FLASH overview

Nikola Stojanovic

PIDID collaboration meeting,
Hamburg, 16.12.2011

HELMHOLTZ GEMEINSCHAFT

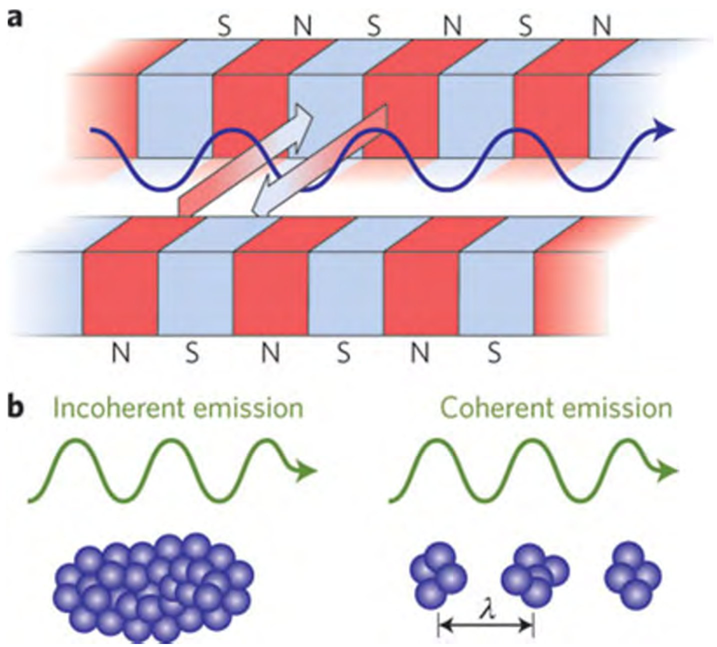
DESY

Outline

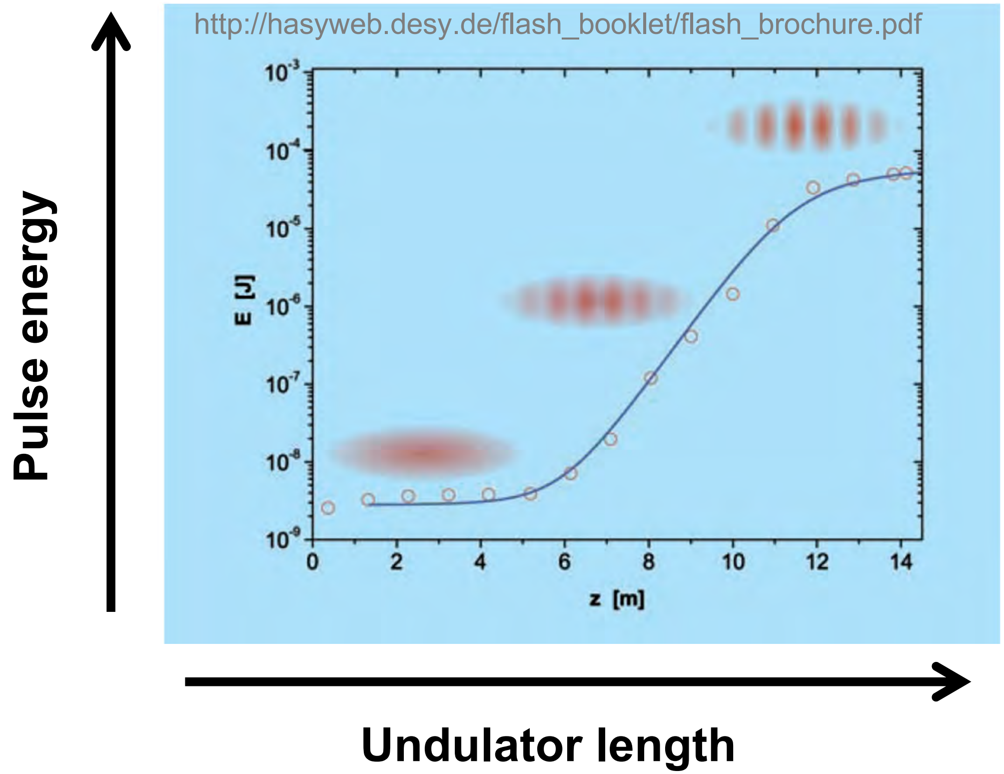
- Overview of the FLASH facility
- Examples of research at FLASH

SASE at FLASH

SASE – Self Amplified Spontaneous Emission



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

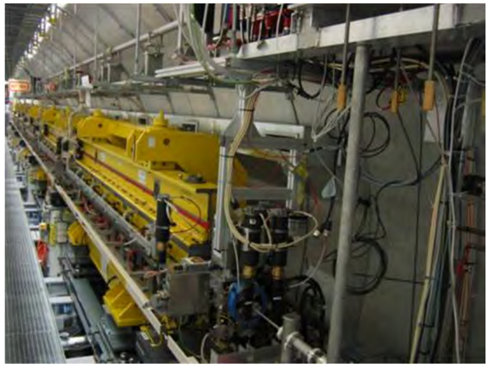


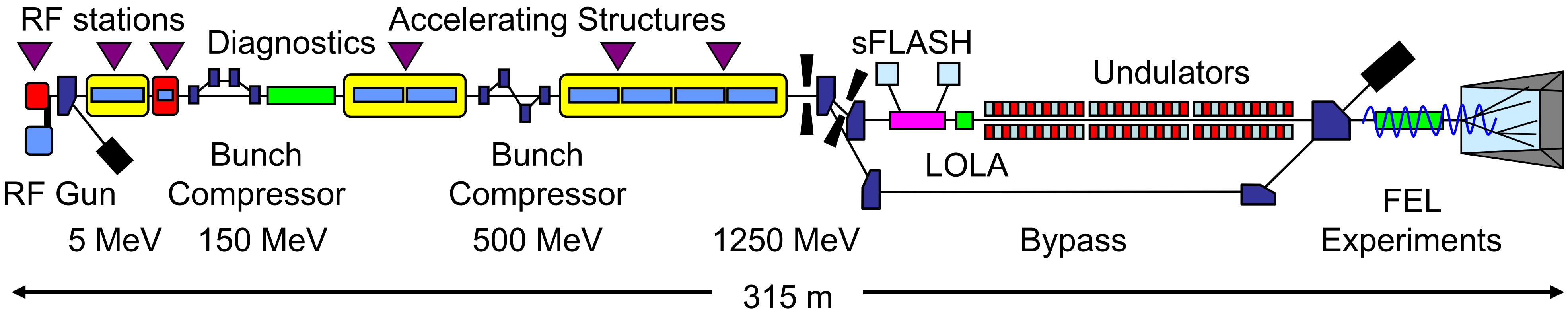
<u>Electron beam requirements:</u>

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

FLASH layout



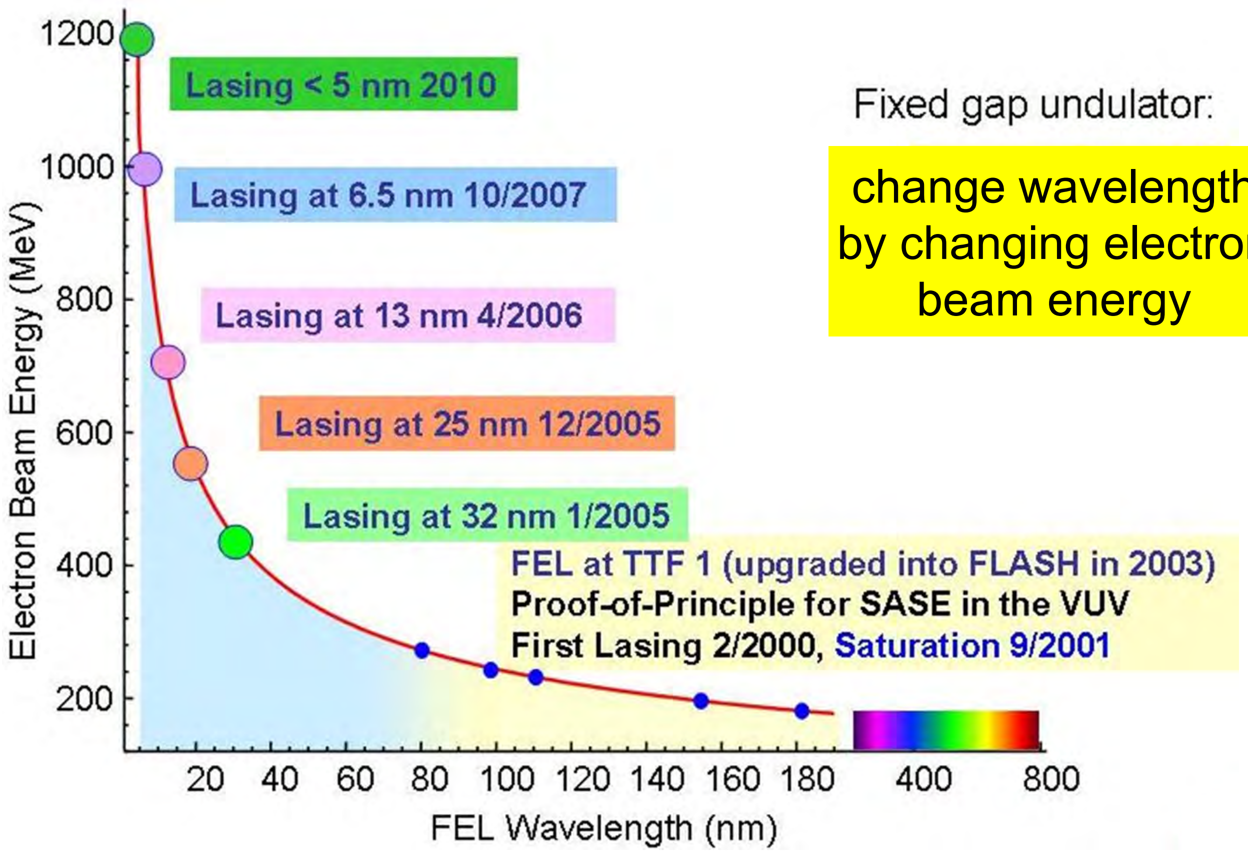





FLASH performance

• Energy range	~ 0.3 – 1.25 GeV
→	~ 60 – 4.1 nm (~20 – 300 eV)
• Pulse energy	~ 10 - 300 μJ
• Pulse duration	~ 10 - 200 fs
• Peak power	1 - 10 GW
• Bandwidth Δλ/λ	~ 1 %
• **Aug 2005**	**start of user expts.**



