FLASH Upgrade

Far-Infrared (FIR) undulator

Medium and long-term issues:

Decrease wavelength and/or increase brilliance

Enable quasi-simultanous operation at 2 wavelengths

Provide more space for users

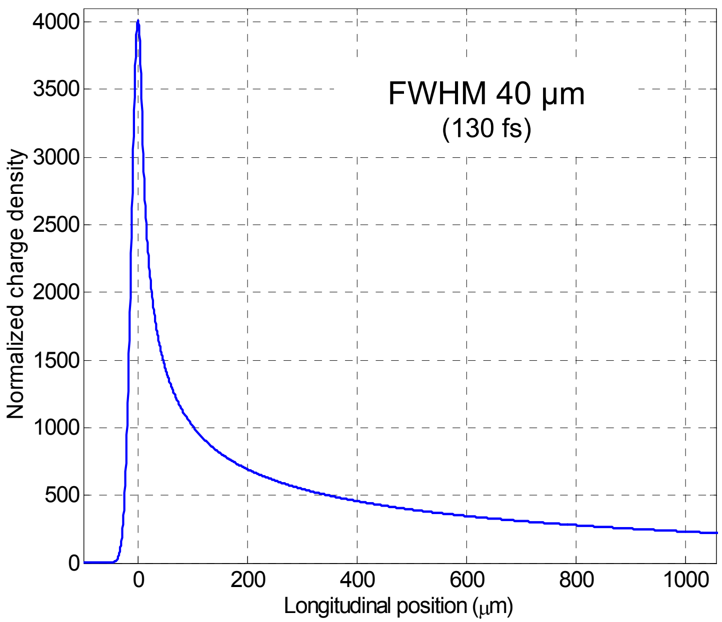
Motivation:

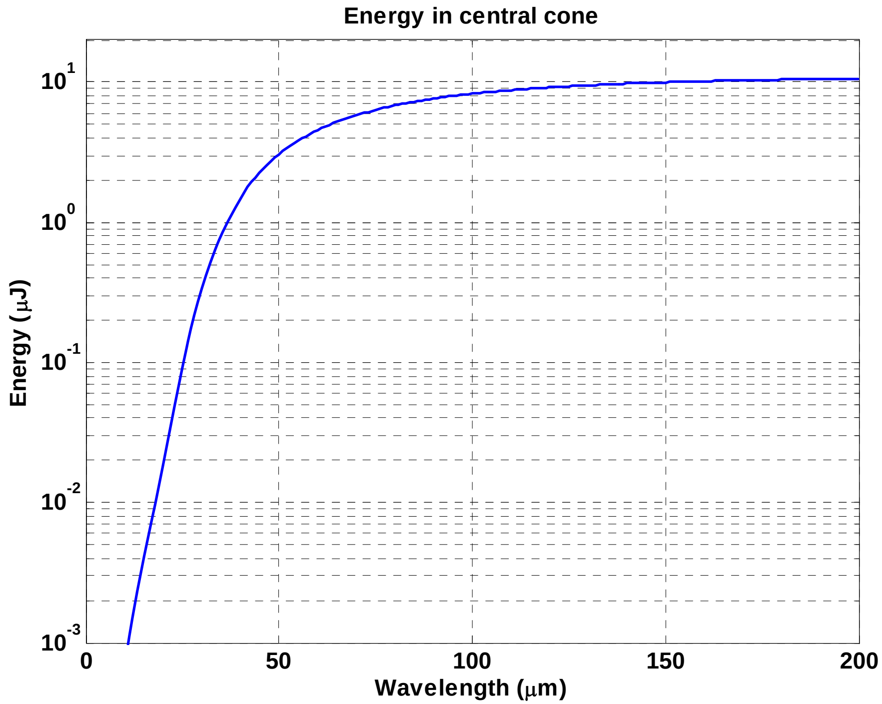
Maximize scientific output, in particular through 2009

