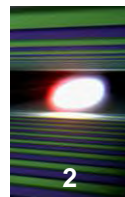




Status of the European XFEL & SASE 2 instruments

International Workshop Series on the Science and Instrumentation
at the European XFEL: Femtosecond X-ray Experiments
Budapest, Dec 9-11, 2009

Thomas Tschentscher
thomas.tschentscher@xfel.eu



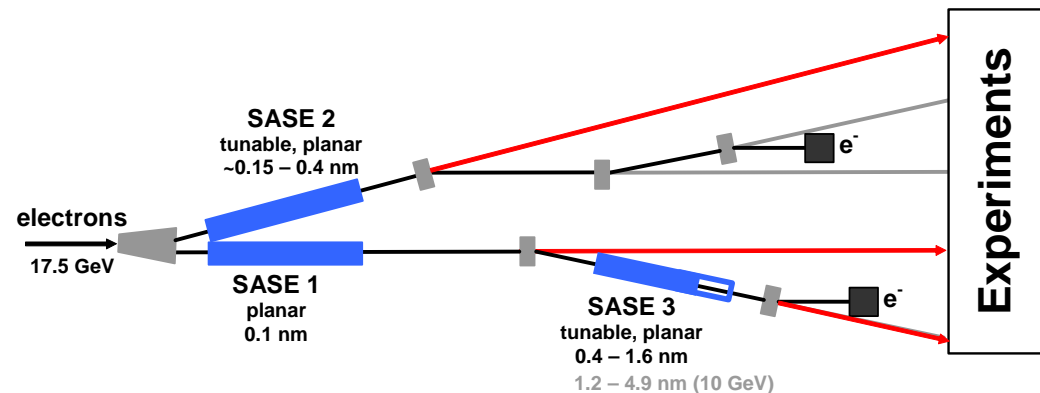
- **Status of the European XFEL**
 - The project
 - The international facility
 - The status & timeline
- **SASE 2 instruments**
 - SASE 2 source and beam transport
 - Femtosecond experiments
 - Selected instrumentation issues
- **Charge to this workshop**

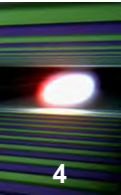
Some specifications

- Photon energy 0.4–12.4 keV
- Pulse duration <100 fs
- Pulse energy few mJ
- super-conducting accelerator
- 10 Hz/4.5 MHz (27.000 b/s)
- 5 beamlines/10 instruments
 - start version with 3 BLs and 6 instruments
- various extensions possible
 - seeding
 - more instruments