Fixed gap undulator:

change wavelength by changing electron beam energy

Undulator

6 modules, 27 m total, 12 mm gap, permanent NdFeB magnets,

B_0 = 0.48 T, K = 1.23, λ_u = 27.3 mm

FLASH performance

Wavelength range (fundamental):

4,1 - 60 nm

Spectral width (FWHM):

0.5 - 2 %

Pulse energy:

up to 100 µJ (average),

>200 µJ (peak)

Pulse duration (FWHM):

10 - 200 fs

Peak power (fundamental):

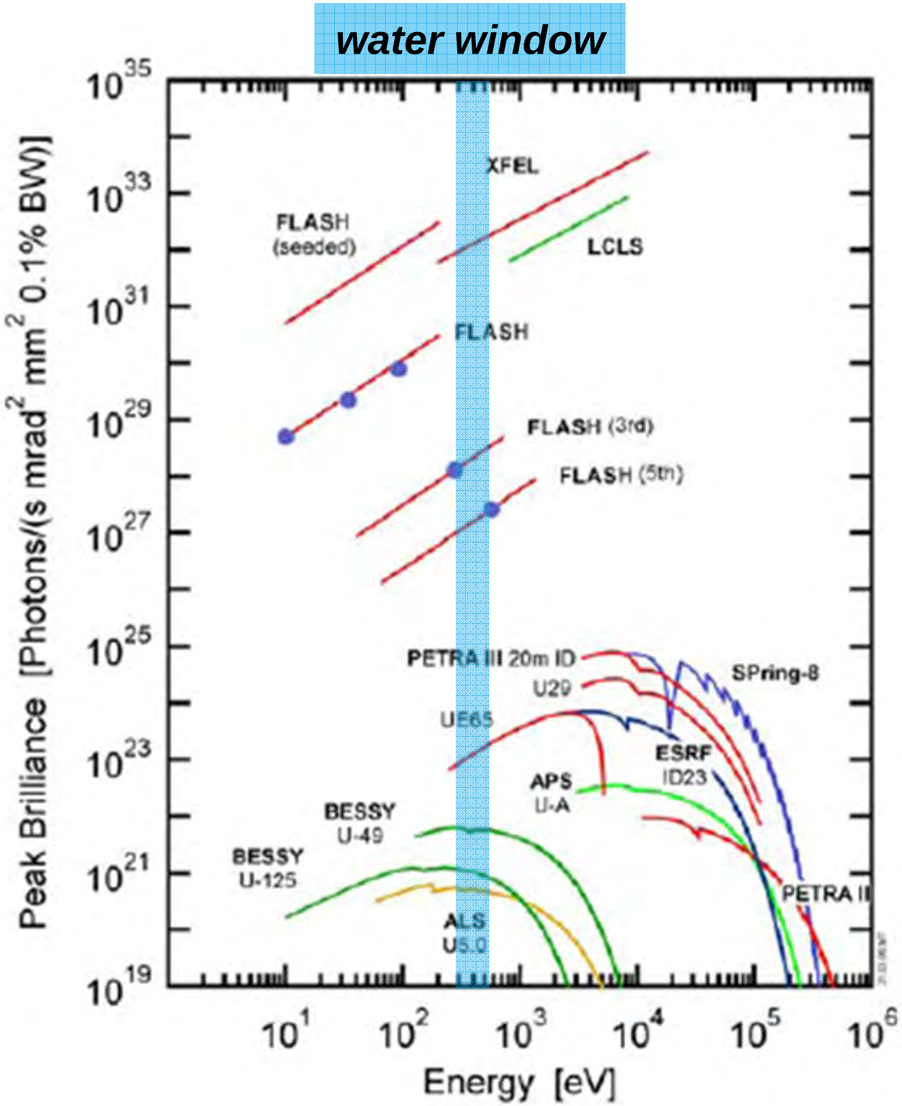
1-5 GW

Average power (fundamental):

up to 0.1 W *(up to 3000 pulses / sec)*

Peak brilliance:

up to $5x10^{29}$



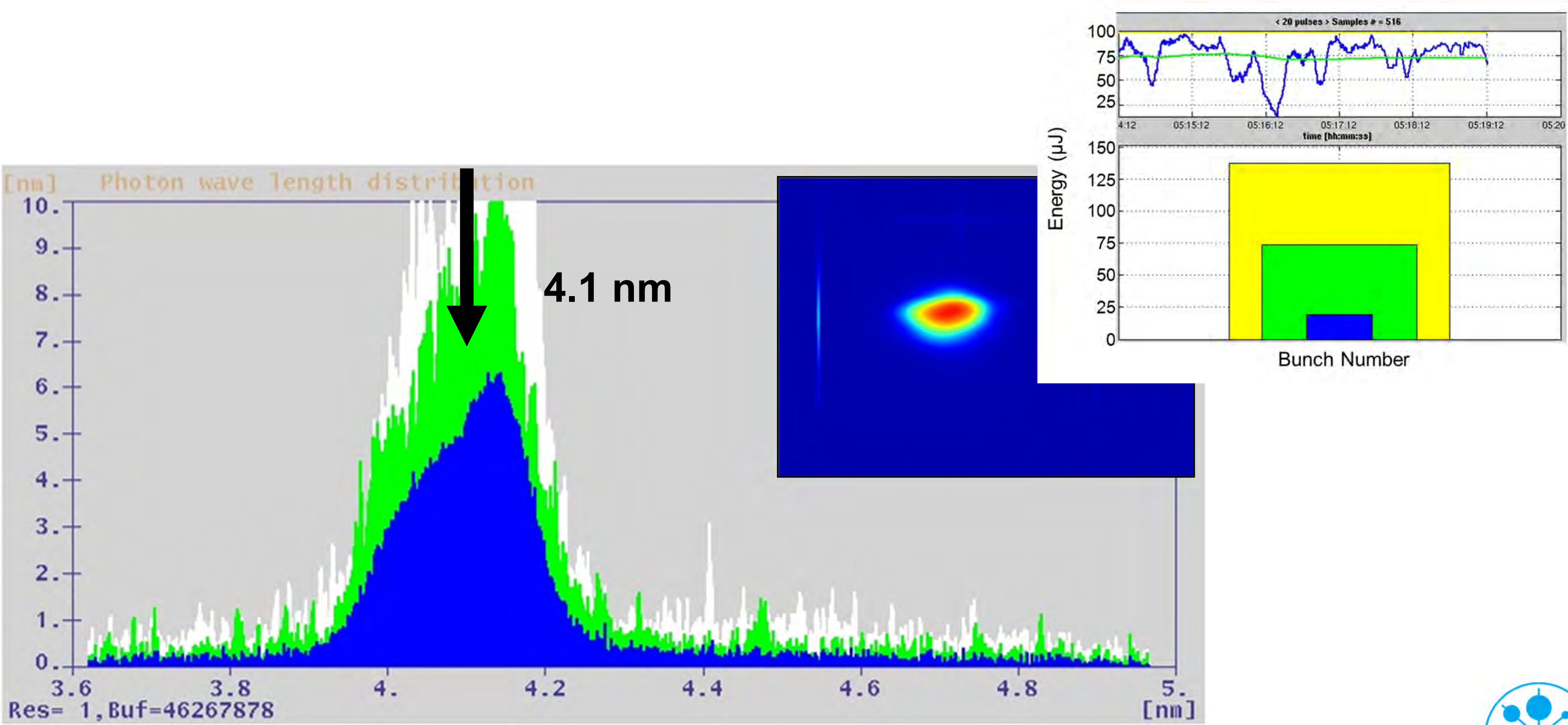
peak brilliance

FLASH performance: water window

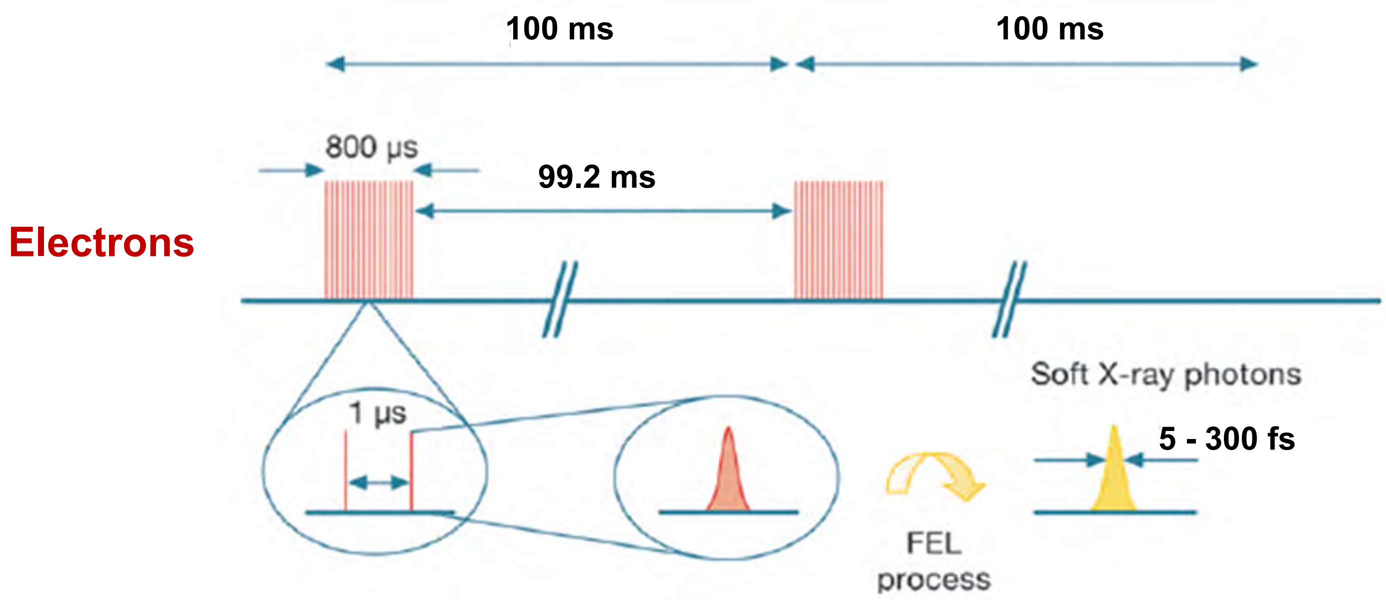
> Sep-2010: achieved the electron beam energy above 1.2 GeV

> First lasing in the water window at 4.12 nm with the fundamental

> Single pulse energy ~130 µJ (max), ~70 µJ (av)



