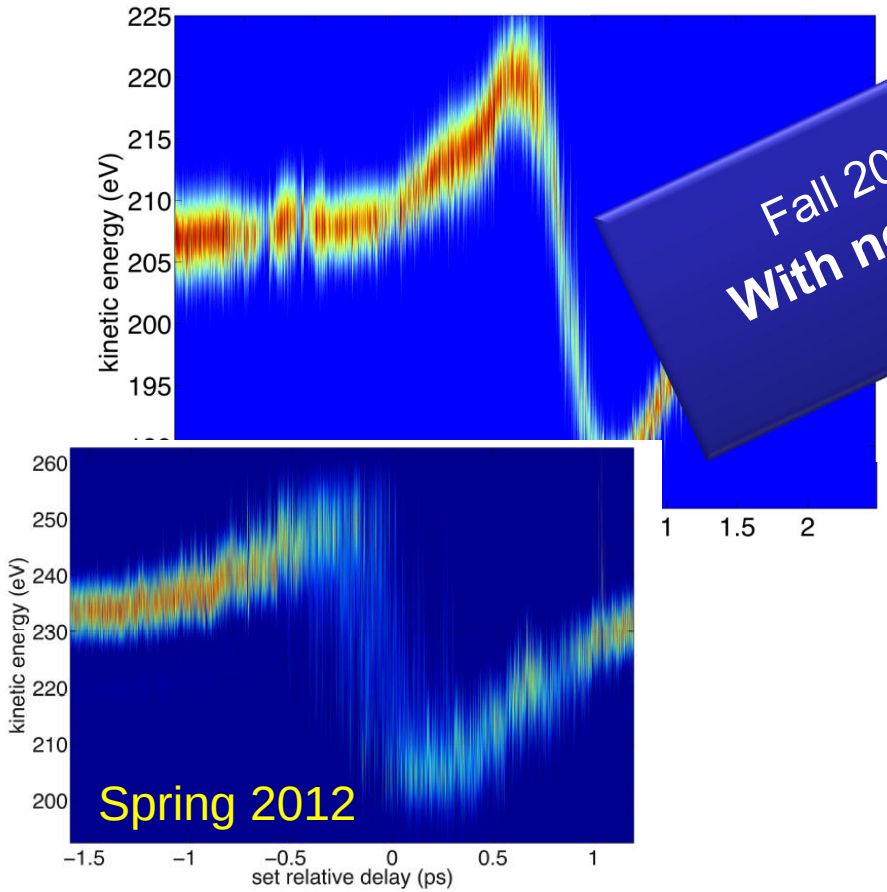
Arrival Time vs. Driving Laser

Arrival time encoded in the data – with ~ 10 fs resolution

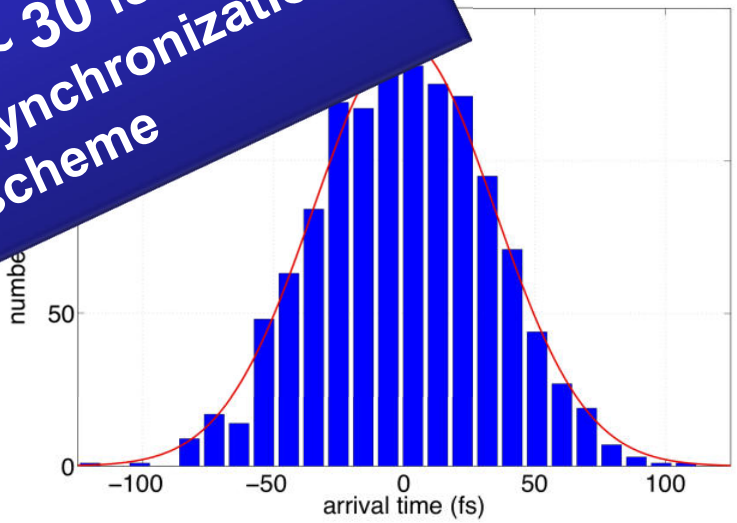


Arrival Time vs. Driving Laser

Arrival time encoded in the data – with ~ 8 resolution



Fall 2012: **~ 30 fs rms**
With new synchronization scheme



Courtesy A. Cavalieri et al