Learn technologies for XFEL

Keep on contributing to TESLA Technology Collaboration/ ILC project

Measurement of longitudinal bunch profile by THz spectroscopy





Bunch profile contains harmonics up to 20 µm wavelength

⟹ Radiation power is coherent $\propto N_e^2$ for all wavelengths down to 20 µm

spectral energy density:

$$\frac{dU}{d\omega} = C\ N^2 \left| F_{long}(\omega) \right|^2 T(\omega, \gamma, r_b, \theta, source)$$

$$F_{long}(\omega) = \int_{-\infty}^{\infty} \tilde{\rho}(t) \exp(-i\omega t)\, dt$$

Pros and cons in comparison with time domaine methods (like LOLA, EOS):

\+ Can detect structure within bunch down to 1µm (3 fs)

-- Reconstruction of charge profile from spectrum not simple

n.b.: There is another method under way: Optical Replica

These are all new methods or new domains of operation

→ Only experience will tell

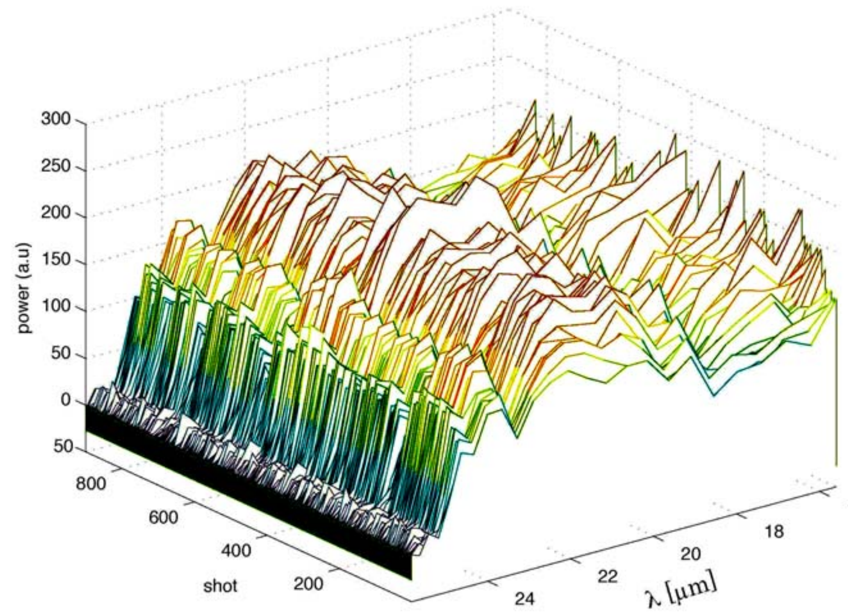
Lastest achievement:

multichannel detectors ⟷ **<u>single shot spectrum</u>** (Hossein Delsim-Hashemi)

reflective (instead transmission) gratings

→ can be mounted in stages → covers large spectral range

Recent development at DESY



Pyro-electric line detector from individual pyros

+ 30 channels
+ room temperature
+ no window, works in vacuum
+ fast read out
+ noise equivalent energy NEE : 60 pJ / pulse
+ smooth response function (suppressed resonances)

Up to now: single stage device

- simultaneous wavelength range limited
- patching problematic, machine fluctuations & calibration

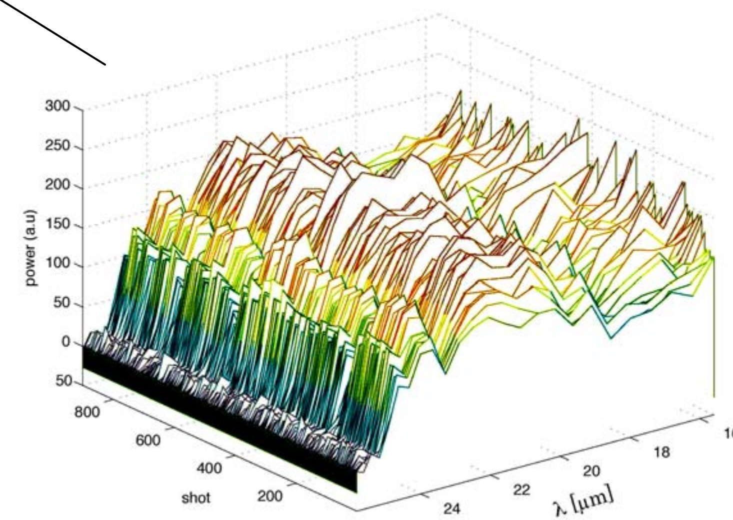
First spectra

Zur Anzeige wird der QuickTime™
Dekompressor „Animation“
benötigt.