Pulse scheme at FLASH



Tiedtke, K. et al.. New Journal of Physics 11 (2009) 023029

Repetition rate:

10Hz - Base repetition rate

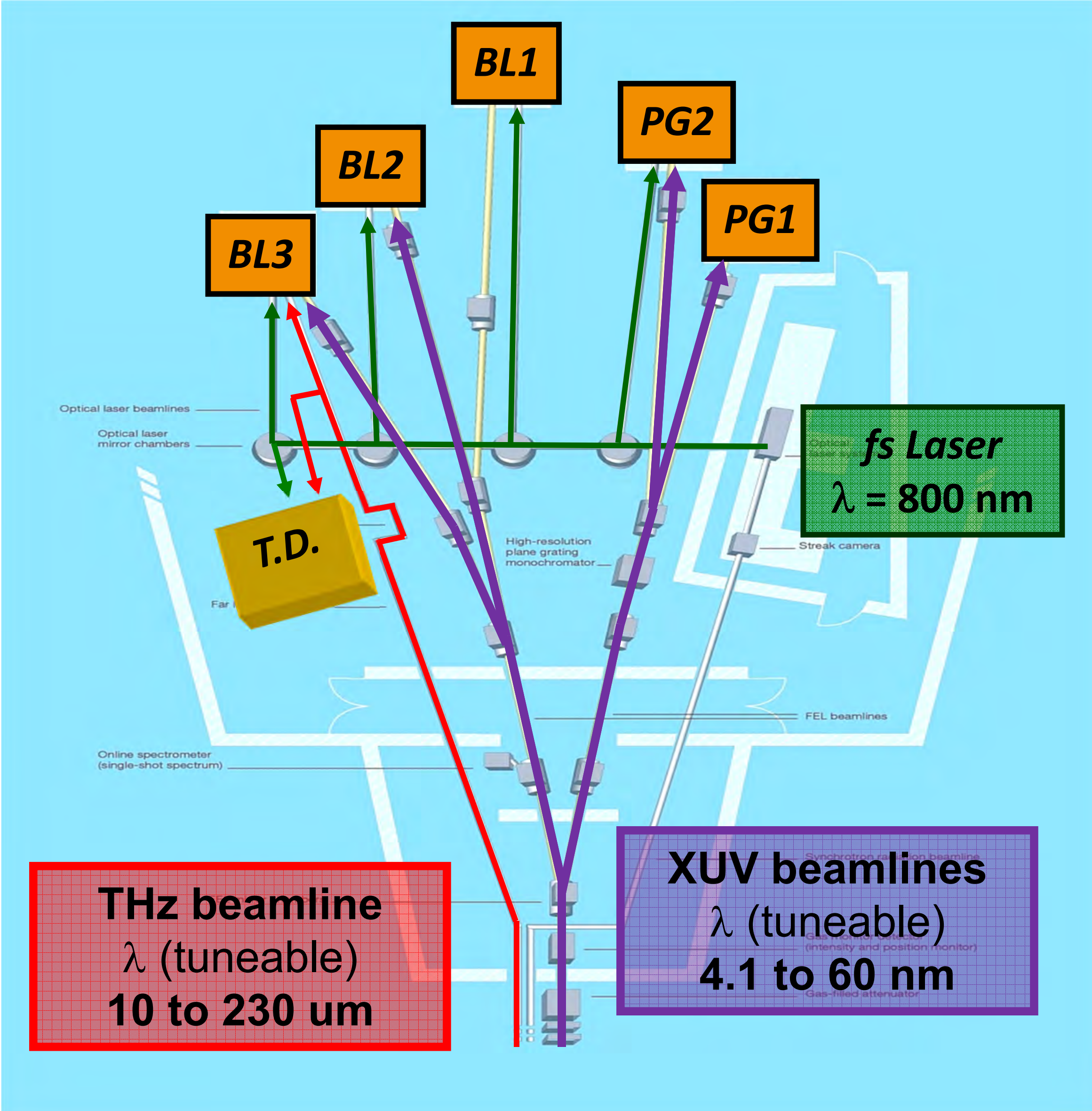
1MHz - within the macro-pulse

FLASH hall - beamlines

- **PG1 – 50 um** (monochromator)
- **PG2 – 50 um** (monochromator)
- **BL1 – 100 um**
- **BL2 – 25 um**
- **BL3 – 25 um**

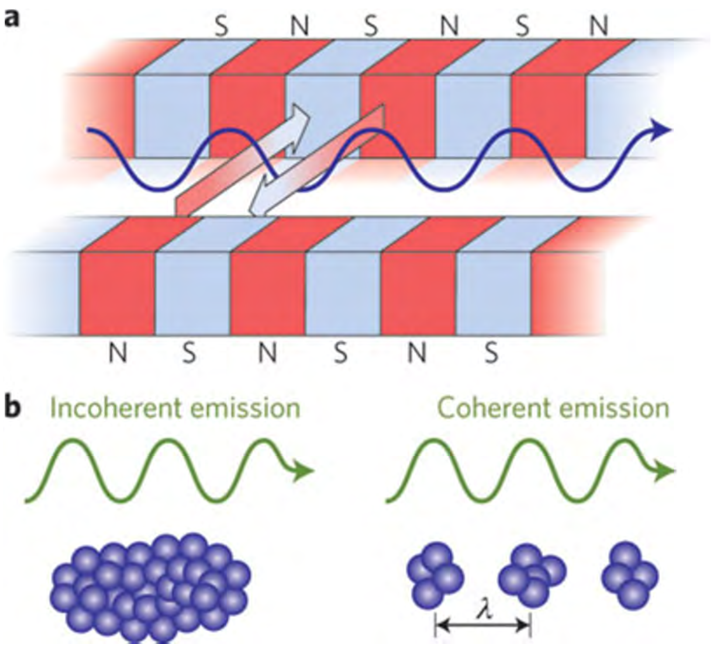
  few 1000um (unfocused)

  + tuneable THz (0.5-230um)

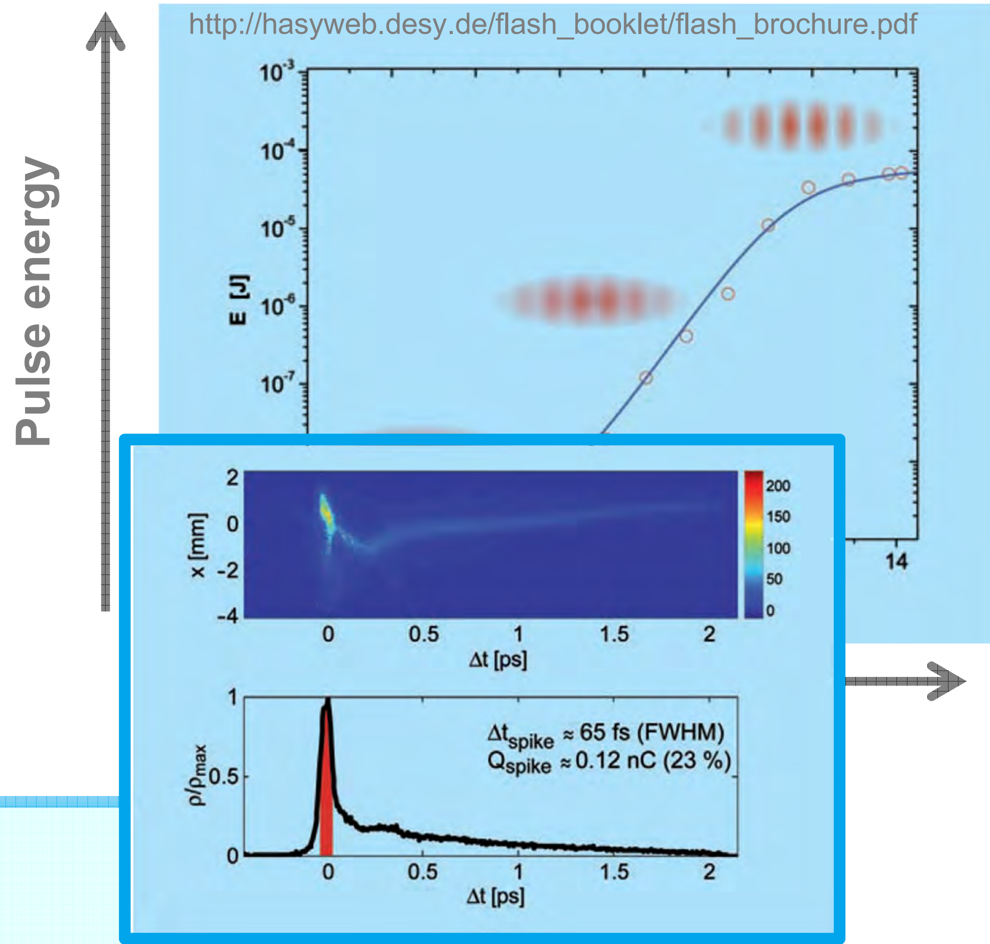


SASE at FLASH: short pulses

SASE – Self Amplified Spontaneous Emission



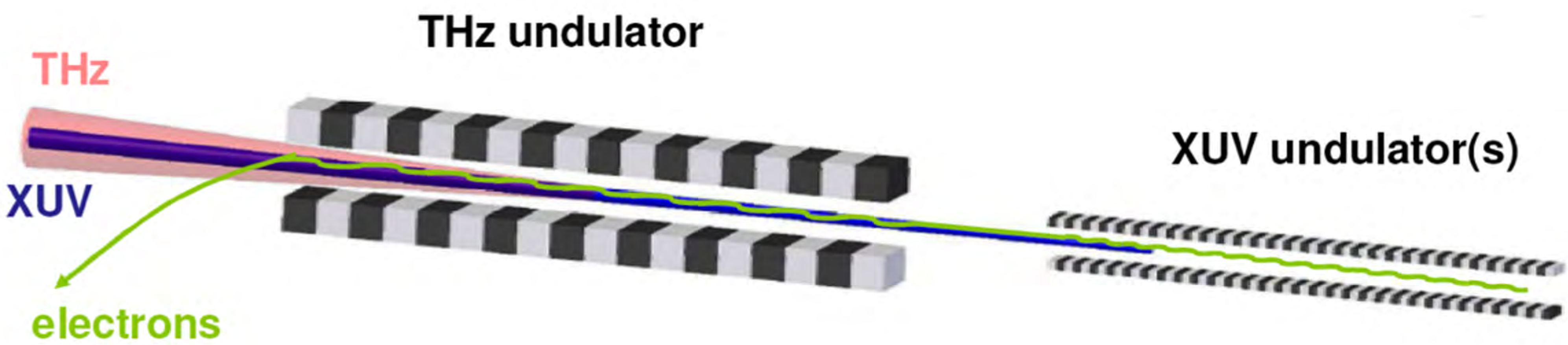
S. Jamison, *Nature Photonics* ***4, 589 - 591 (2010)***