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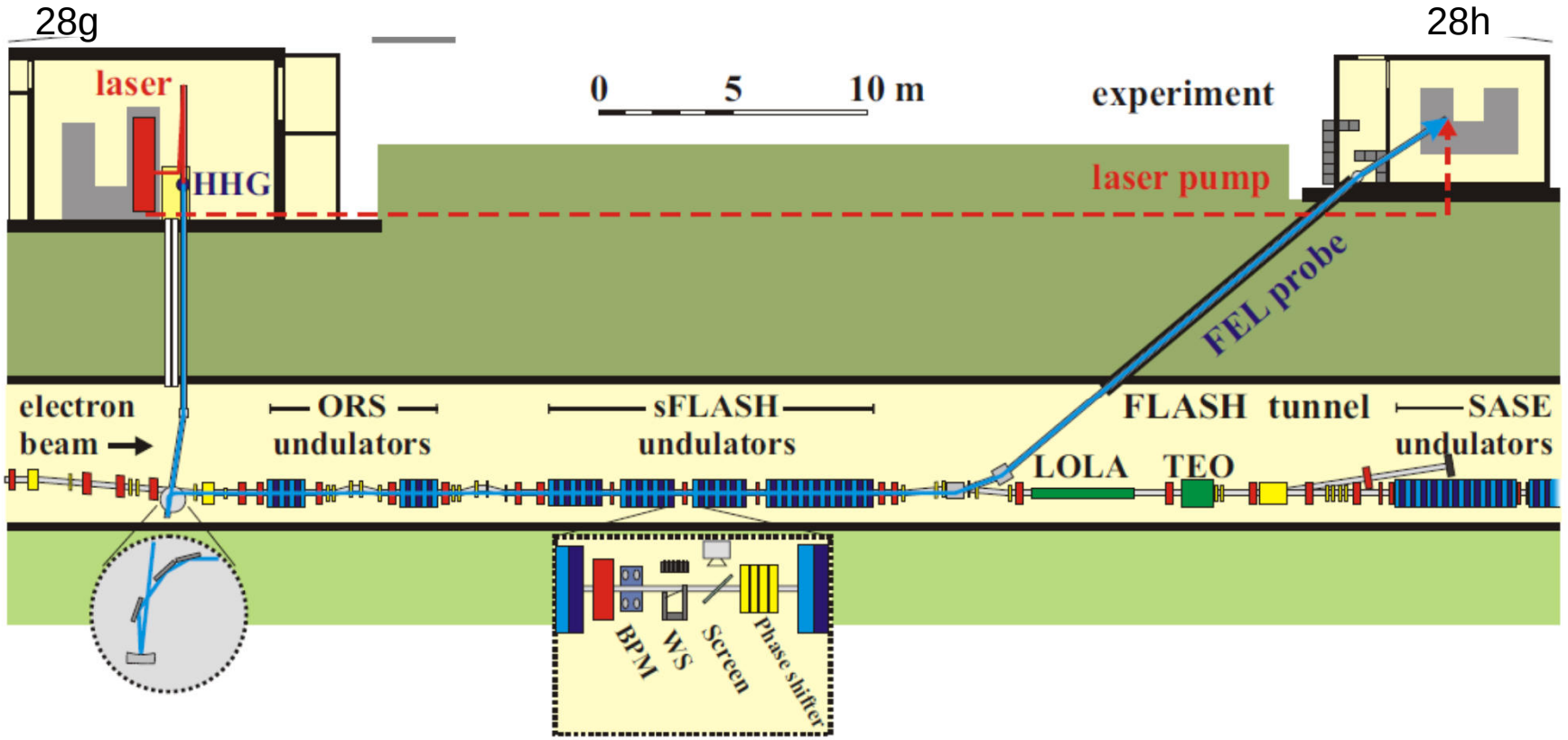
The New Experiment - Motivation

- Using sFLASH Undulators with or without seeding
- THz generation - improving



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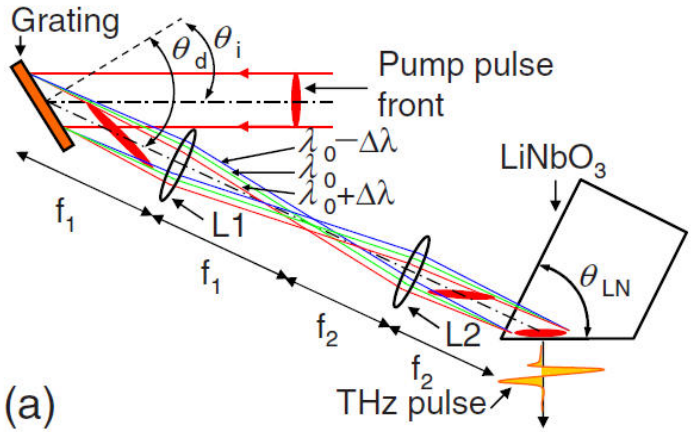
THz Source Improvement – Pulse Front Tilt