- single transmission grating
- during SASE conditions (5.10.06)

~ 20 fs fwhm

- single reflective grating
- during SASE conditions (20.8.06)



Measurement of longitudinal bunch profile by THz spectroscopy

Present state of art: use OTR or synchrotron radiation from dipole magnets

Alternative: Dedicated FIR undulator downstream of FEL undulator
→ Scan wavelength by changing K-parameter
→ electromagnetic device

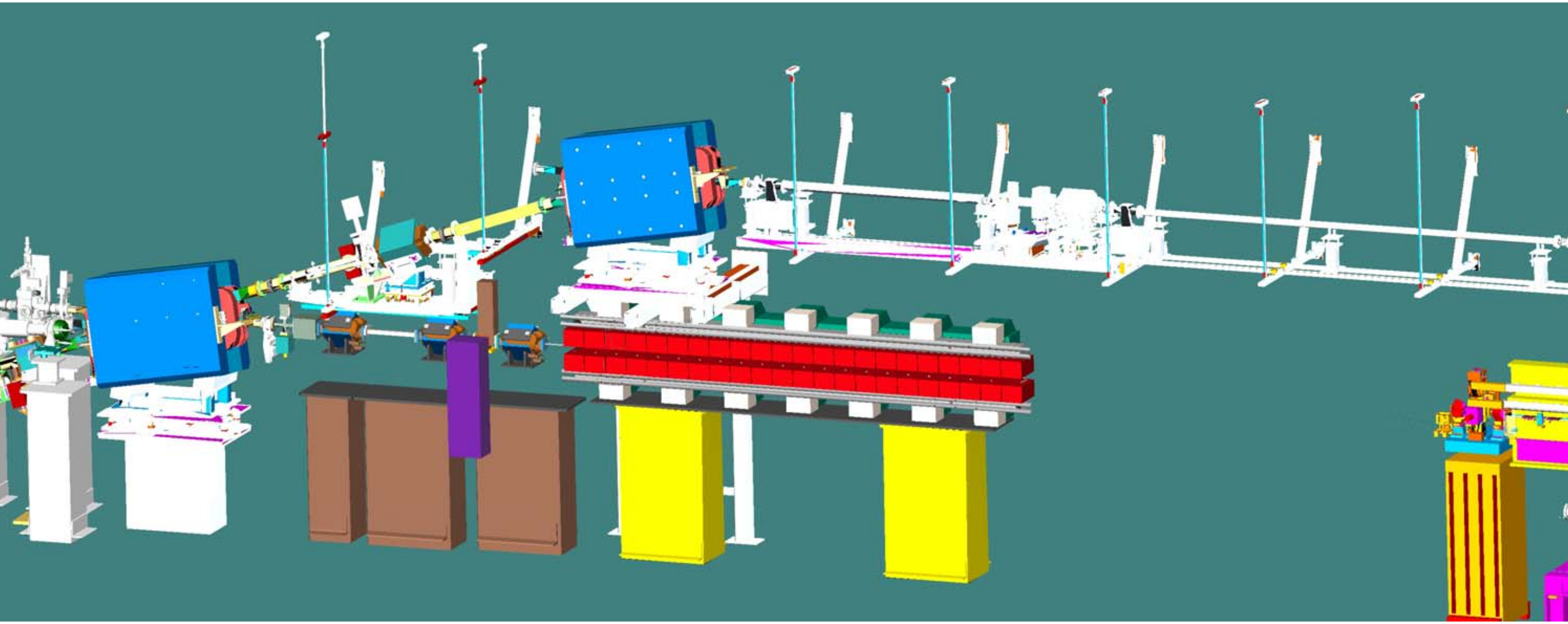
OTR or synchrotron radiation	FIR-undulator
+ single shot spectrum + can be installed at several locations	+ non-destructive + measures bunch profile in FEL process (i.e. after final compression) + much more radiation power + no spectrometer needed, only power measurement

FIR undulator radiation will we directed onto EXP-hall.