Electron beam requirements:

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

THz at FLASH – Tunable source



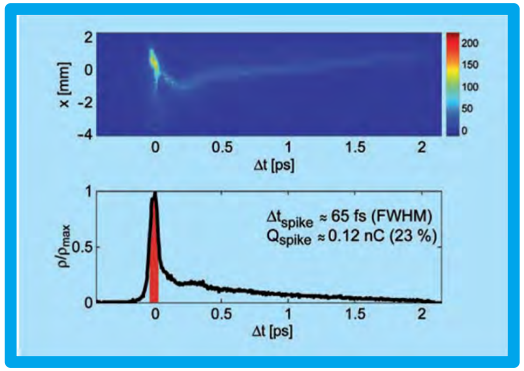
<u>Cascaded design</u>:

- Parasitic operation
- Synchronized to XUV pulse

<u>Short electron bunch</u>:

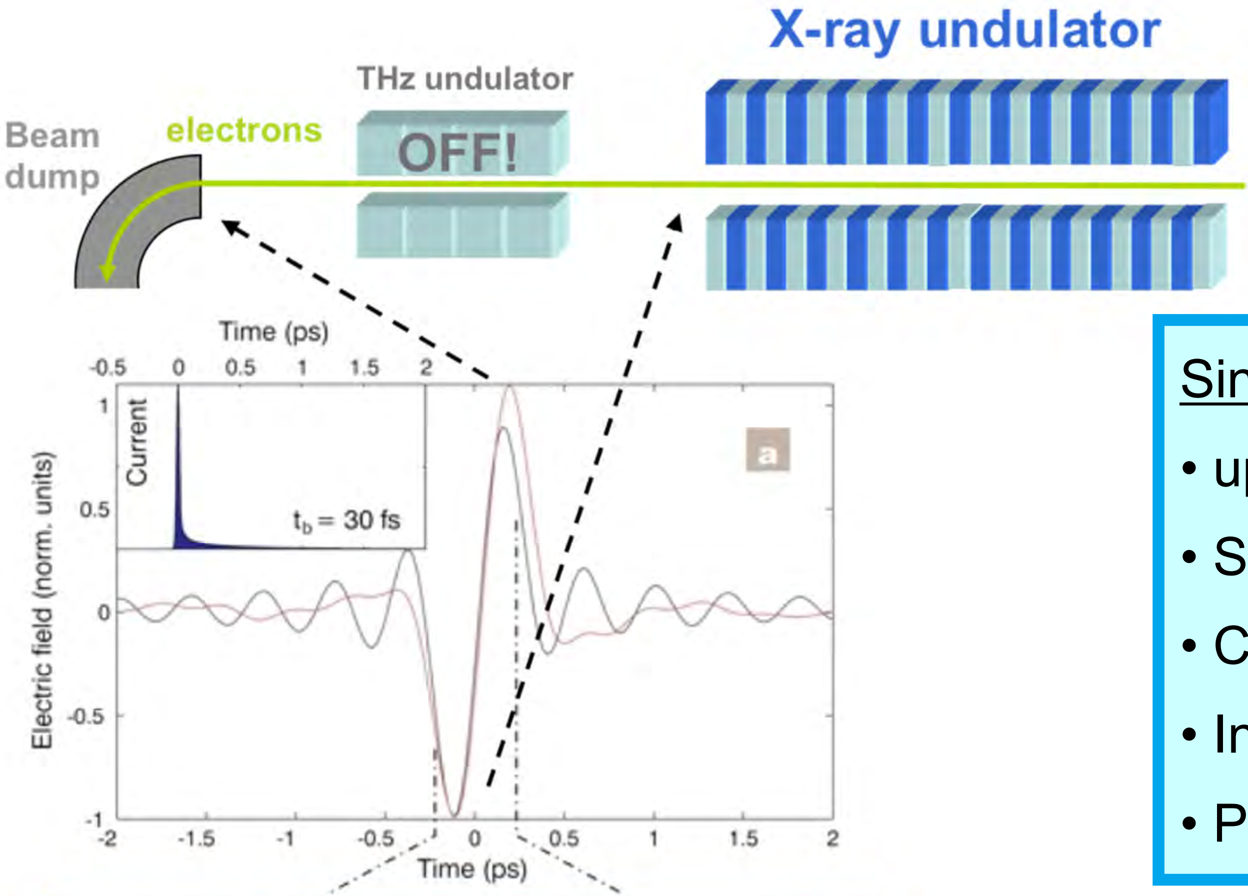
- Intensity ~ N_e^2 **(up to 70uJ)**
- Coherent and CPE stable

<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).

THz at FLASH – Single cycle



Calculation and measurement*

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

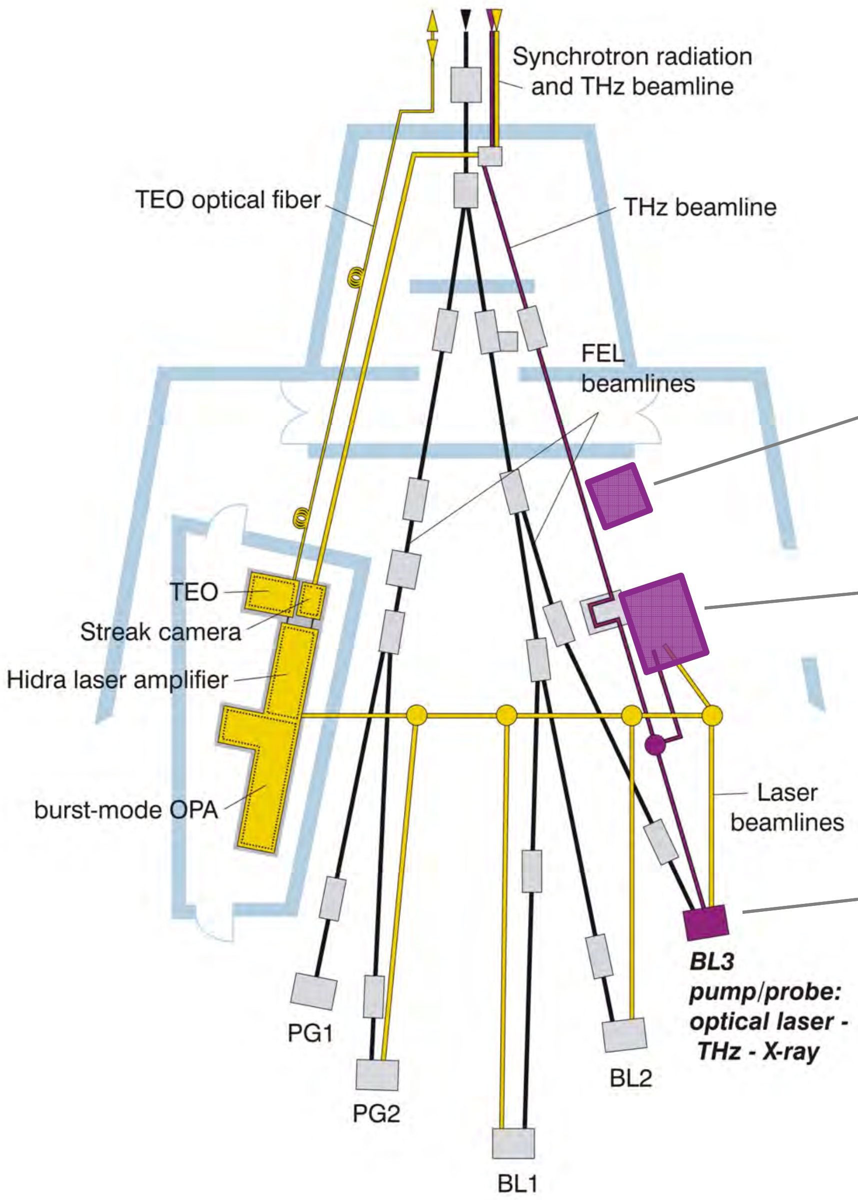
… for Free!

Single cycle (edge radiation):