H. Hirori et al, Appl. Phys. Let. **98,** 091106(2011)



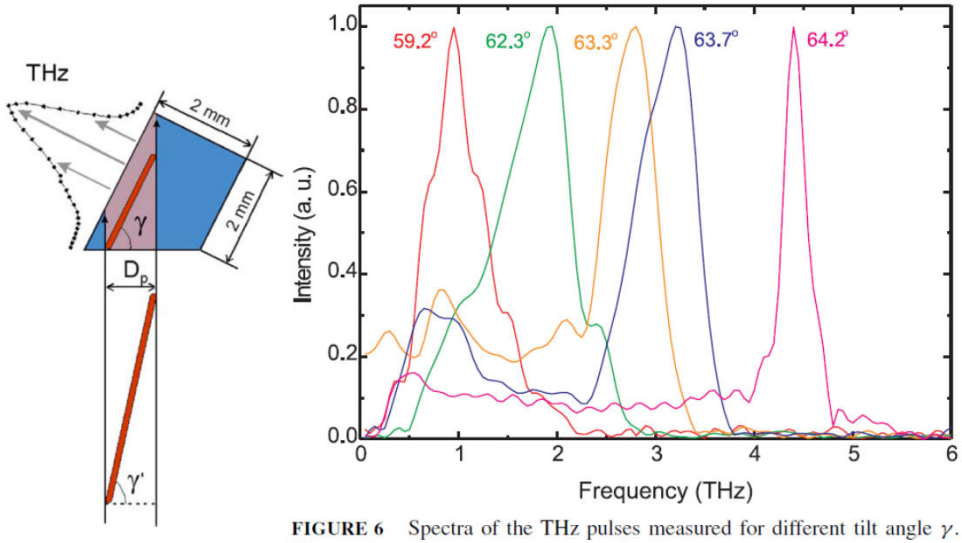
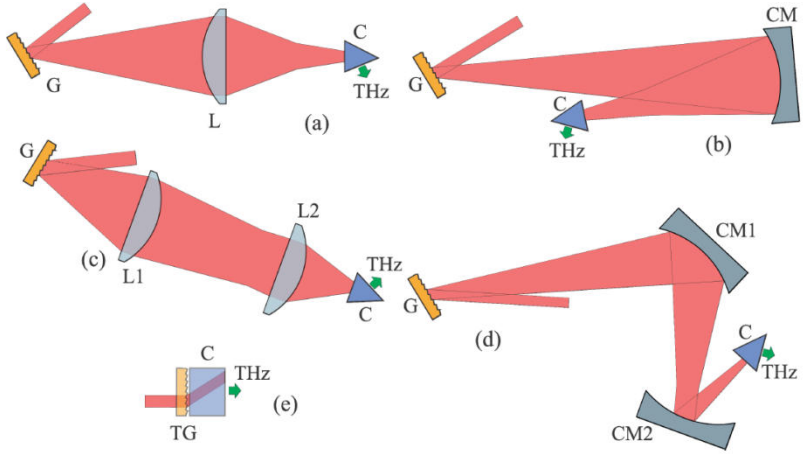
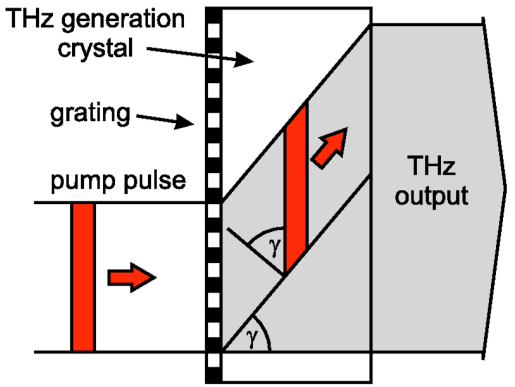


FIGURE 6 Spectra of the THz pulses measured for different tilt angle γ. The maxima of the spectra are normalized

J. Hebling et al, Appl. Phys. B 78, 593–599 (2004)

M. Kunitski et al, Opt. Expr. 6826 ,Vol. 21, No. 6, (2013)





L. Pálfalvi et al, Appl. Phys. Lett. **92**, 171107 (2008)

THz Source Improvement – Cooled & Doped (Mg) the Crystal

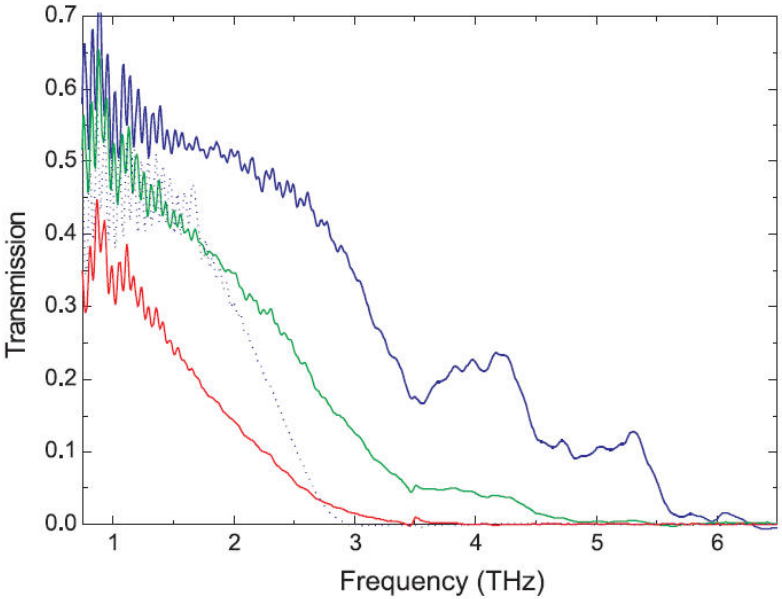


FIGURE 3 Measured transmission of 0.5-mm-thick Mg-doped stochiometric $LiNbO_3$ crystals with 0.6% (*solid lines*) and 4% (*dotted line*) doping level at temperatures of 200 K (*red*), 100 K (*green*), and 10 K (*blue*)