→Further option: pump(FIR) - probe(FEL) experiment with auto-synchronisation

Far-infrared Undulator

- Electromagnetic undulator
- Generates radiation (1-200) µm (at 500 MeV)
- Infrared radiation source, pump/probe experiments
- Beam diagnostics



Gap	40 mm	K-value	3 – 49
Period length	400 mm	Weight	4.5 t
Number of periods	9	Total power	87 kW

View of EXP area

Photos of undulator at JINR

Installation of undulator & electron diagnostics coordinated by Oliver Grimm

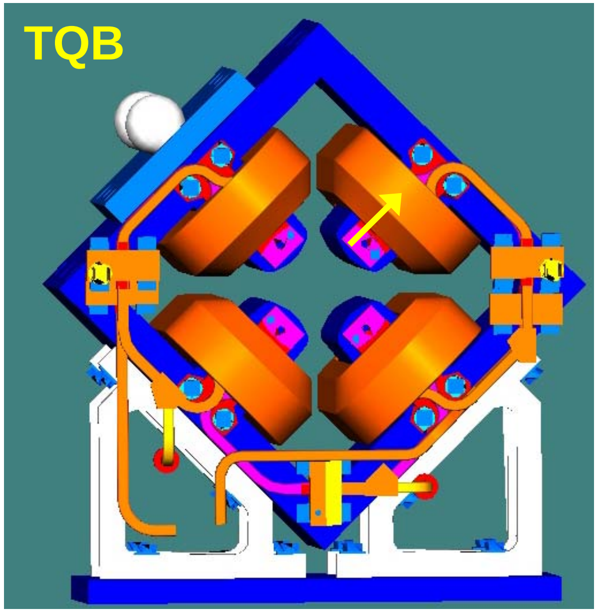
FIR beamline into EXP-hall & user issues coordinated by Michael Gensch

Issues of increasing quad aperture

— Achievable gradients —

Maximum TQA strength for operation modes A and B
(long bunch trains, energy spread measurement at OTR 9DUMP)

$k=4.0\ m^{-2} \rightarrow l_{mag}\sqrt{K} = 0.54$ (N. Golubeva)



Poles will be shortened on back side by 6 mm

Current quads **TQA**: gap 40 mm, max 36 T/m (@298 A, ΔT=30°C), l_{mag}=27 cm (yoke 25 cm)

$K_{max} = 6.7\ m^{-2}$ (@1.6 GeV) $l_{mag}\sqrt{K_{max}} = 0.70$ (Current p/s max 120 A -> $l_{mag}\sqrt{K_{max}} = 0.44$)

Quads **TQB**: gap 50 mm, max 27 T/m (@347 A), l_{mag}=33 cm (yoke 30 cm)