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

THz at FLASH – Beamline

… and THz ports



THz diagnostics port - THz only

Pulse energy, spectrum …

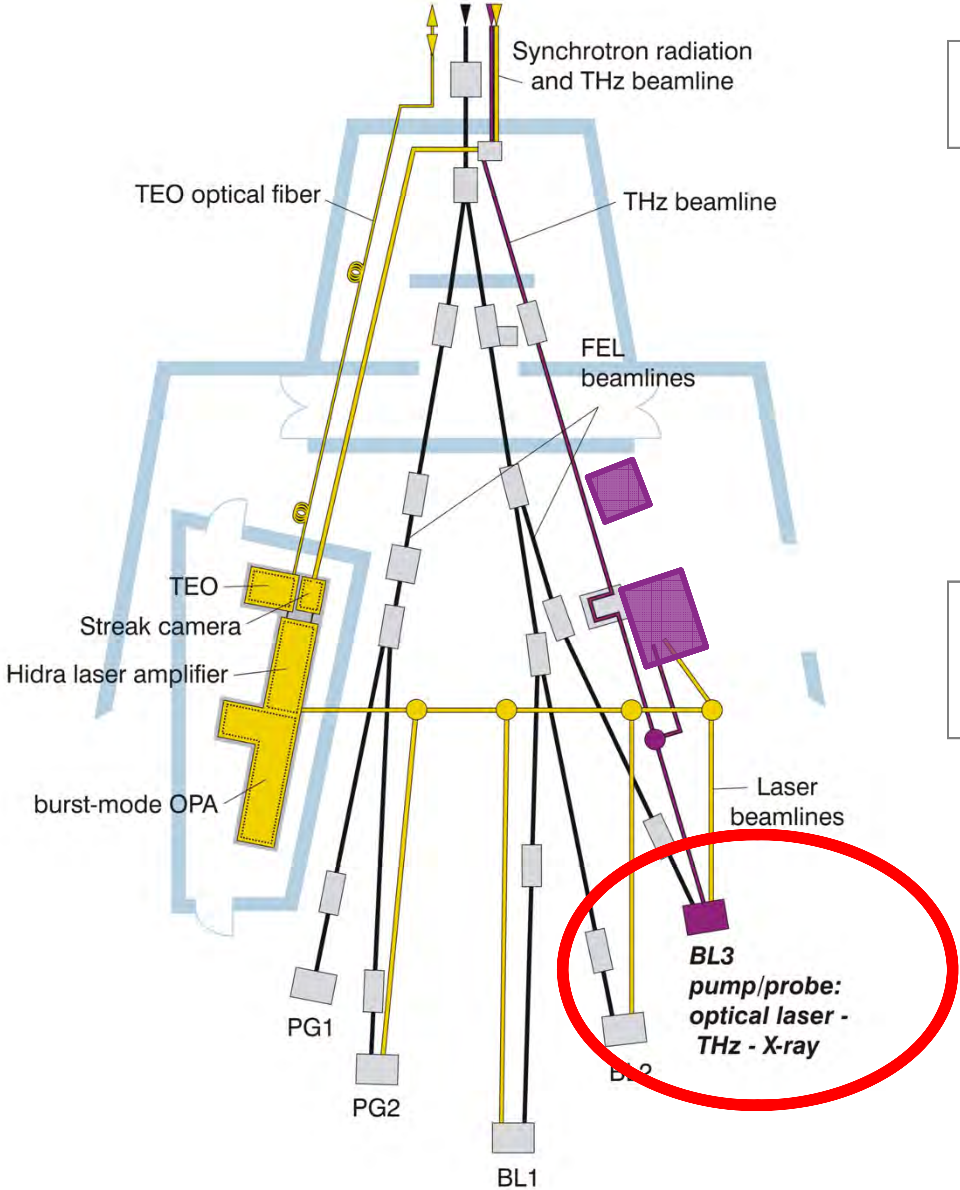
THz pump/probe port - THz & VIS

Pulse duration, timing, experiments…

THz end station @BL3 - THz & VIS & XUV

User experiments …

THz at FLASH – User experiments



Resonant vibrational control in complex materials

1) *in strongly correlated oxides*

M. Gensch *(HZDR,Dresden) + CFEL …*

9 shifts

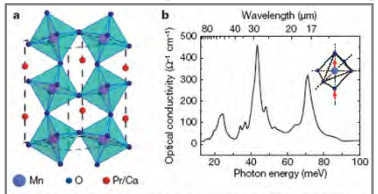
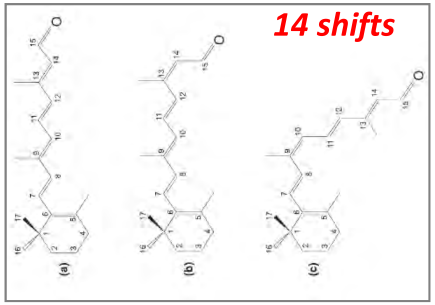


Figure 1 | $Pr_{0.7}Ca_{0.3}MnO_3$ crystal structure and vibrational spectrum.

2) *of biomolecules*

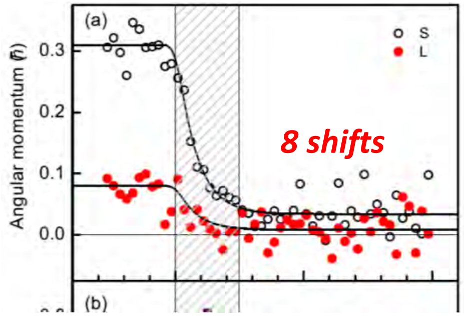
Dr. T. Laarmann (DESY) + …

14 shifts



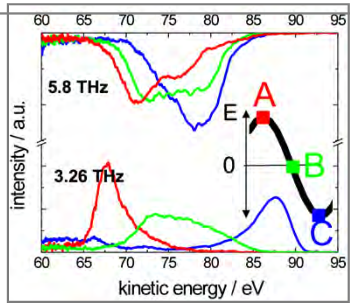
3) Control of magnetization in ferromagnets

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; …)

Research areas at FLASH

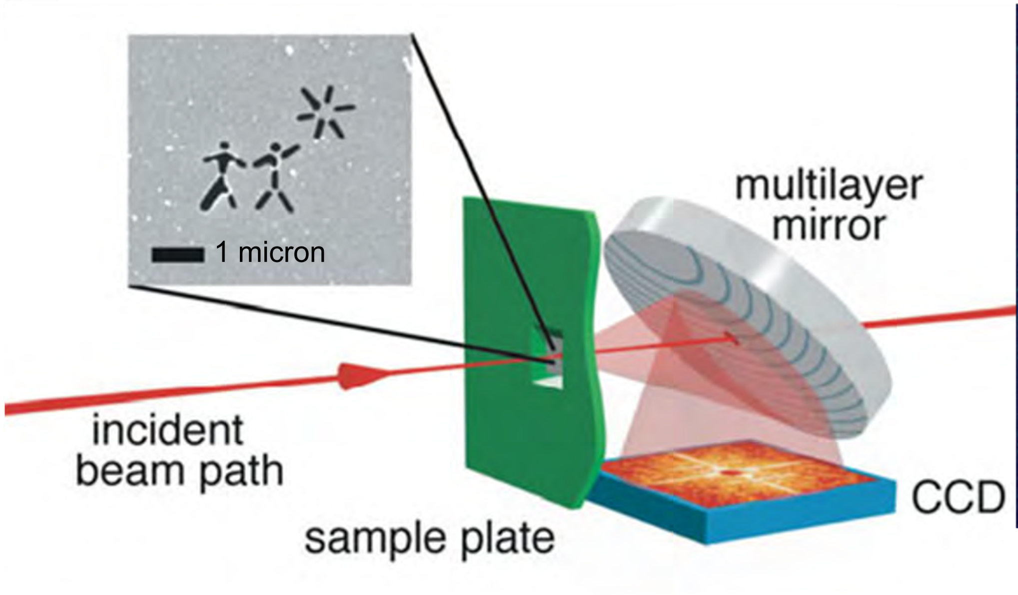
- **Interaction of ultra-intense XUV pulses with matter**
  - multi-photon excitation of atoms, molecules, clusters…
  - creation and characterization of dense plasmas
  - **imaging of biological samples**
- **Investigation of extremely dilute samples**
  - photo-dissociation of molecular ions
  - spectroscopy on highly charged ions
  - spectroscopy and imaging of mass selected clusters
- **Investigation of surfaces and solids**
  - XUV laser desorption
  - femtosecond surface dynamics (excited by THz/VIS)
  - photoelectron spectroscopy of surfaces and solids
  - RIXS and Raman spectroscopy
- **Femtosecond time-resolved experiments**
  - pump-probe exp. on solids, molecules and atoms
  - synchronization FEL/THz - optical laser

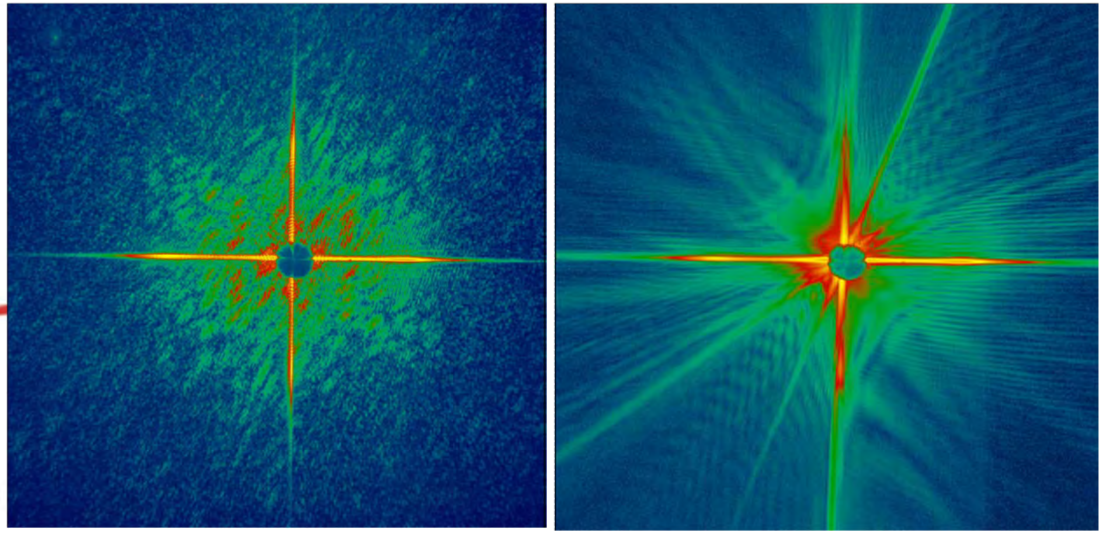
> 30 different instruments have been used at FLASH

> 150 science publications

http://hasylab.desy.de/facilities/flash/publications/selected_publications/index_eng.html

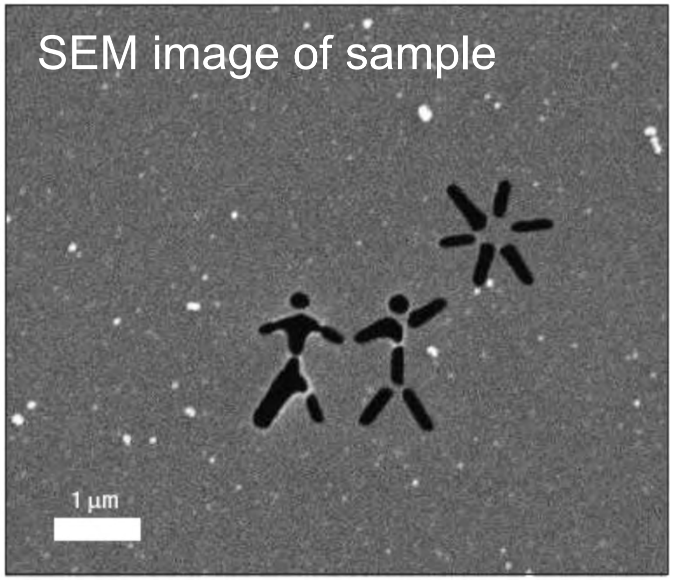
3.1: Applications: Molecular imaging

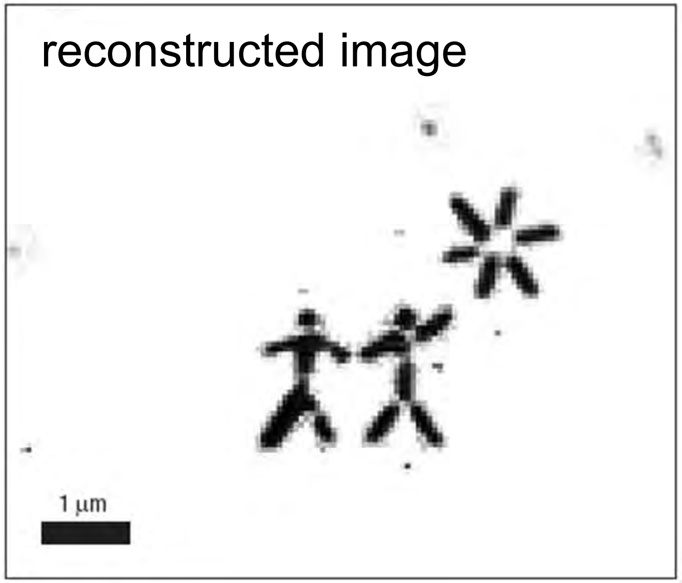




20 µm focus, 30 fs pulse, ~10^{14} W/cm²;

Sample heated to 60 000 K!