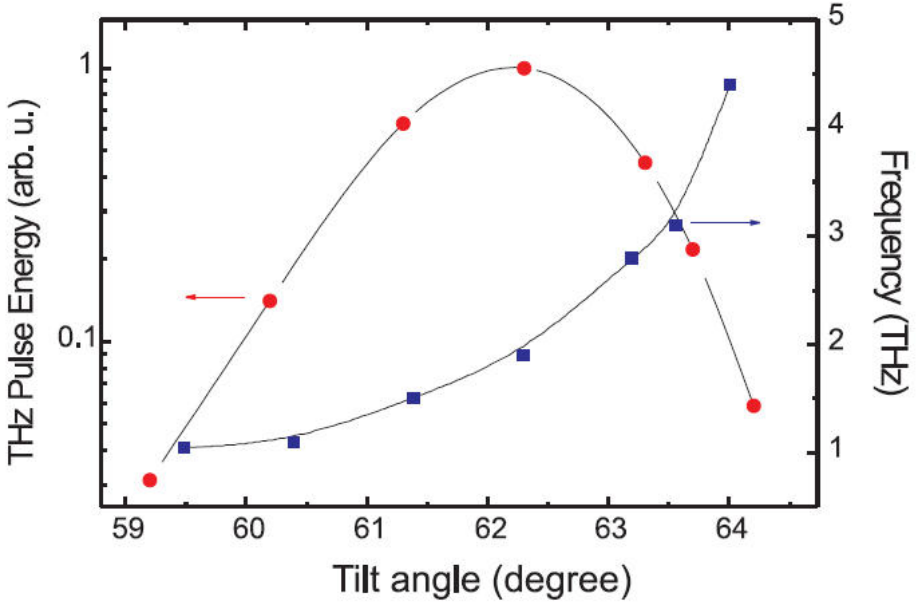
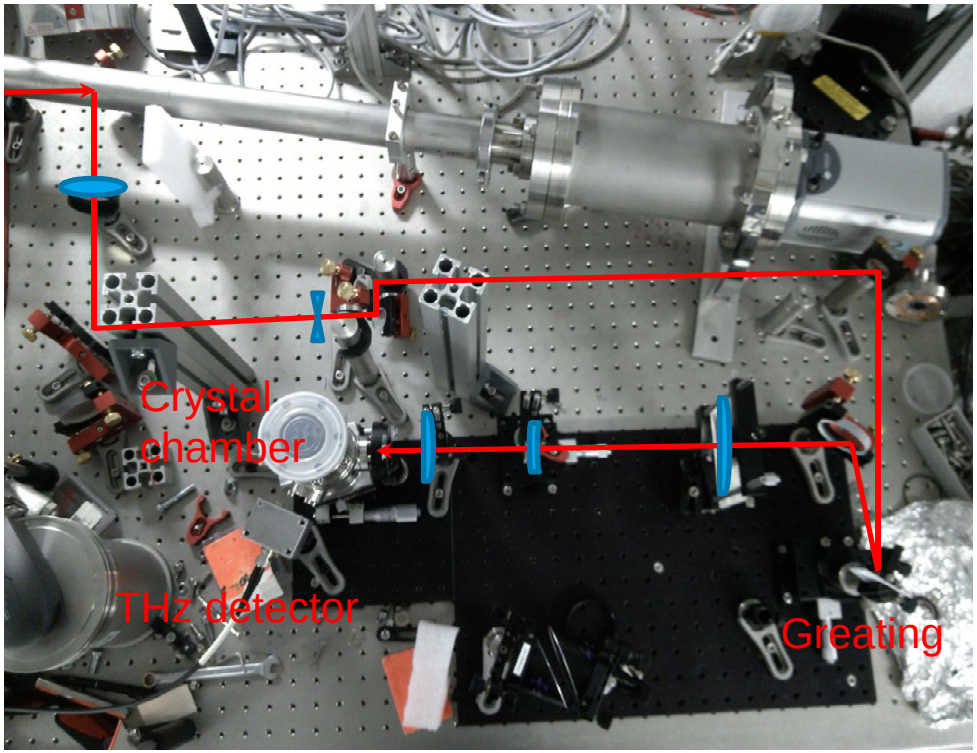


FIGURE 7 Dependence of the energy and frequency of the THz pulses on the tilt angle γ. The lines are guides to the eye