First beam 2014

Start of user operation 2015





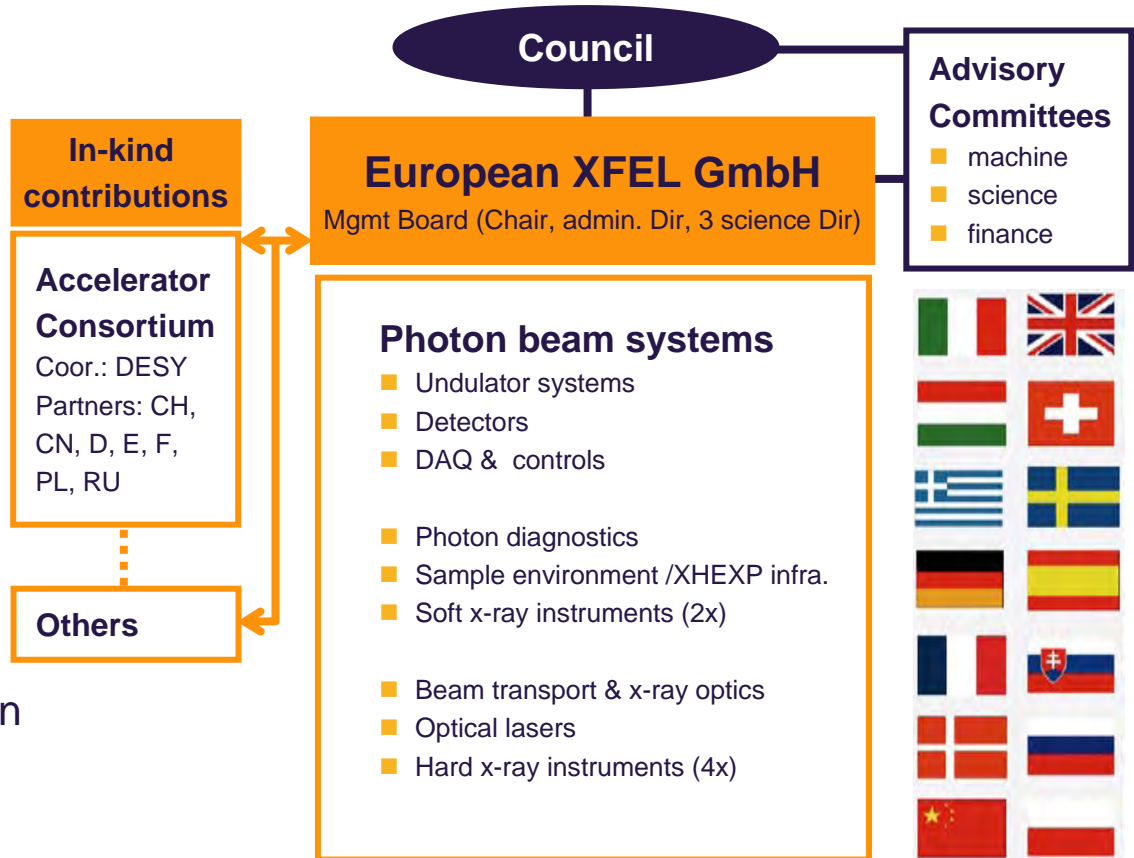
The European XFEL GmbH will be an institute based on German law with initially 10 shareholders representing the international partners. It shall

- construct
- commission
- operate

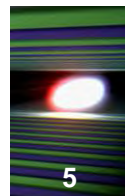
the European XFEL.

The German shareholder DESY takes special role in the overall process.

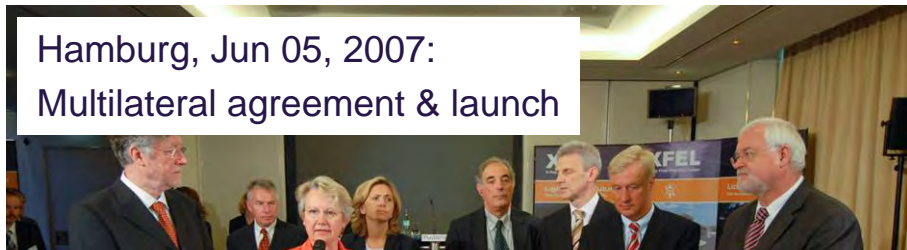
- preparation
- host lab
- accelerator construction & operation



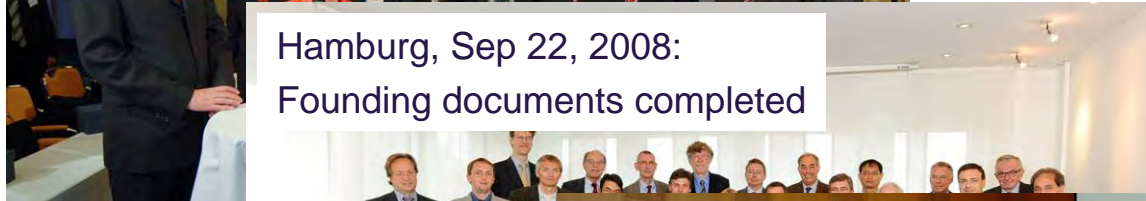
The making of ...