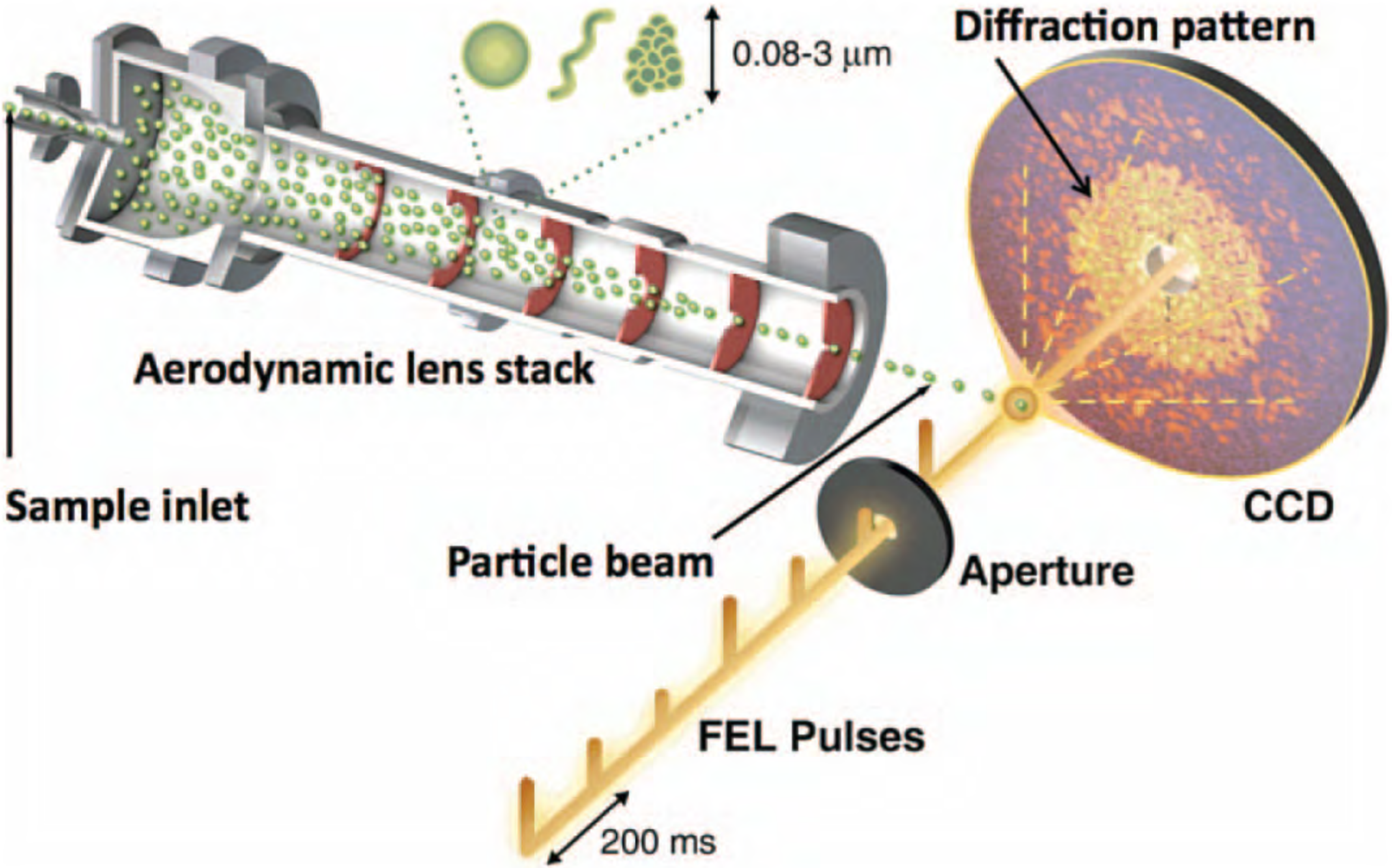




→ diffraction limited resolution at 32 nm wavelength

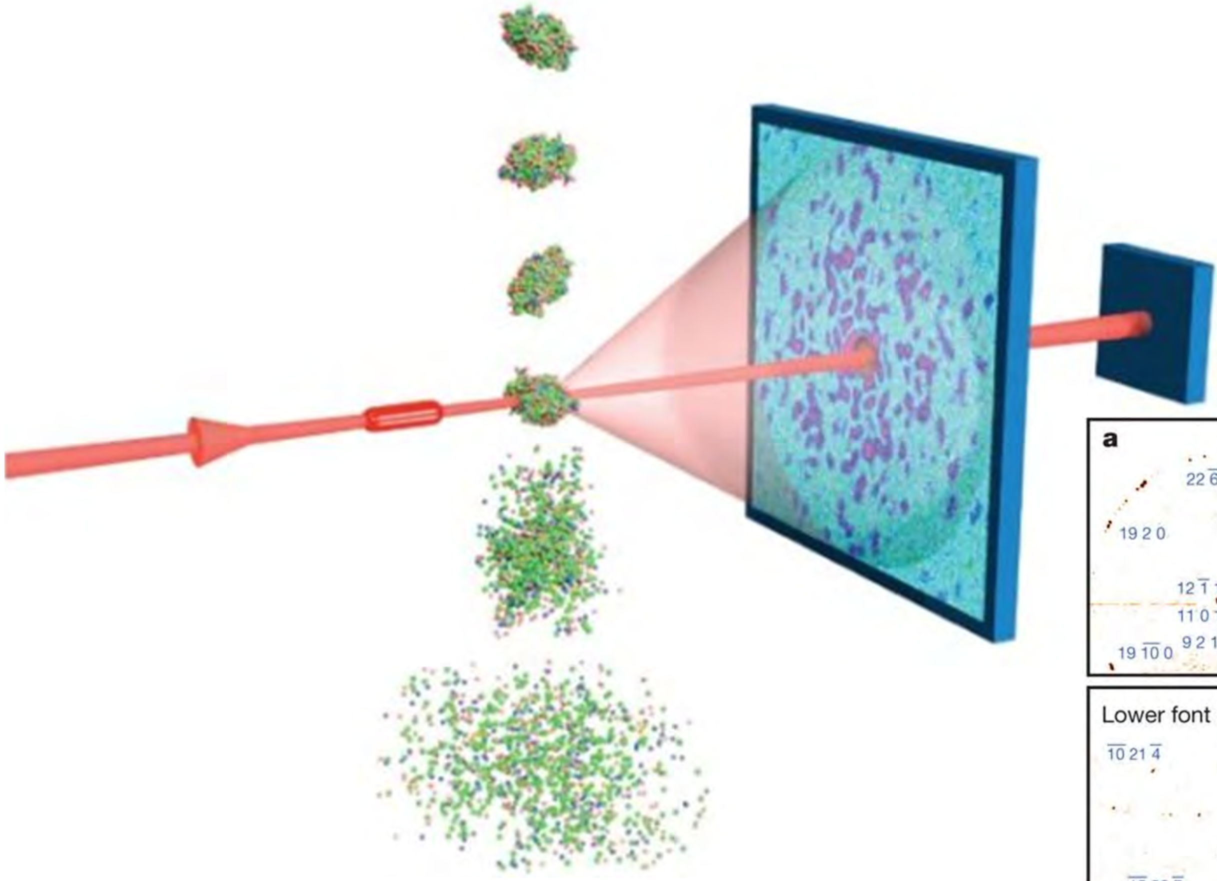
H. Chapman et al., Nature Physics 2, 839 (2006)

3.2: Applications: Molecular imaging



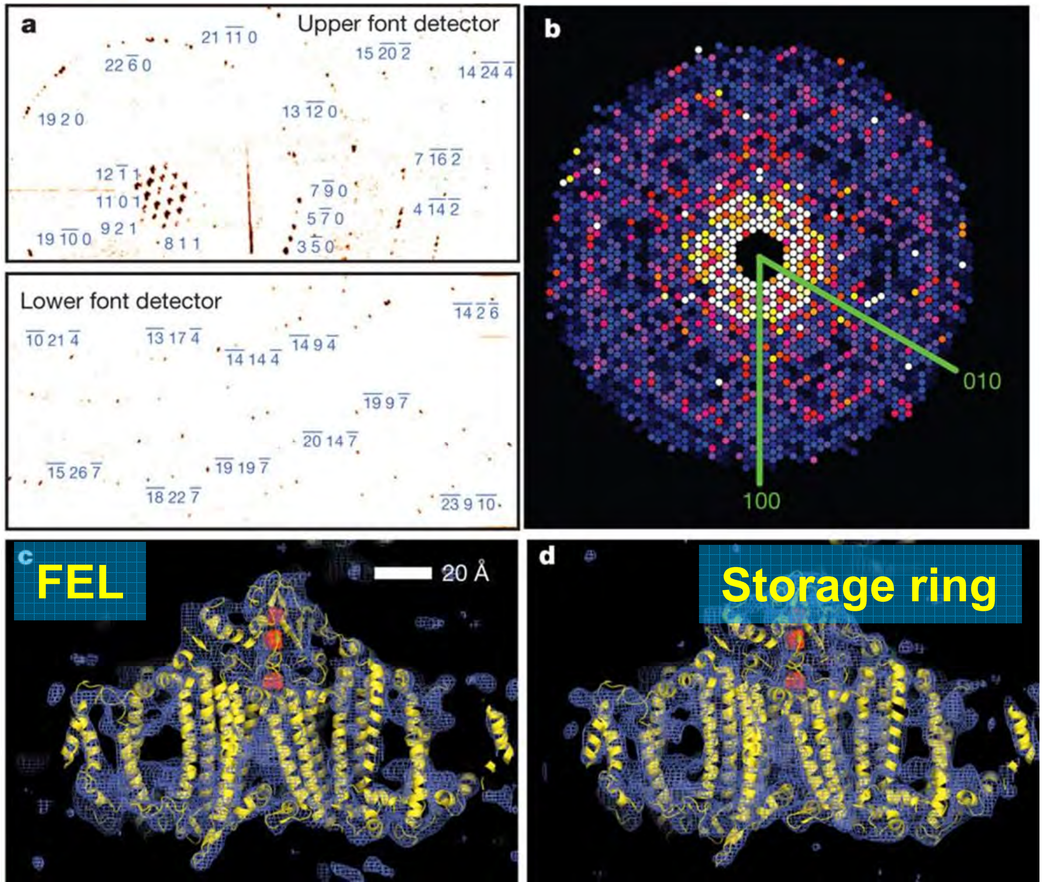
M.J. Bogan et al., Aerosol Science and Technology, 44:i–vi (2010)