J. Hebling et al, Appl. Phys. B 78, 593–599 (2004)

THz Source -Cooling



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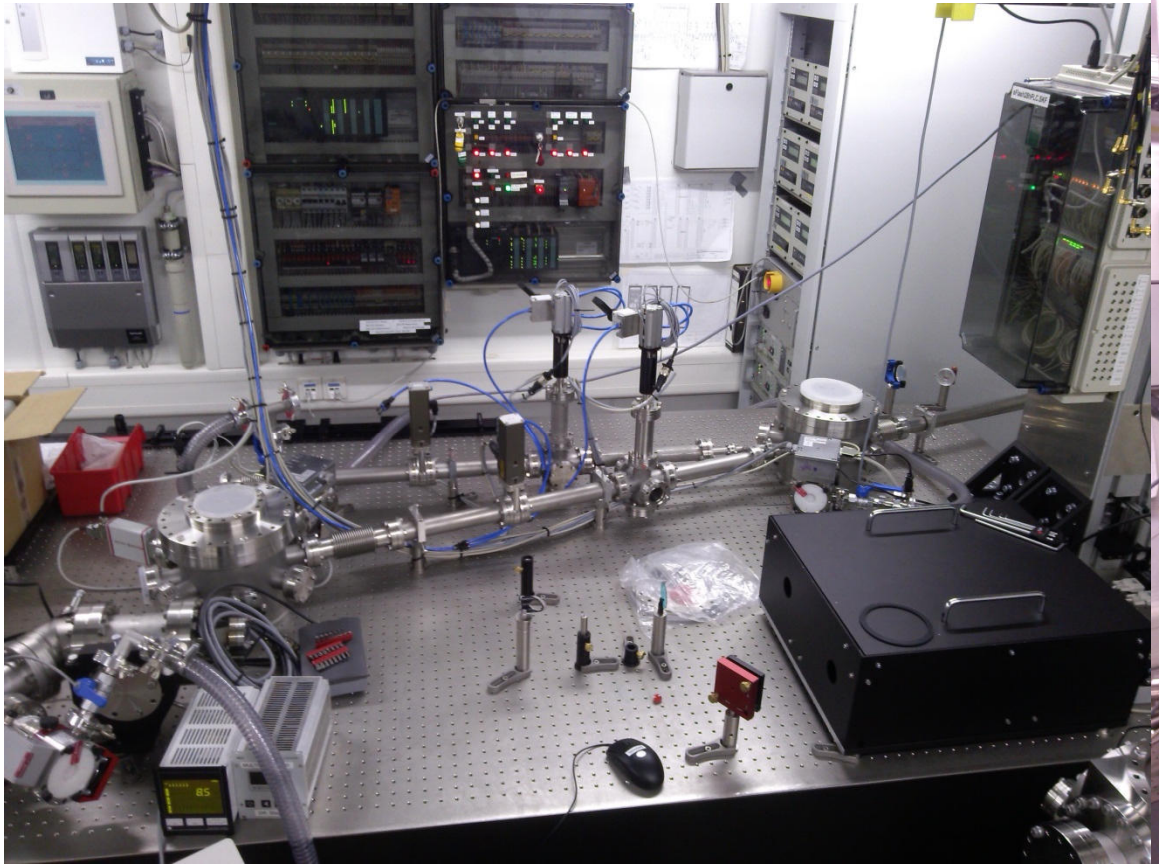
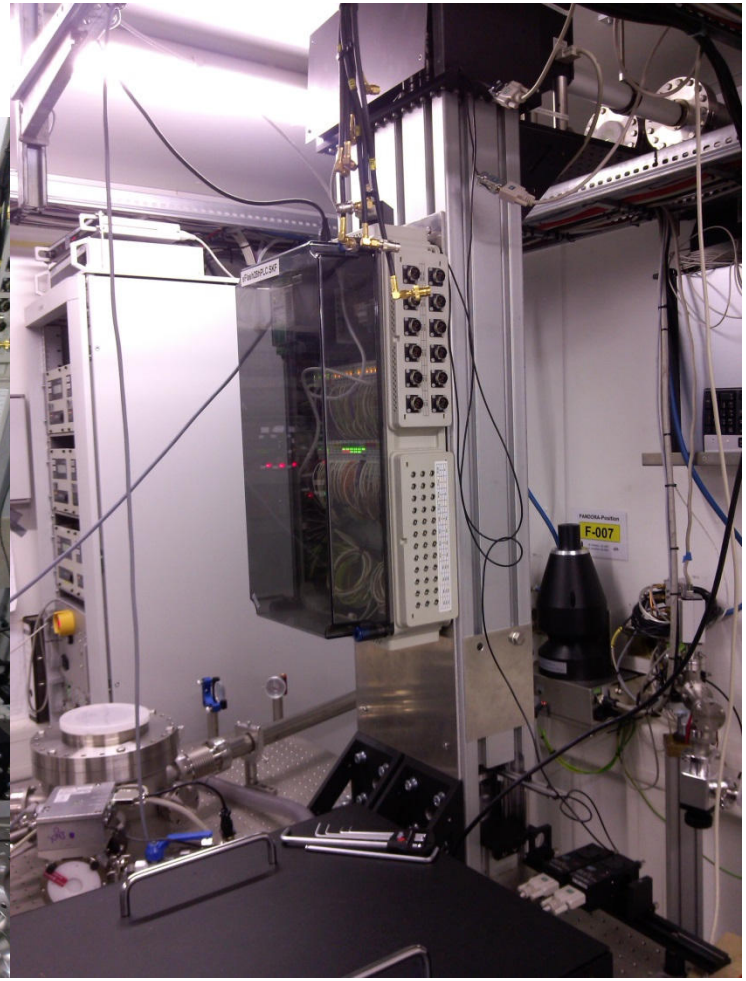
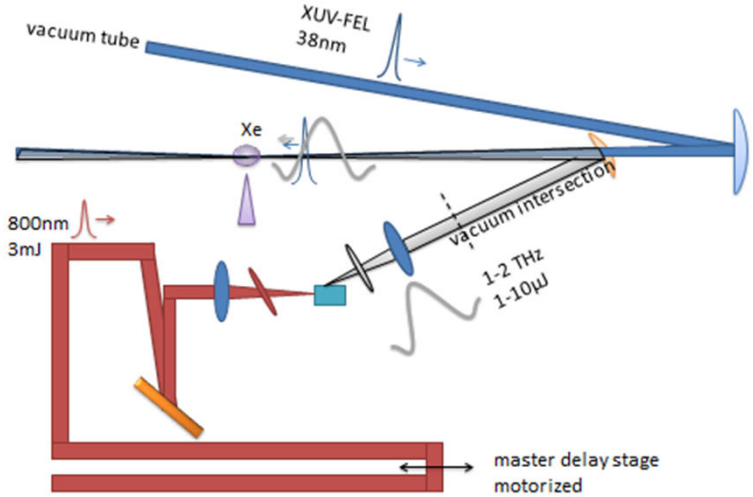
DESY 28h - Experiment