Hamburg, Jun 05, 2007:
Multilateral agreement & launch



Hamburg, Sep 22, 2008:
Founding documents completed



Berlin, Sep 23, 2009:
Initialling of founding documents

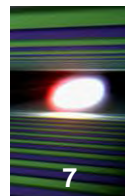


Hamburg, Sep 28, 2009:
Foundation of European XFEL GmbH

The international treaty

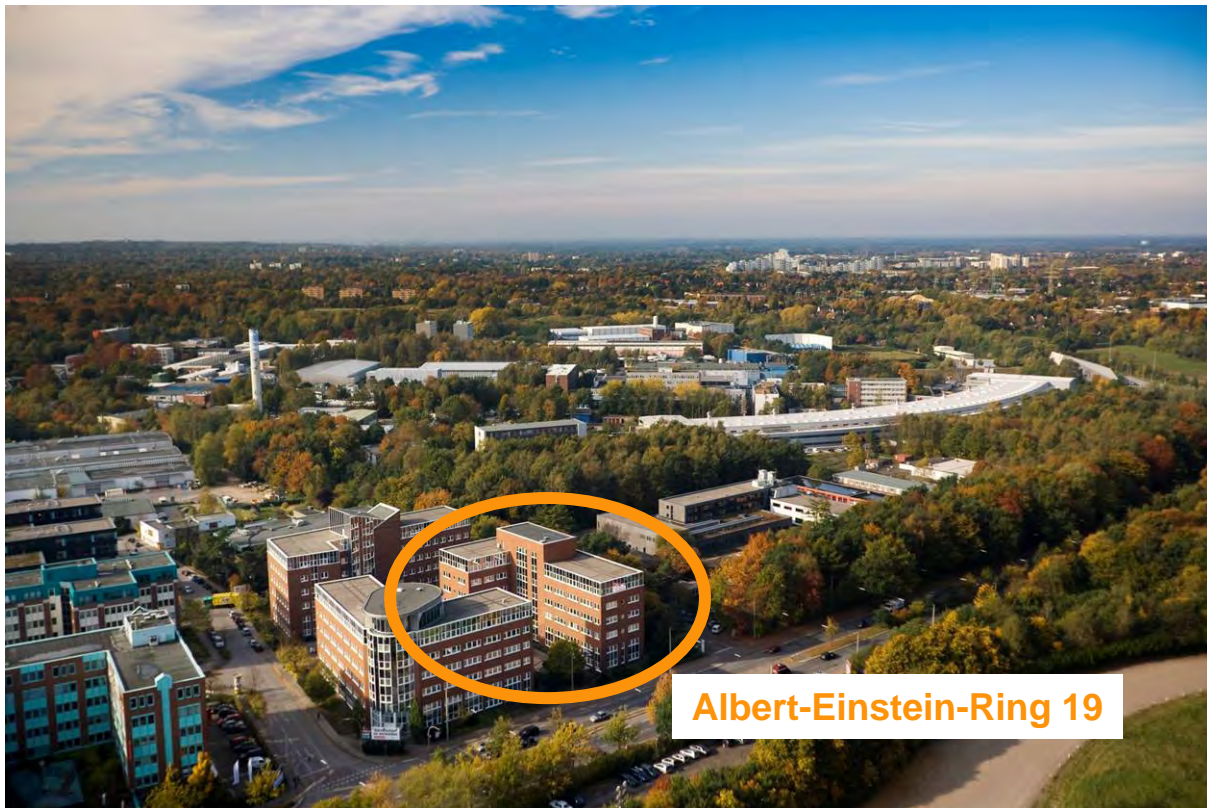
Nov 30, 2009, Town hall City of Hamburg
Signing the European XFEL convention





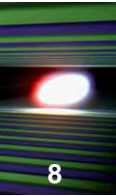
Recruitments & staff working for the project

- 47 staff (Dec 4, 2009)
- Administration
 - Human Resources
 - Finance
 - Procurement
- Engineering
 - Undulators
 - X-ray optics
 - DAQ
- Scientific staff
 - all WPs
 - Instruments
 - In-house research
- Current openings
 - Leading scientists (HED, SPB, MID, SCS, opt. lasers)
 - Scientist photon diagnostics
 - Scientist magnetic measurement