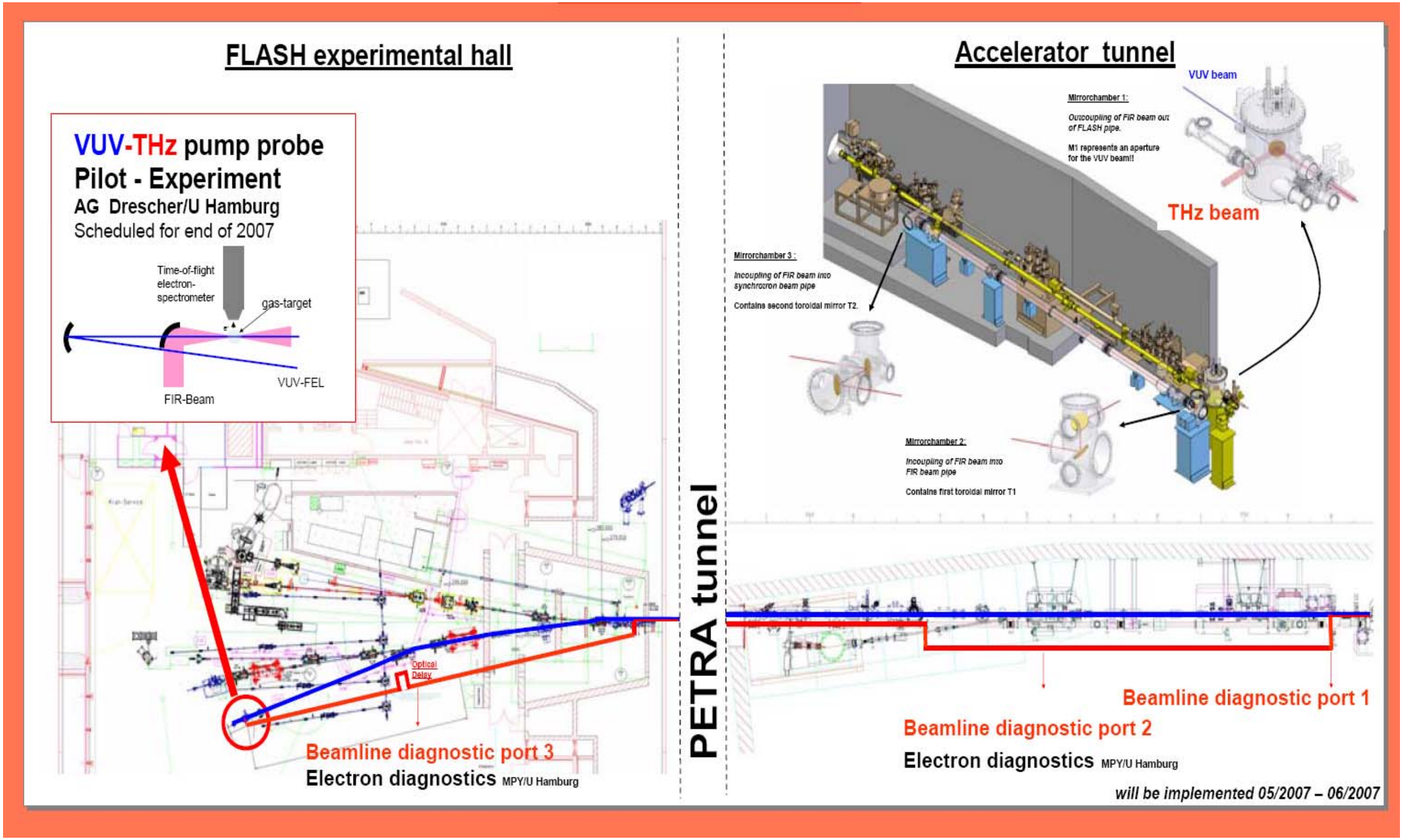
$K_{max} = 5.0\ m^{-2}$ (@1.6 GeV) $l_{mag}\sqrt{K_{max}} = 0.74$

Field quality $\Delta B/B \approx 10^{-4}$ at 20 mm radius

Quads **TQB** modified: gap 62 mm, max 26 T/m (@520 A , ΔT=41°C), l_{mag}=33 cm (yoke 30 cm)

$K_{max} = 4.8\ m^{-2}$ (@1.6 GeV) $l_{mag}\sqrt{K_{max}} = 0.72$ 290 A for $l_{mag}\sqrt{K} = 0.54$

Field quality $\Delta B/B \approx 10^{-2}$ at 20 mm radius (Opera 2d calculation by A.Petrov)