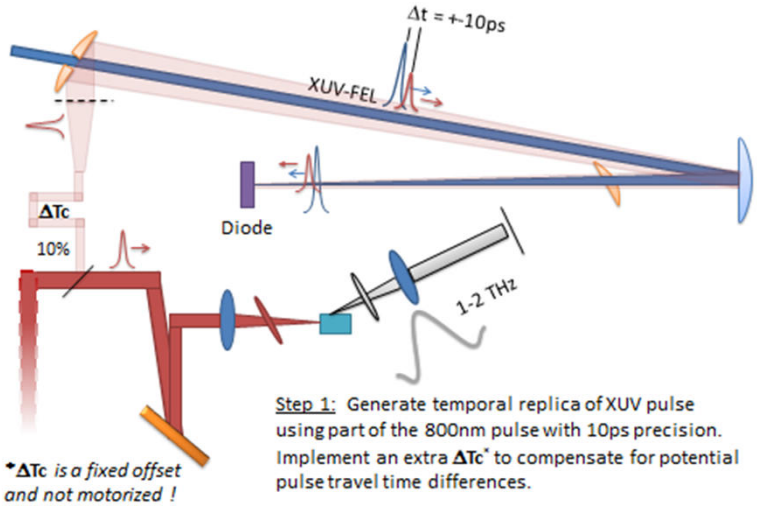
- FEL light from sFLASH Undulators with or without seeding
- IR laser (seeding laser)



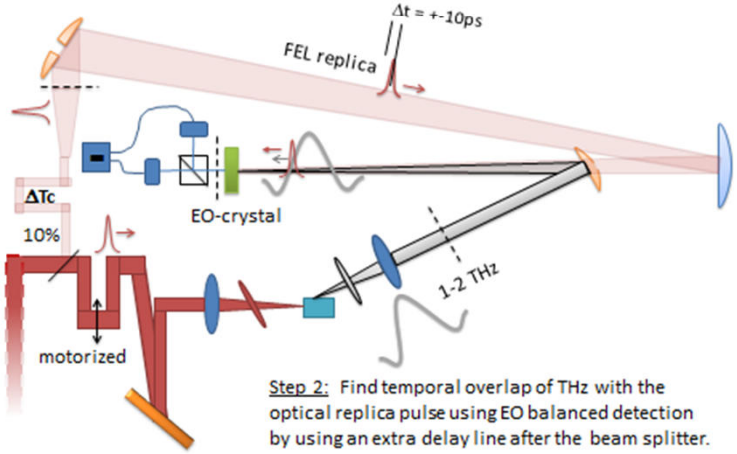


Synchronization scheme

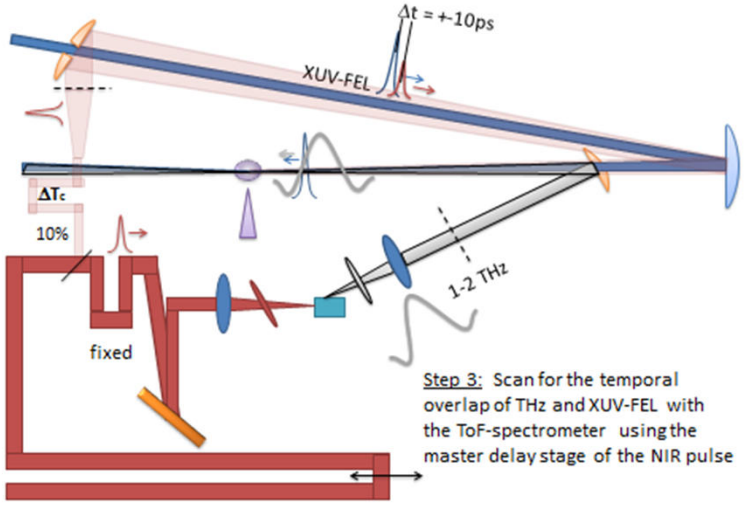




Step 1: Generate temporal replica of XUV pulse using part of the 800nm pulse with 10ps precision. Implement an extra ΔTc* to compensate for potential pulse travel time differences.



Step 2: Find temporal overlap of THz with the optical replica pulse using EO balanced detection by using an extra delay line after the beam splitter.



Step 3: Scan for the temporal overlap of THz and XUV-FEL with the ToF-spectrometer using the master delay stage of the NIR pulse