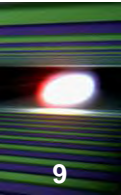


→ www.xfel.eu

Overall schedule of the European XFEL



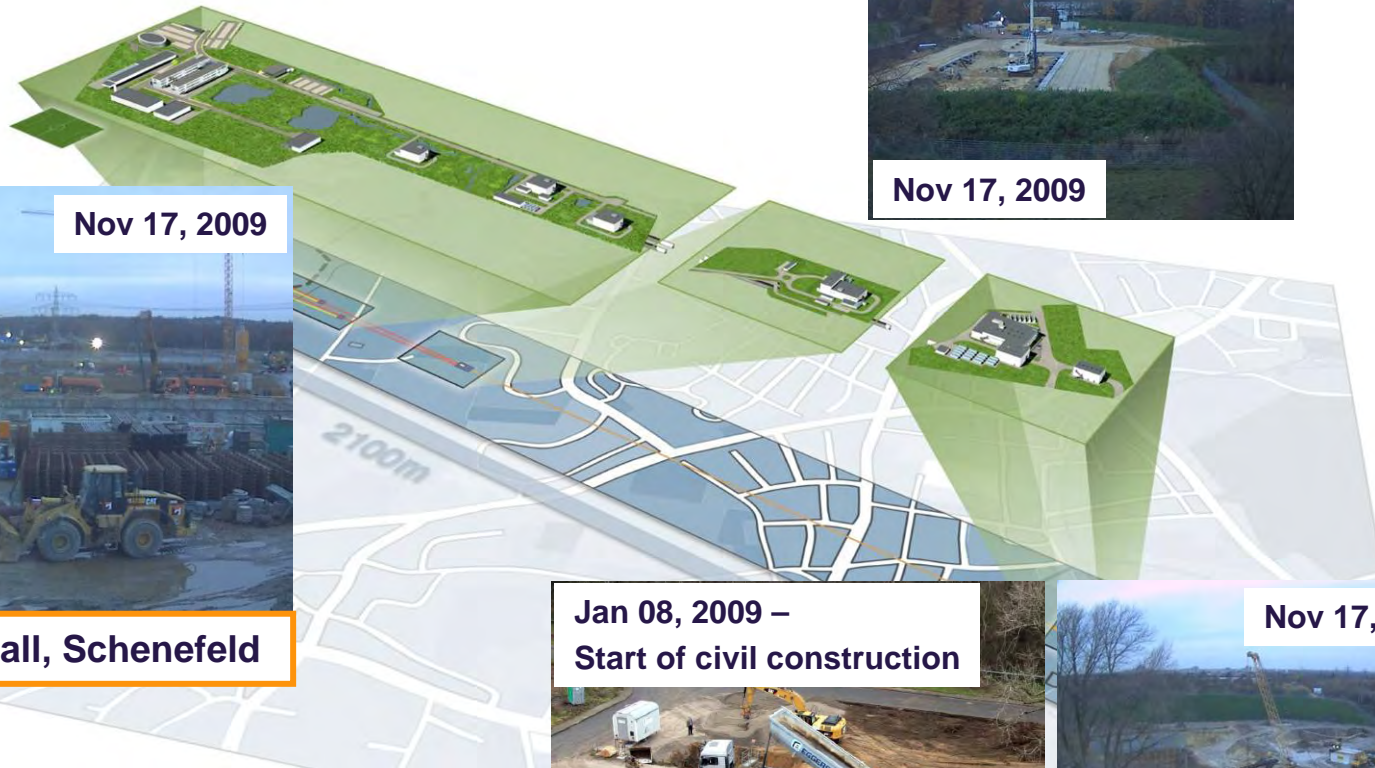
European XFEL – Civil construction



Switchyard, Hamburg-Osdorf



Nov 17, 2009



Nov 17, 2009



Experiments hall, Schenefeld

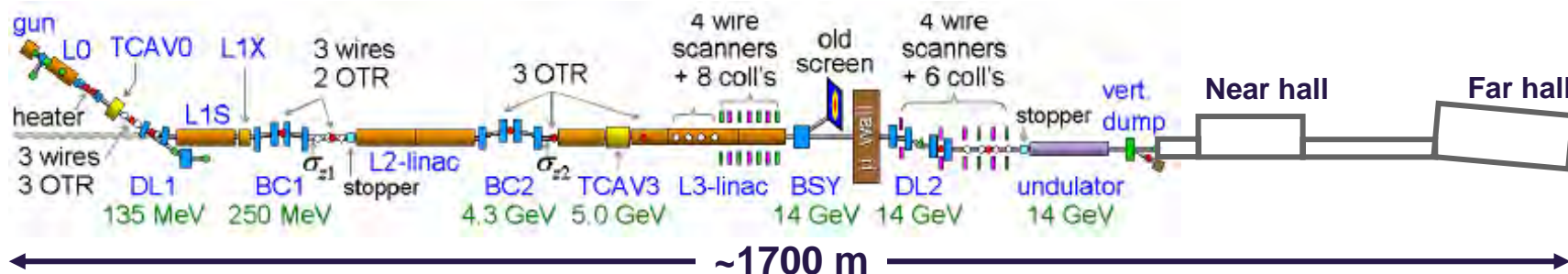


Jan 08, 2009 –
Start of civil construction



Nov 17, 2009