FLASH experimental hall
Accelerator tunnel
VUV-THz pump probe
Pilot - Experiment
AG Drescher/U Hamburg
Scheduled for end of 2007
Time-of-flight electron-spectrometer
gas-target
VUV-FEL
FIR-Beam
VUV beam
Mirrorchamber 1:
Outcoupling of FIR beam out of FLASH pipe.
M1 represents an aperture for the VUV beam!!
THz beam
Mirrorchamber 3 :
Incoupling of FIR beam into synchrotron beam pipe
Contains second toroidal mirror T2.
Mirrorchamber 2:
Incoupling of FIR beam into FIR beam pipe
Contains first toroidal mirror T1
PETRA tunnel
Optical Delay
Beamline diagnostic port 3
Electron diagnostics MPY/U Hamburg
Beamline diagnostic port 1
Beamline diagnostic port 2
Electron diagnostics MPY/U Hamburg
will be implemented 05/2007 – 06/2007

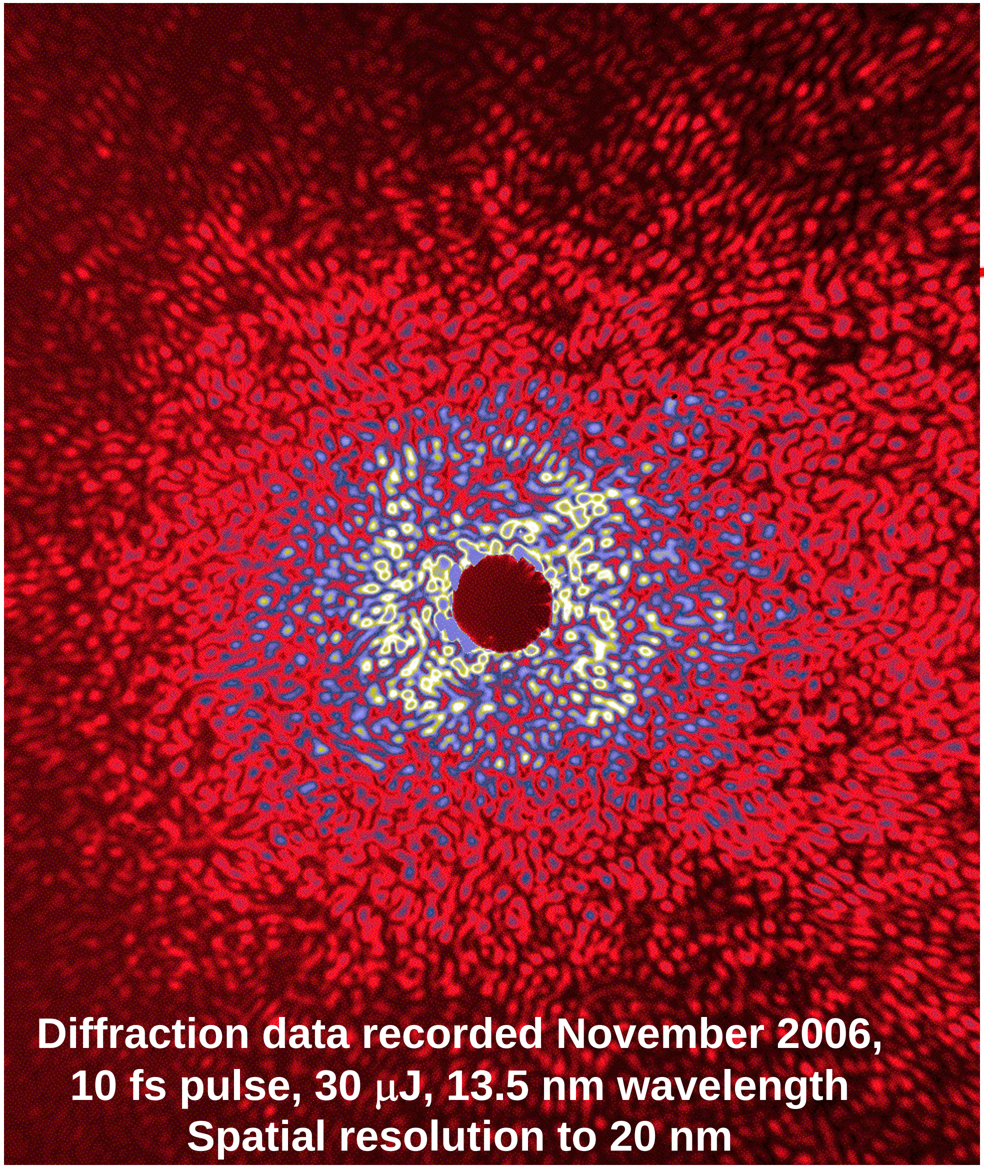
Crucial question:

Are there key experiments around 4 nm that can **only be performed** at ~GW peak power level?