3.3: Applications: Molecular imaging



<u>Membrane protein:</u>

<u>Photosystem I</u>

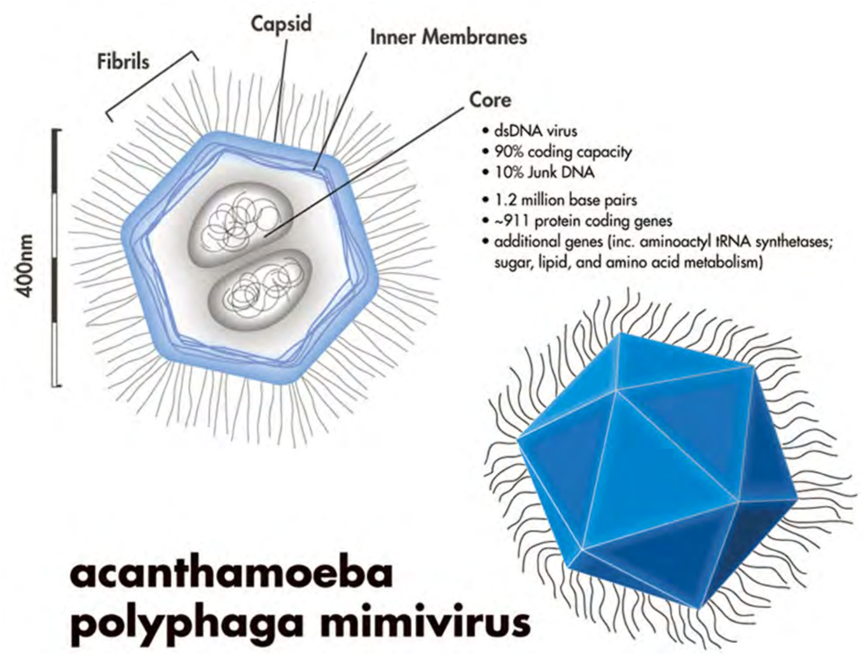


<u>Diffraction before destruction:</u>

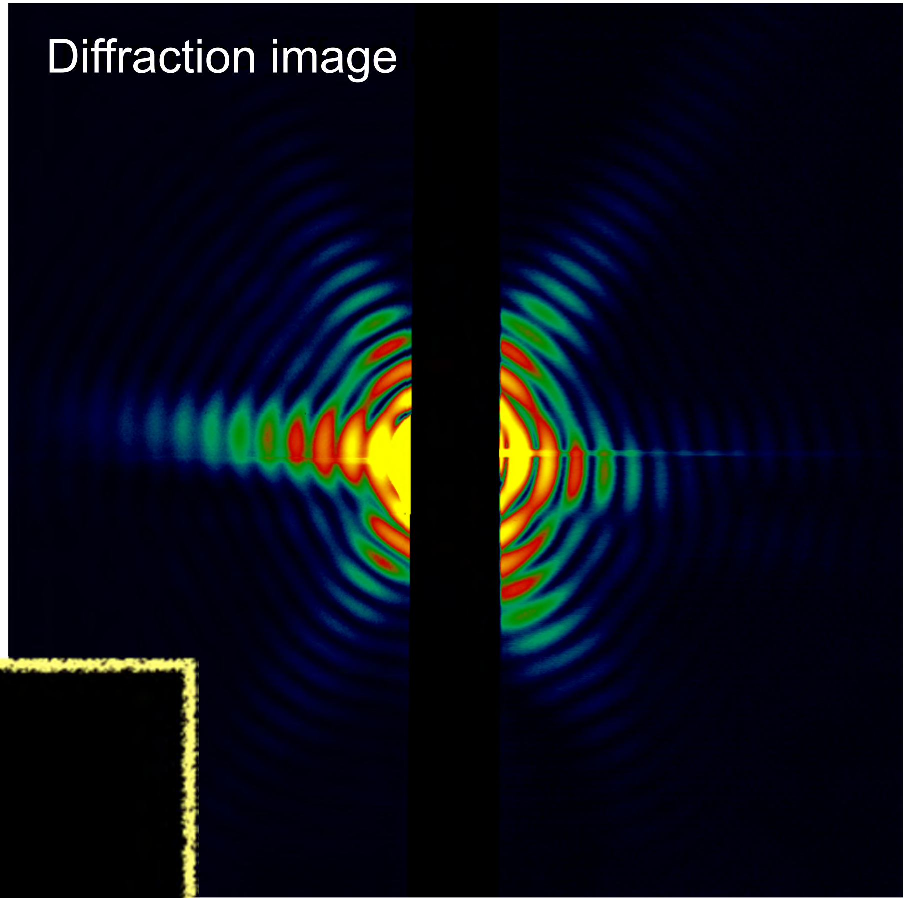
- fluence 900J/cm^2 (@ 70fs)
- sample dose - 700 Mgy (3rd gen. - 30Mgy)

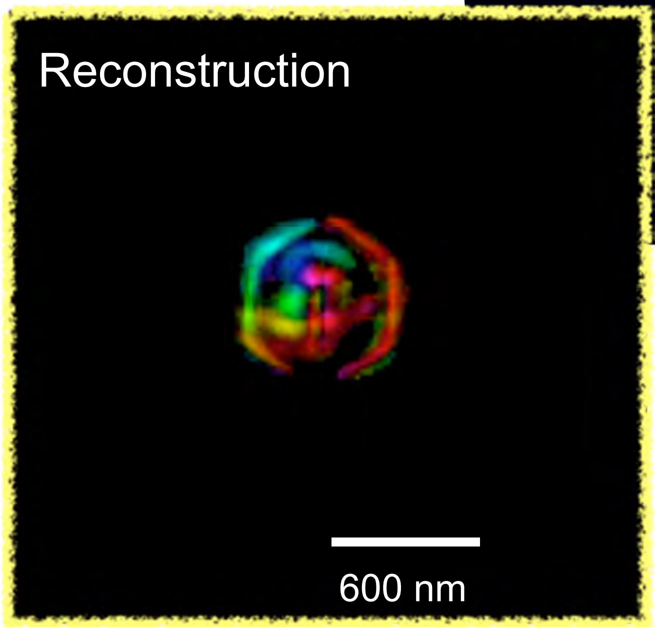
H. Chapman et al., *Nature* 470, 73 (2011)

3.4: Applications: Molecular imaging



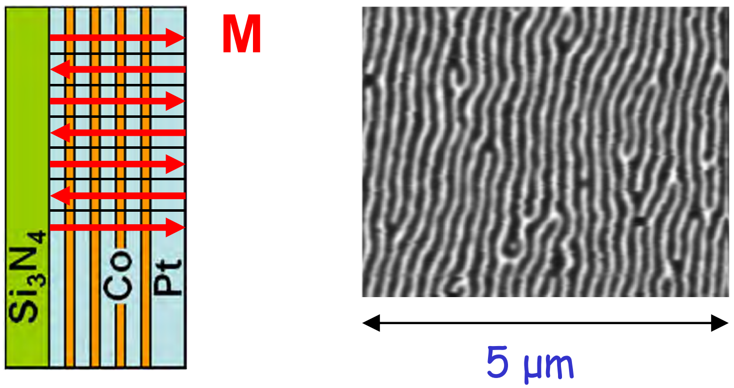
Graphic: wikipedia.org





M. Marvin Seibert et al.,
Nature 470, 78 (2011)

3.5: Applications: Dinamics in solids

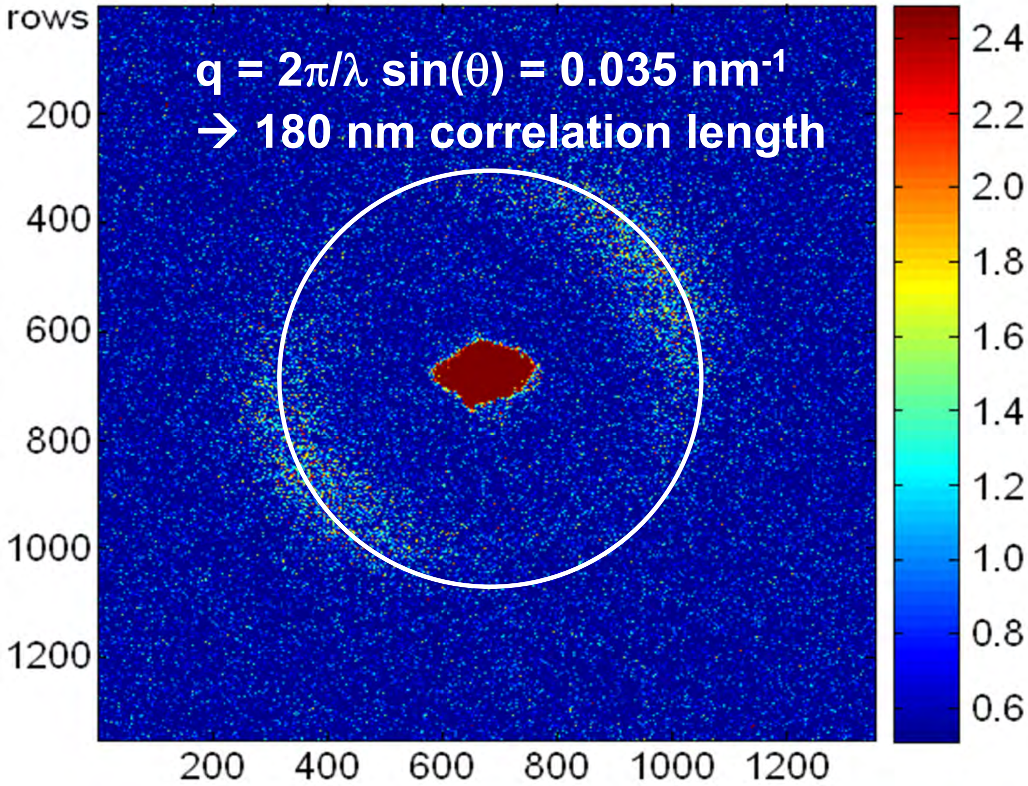


Sample cross section

Magnetic Force Microscopy

Co/Pt multilayers form a periodic magnetic domain pattern with magnetic moments m_j parallel and antiparallel to the surface normal