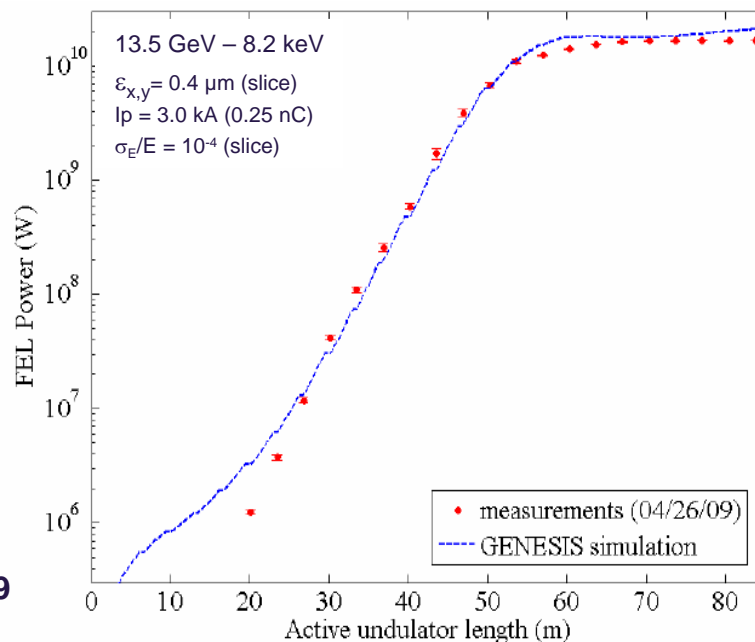
Injector-site, DESY, Hamburg-Bahrenfeld



Extreme high performance at start

- gun emittance of $\sim 0.4 \mu\text{m}$ preserved in Linac
- low bunch charges 0.02 – 0.25 nC
- pulse energy close to prediction
- pulse duration tunable: few fs – few 100 fs
- high reliability of x-ray beam delivery
- easy tunable (photon energy, pulse duration)