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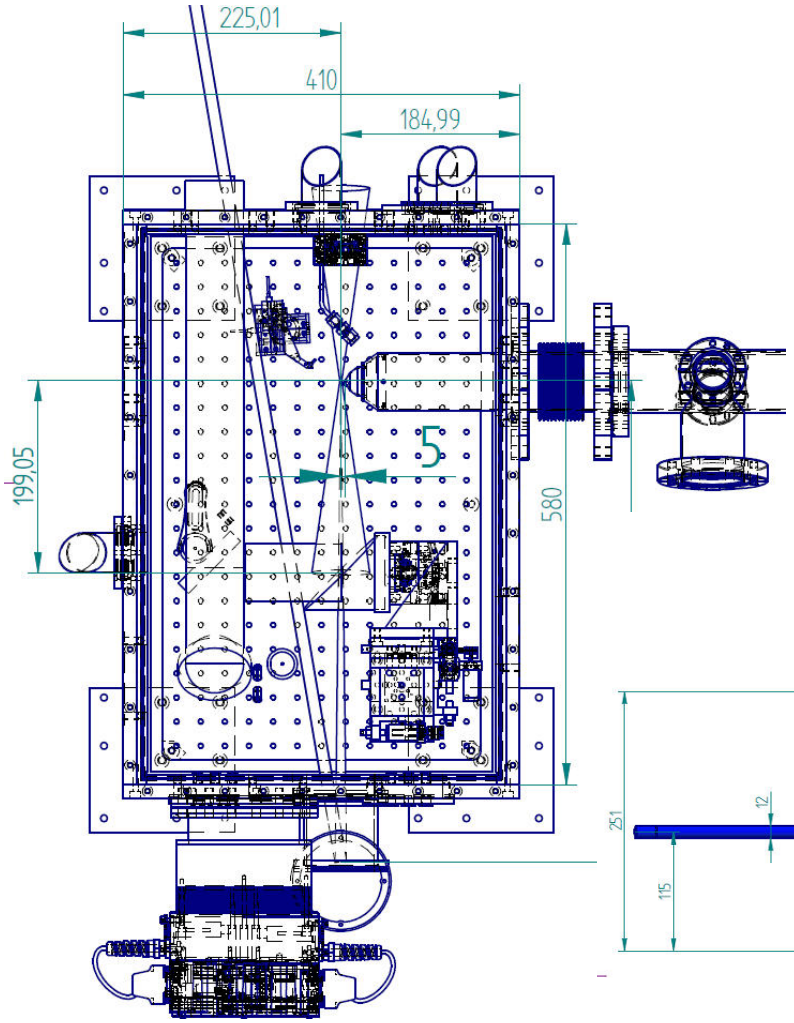
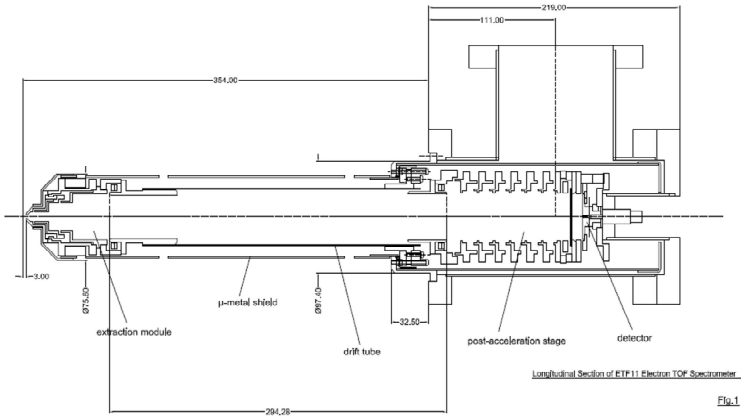
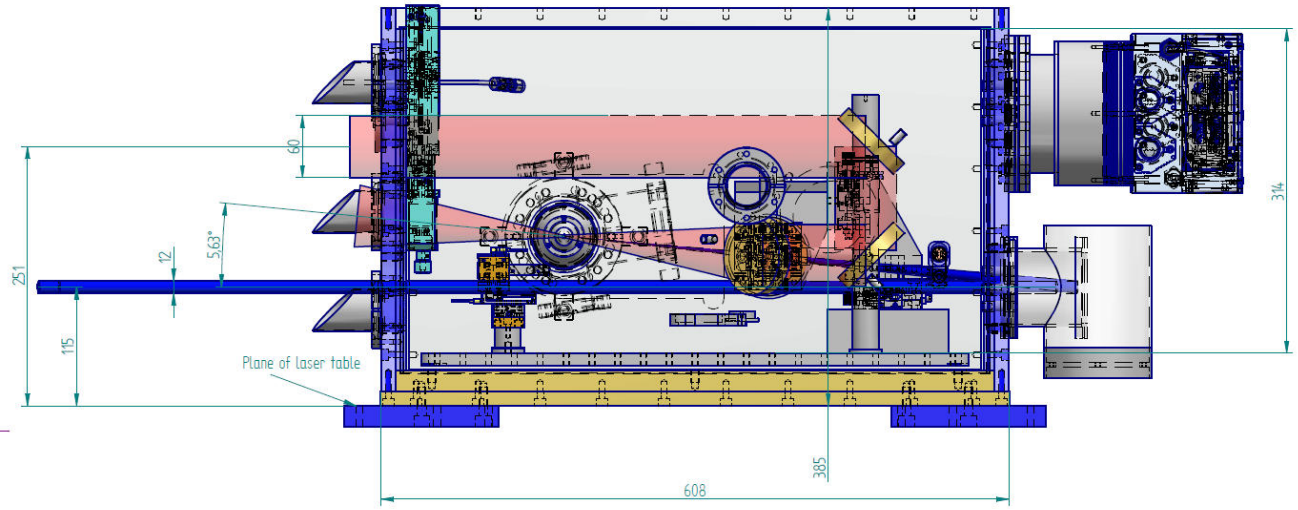
DESY 28h – THz Streaking Chamber