E = 778.1 eV → ON resonance



Proof-of-principle using 5th harmonic at 1.59 nm (Co L3)
1000*100 pulses with 7000 photons/pulse on the sample

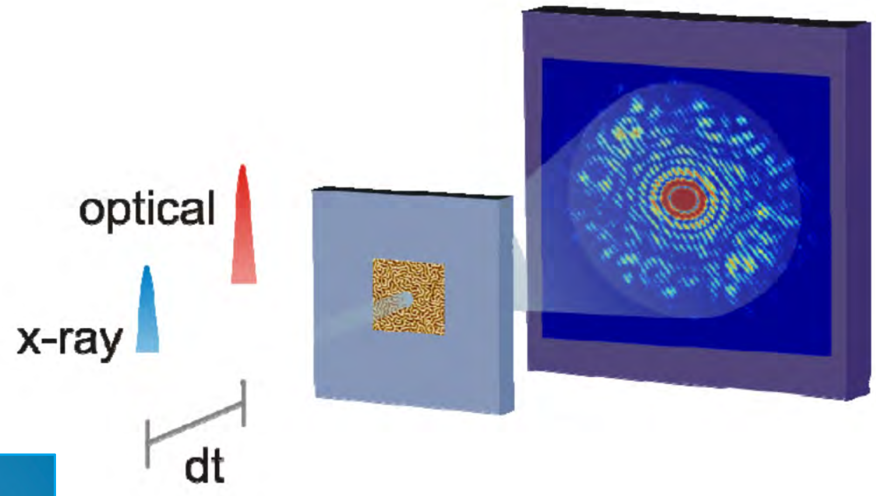
1.) **single shot experiments feasible on SASE3 at XFEL**

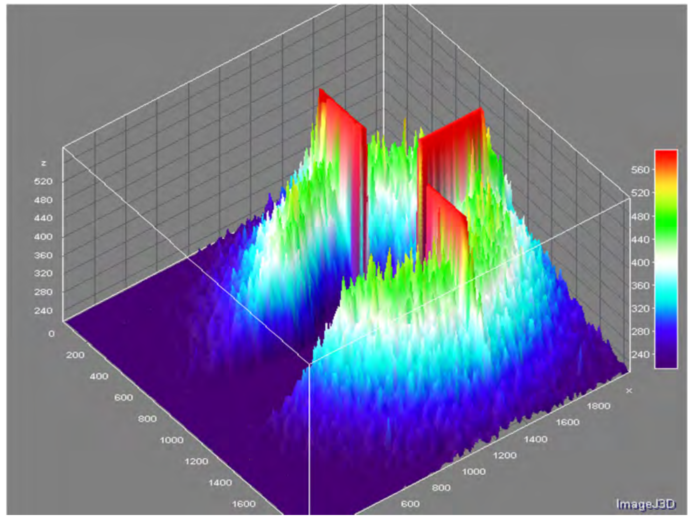
2.) **~ 4 orders of magnitude can be gained at FLASH by appropriate optics plus energy upgrade using 3rd harmonic**

C.Gutt et al., PRB 79, 212406 (2009)

3.6: Applications: Dinamics in solids

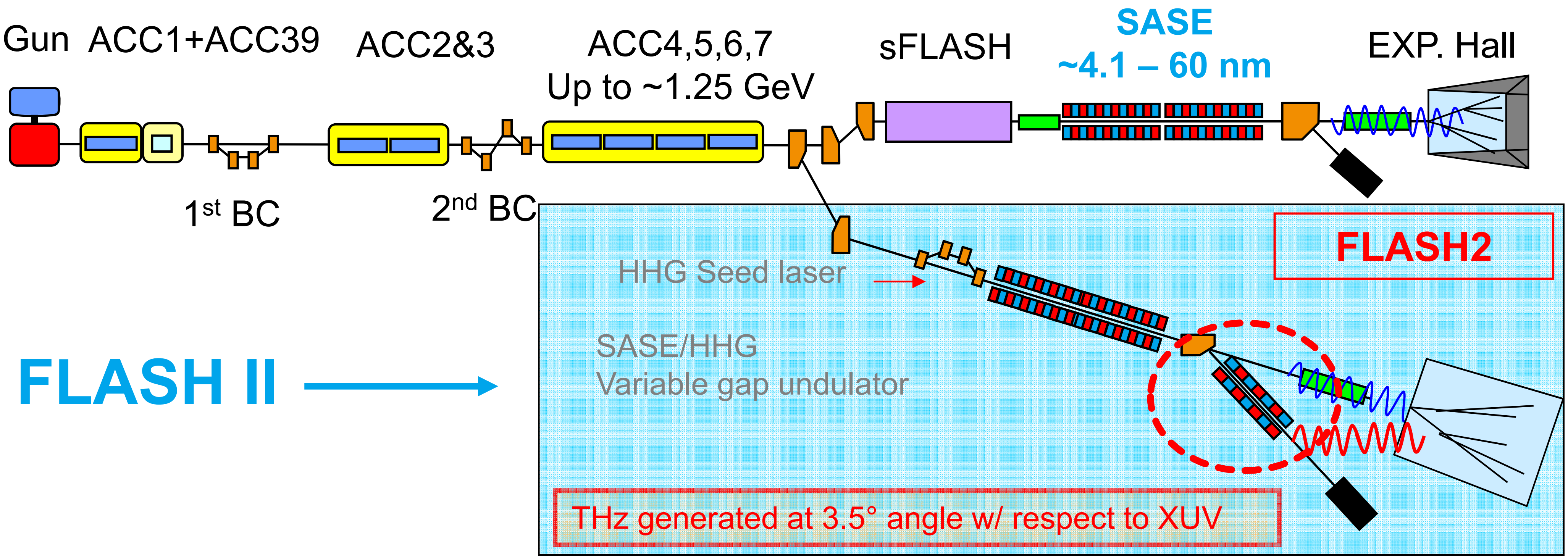
Ultrafast magnetisation dynamics

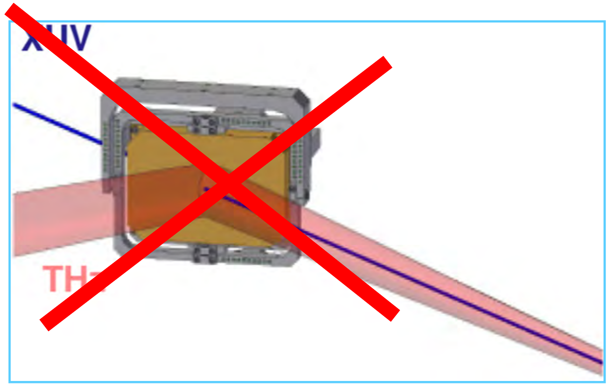




Co M2/3 edge @ 20.8 nm 3p → 3d

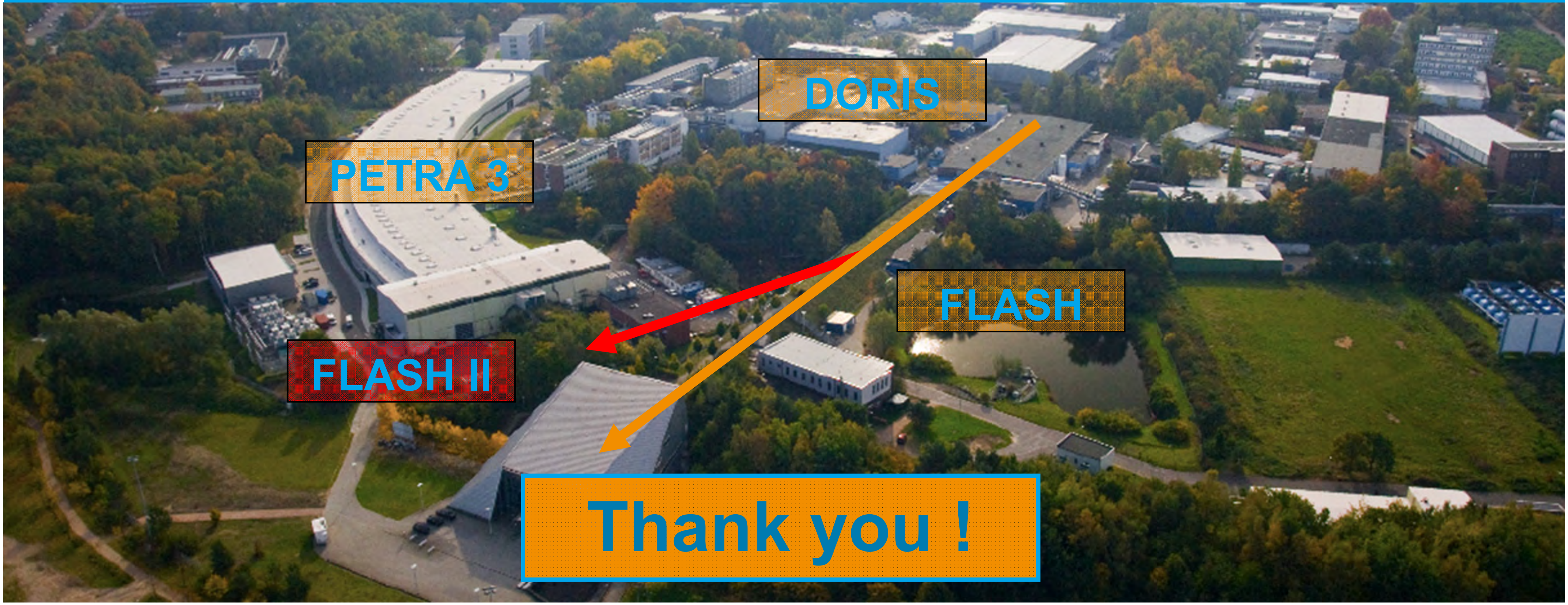
THz at FLASH2





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

The FLASH II project



- Use the existing linac for 2 (3) FELs
- Build 2nd FEL in a new tunnel, based on variable gap undulators and seeding, plus new experimental hall

→ increase efficiency, more beamtime for users