→ further improvements to be expected



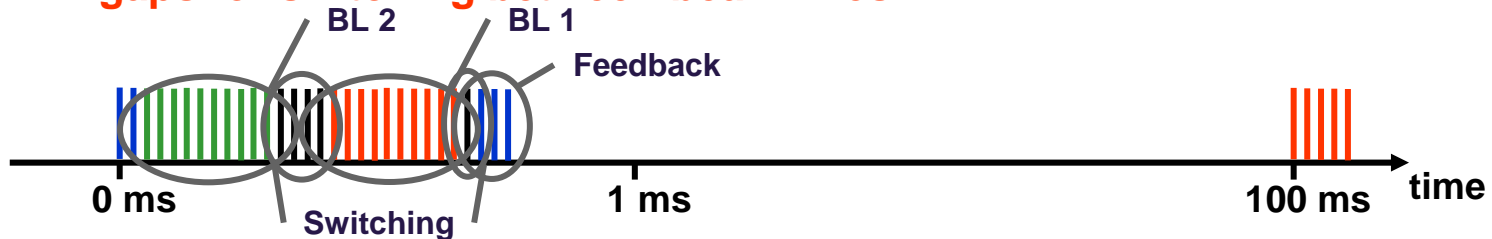
P. Emma et al., Proc. PAC 2009

Accelerator performance

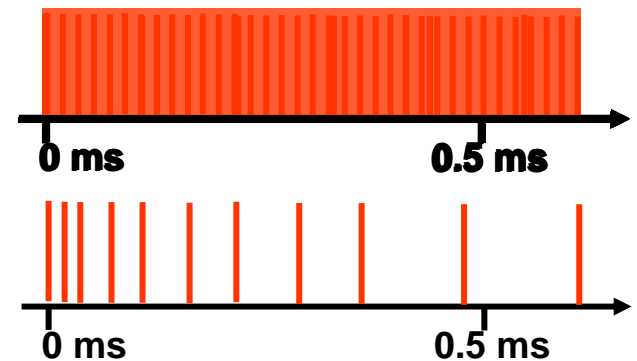
- similar emittance ($< 0.5 \mu\text{m}$) for small charge (0.1 – 0.25 nC)
- still acceptable emittance ($\sim 1 \mu\text{m}$) for 'TDR' charge (0.5 – 1 nC)
- pulse duration in a similar range from few to 100s of femtoseconds
- additional advantage: bunch/pulse train operation
 - large number of bunches
 - possibility to serve several beamlines quasi-simultaneous
 - stable operation using feedback schemes

Possible European XFEL delivery patterns

- operate sc-accelerator in almost steady-state mode
- division of bunchtrain into functional portions :
 - intra-train feedback → stabilization (x , t , E)
 - two sub-trains going to two e^- beam lines
 - gaps for switching between beam lines



- time pattern for each beam line can be determined by experiment
 - single pulses
 - medium repetition rate (10 – 100 kHz)
 - high repetition rates (1 → 4.5 MHz)
 - special fills
 - logarithmic distribution
 - shorter distances (~700 ps – 220 ns)



Accelerator performance

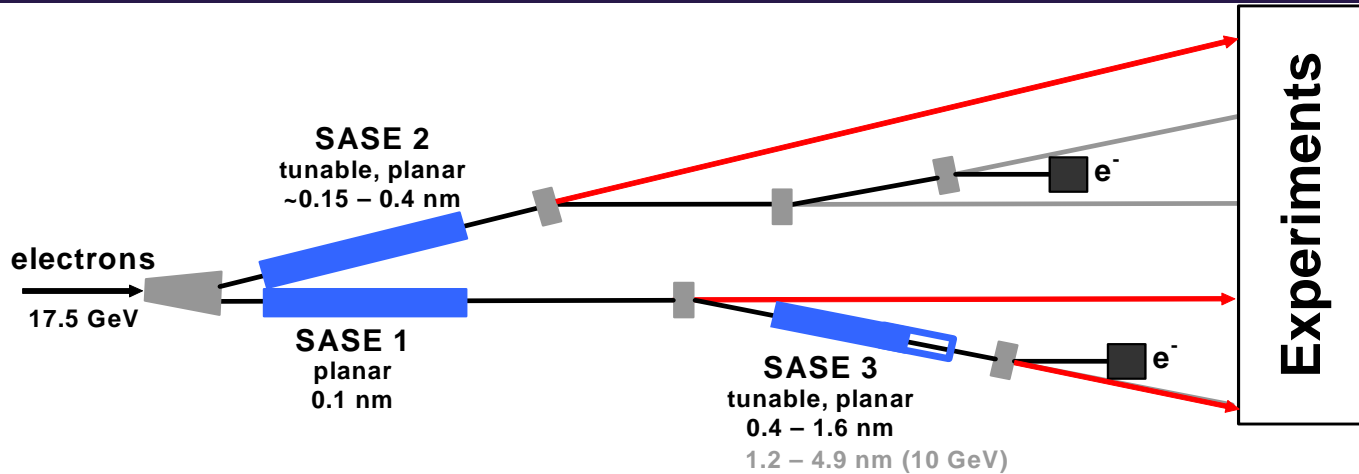
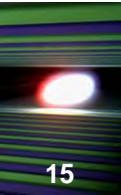
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Undulator and FEL performance benefits from smaller emittance

- design undulator length will provide many operational options
 - low charge/short-pulses ($< 80 \text{ fs}$) \Rightarrow short gain length \rightarrow opt. undulator length
 - high-charge/long pulses ($\sim 80 \text{ fs}$) \Rightarrow design gain length \rightarrow more pulse energy
 - access to shorter wavelengths ($\sim 0.05 - 0.07 \text{ nm}$) is anticipated
 - options to enhance FEL properties (pulse energy, polarization, two-colour, seeding, ...) should be easy realizable