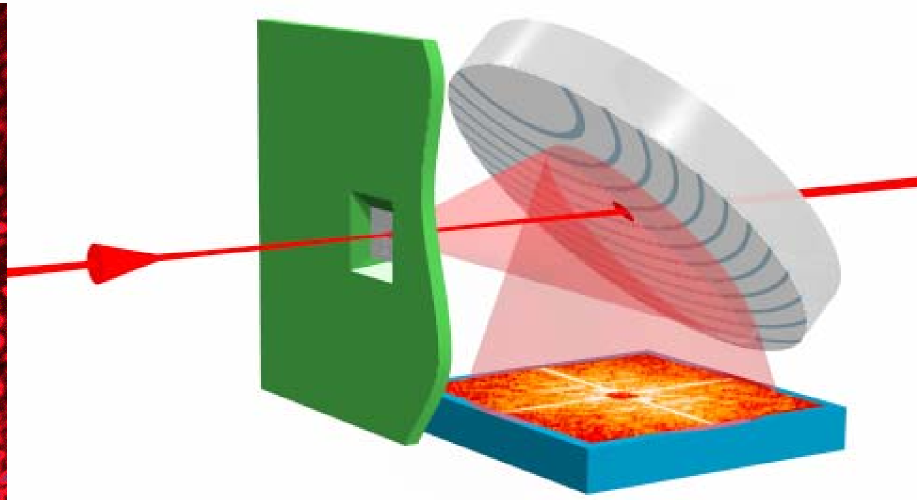
(3rd harmonics at ~30 MW level will be available anyhow!)

New records at the FLASH FEL: 10 fs pulse duration and 20 nm spatial resolution

Courtesy: J. Hajdu



Diffraction data recorded November 2006, 10 fs pulse, 30 μJ, 13.5 nm wavelength Spatial resolution to 20 nm



We have recorded the highest-resolution coherent diffraction patterns of biological objects, using a wavelength of 13.5 nm

Coherent diffraction yields structural information at a resolution only limited by the X-ray wavelength. Ultrafast pulses are required to overcome damage limits

Henry Chapman, Janos Hajdu et al

Stanford Linear Accelerator Center

DESY

Message:

Reaching ~4nm or below at ~GW peak power level opens access to new bio systems

Reaching water window not an issue per se,

e.g. 4.4nm would good as well

Magnetism @ FLASH

Courtesy: G. Grübel

Element	L_{III} absorption edge [eV]
Ti	453.8
V	512.1
Cr	574.1
Mn	638.7
Fe	706.8
Co	778.1

Foreseen upgrade

fundamental:	6.4 nm	193.7 eV
3rd harmonic:	**2.1 nm**	**581.2 eV**

Want to reach Fe:

fundamental:	5.15 nm	240 eV
3rd harmonic:	**1.71 nm**	**720 eV**

Eventually Co:

fundamental	4.65 nm	267eV
3rd harmonic:	**1.55 nm**	**800 eV**

For XMCD and Imaging: **need Circular polarization (undulator or waveplate ?)**

For dynamics (XPCS): **linear polarization might be enough.**

(10^{10} ph/pulse (≈1 µJoule) at a 3rd harmonic (@ ≈700 eV) seem sufficient for an XPCS experiment but need to check optics throughput (need 10^{-4} bw))

Message:

Reseach on Fe and Co systems requires

1.7nm and 1.5nm (resp.) in the 3rd harmonics

→Need:

5.1nm or 4.6nm in the 1st harmonics at FEL saturation

Conclusion (preliminary):

There seems to be a scientific case for uprading linac energy to ~1.3 GeV