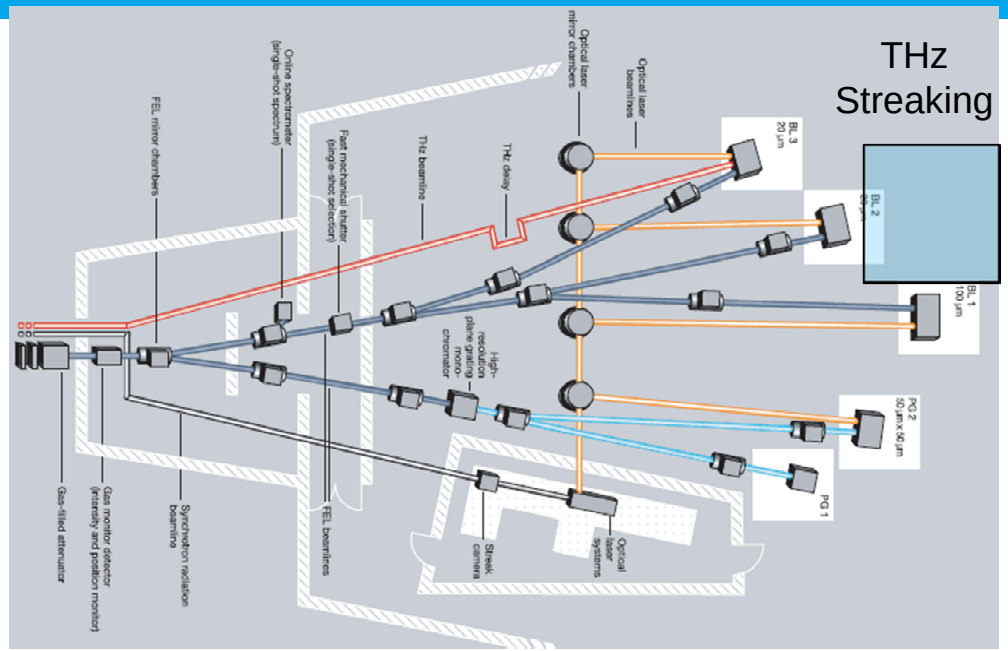
Electron TOF Spectrometer



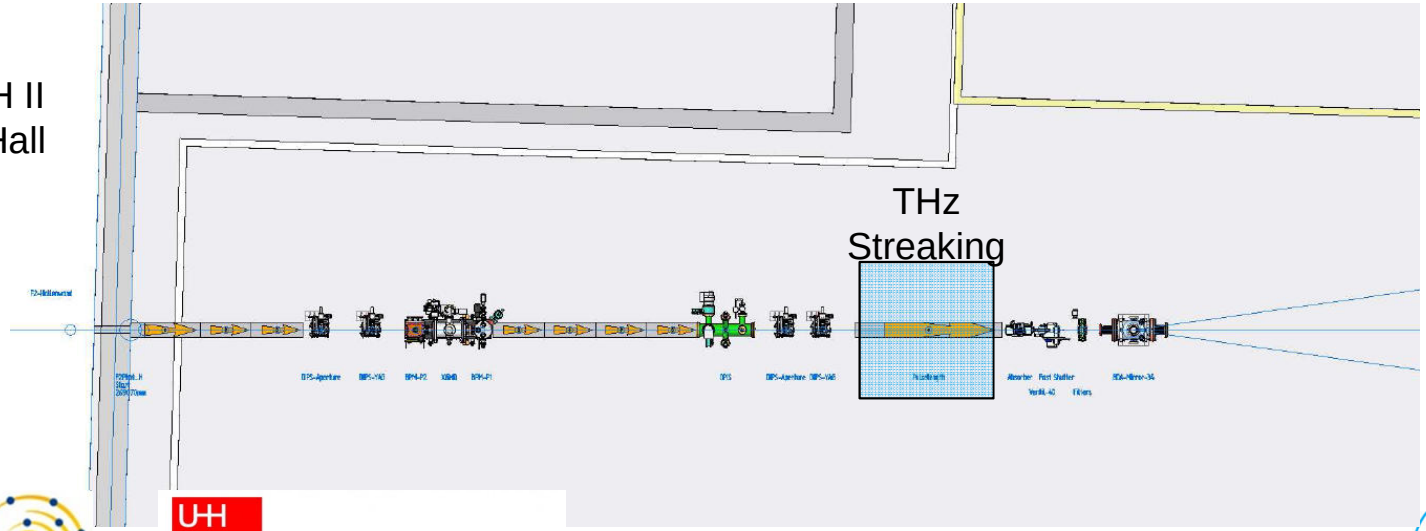


THz Streaking @ FLASH & FLASH II

FLASH
User Hall



FLASH II
User Hall



Summary

- THz streaking first experiments at FLASH
  - Single-shot information
  - Wavelength independent
  - High dynamic range (in pulse duration and FEL energy)
  - **Pulse duration AND arrival time**
- THz streaking at 28h (sFLASH)
  - THz source optimization (geometry, cooling, laser optimization)
  - THz streaking chamber (eTOF, Synchronization, EOS, Gas Source)
- THz streaking at FLASH and FLASH II (Parasitic / Transparent diagnostic)