- **Status of the European XFEL**
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 - SASE 2 source and beam transport
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Startup configuration



Source	Instruments	Photon beam line characteristics
SASE 1	SPB, MID	FEL radiation ~12 keV; High coherence; Spont. radiation (3 rd , 5 th harm.)
SASE 2	FDE, HED	FEL radiation 3-12 keV; High time-resolution; Spont. radiation (3 rd , 5 th harm.)
SASE 3	SQS, SCS	FEL radiation 0.4 – 3 keV; High flux
		FEL radiation 0.4 – 3 keV; High resolution

SPB	Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules
MID	Materials Imaging & Dynamics
FDE	Femtosecond Diffraction Experiments
HED	High Energy Density Matter

SQS	Small Quantum Systems
SCS	Soft x-ray Coherent Scattering

SASE 2 source properties

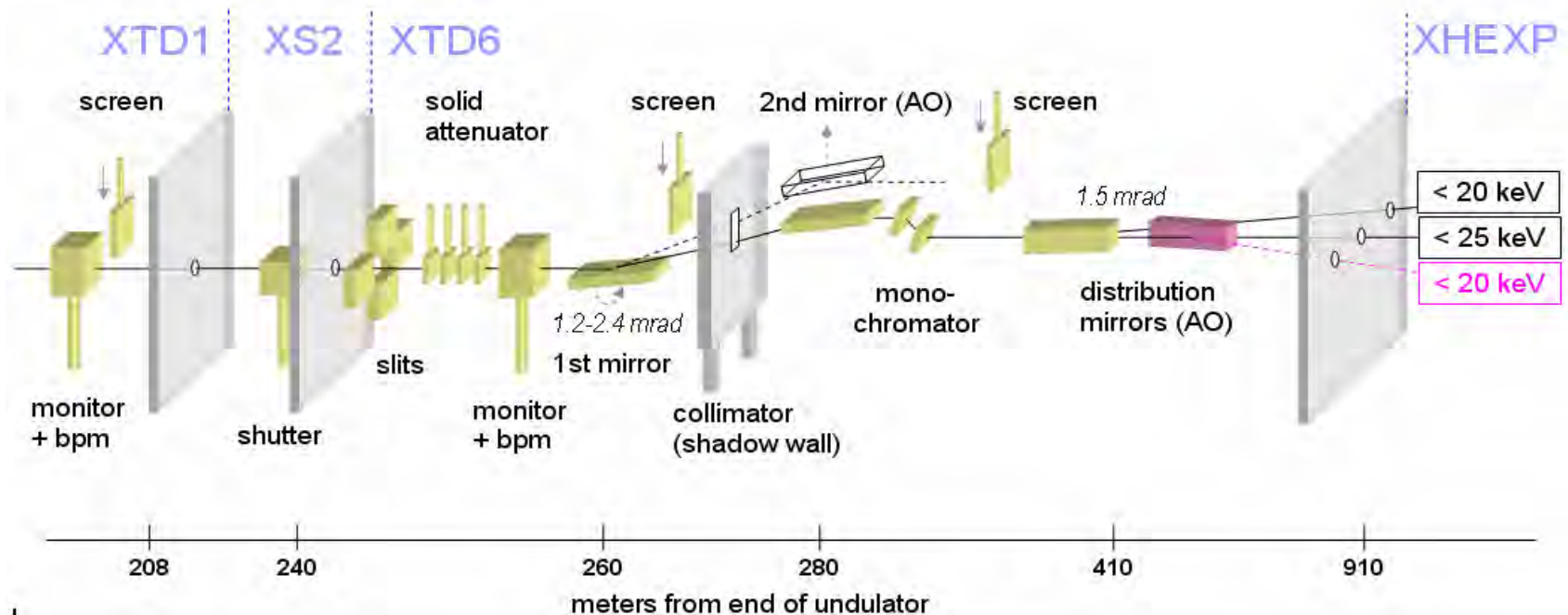
- SASE FEL (& spontaneous undulator) radiation
- horizontal polarization
- FEL line gap-tunable from 3.1 to 12.4 keV (closed gap configuration)
 - higher photon energies O(20 keV) should be possible
 - 3rd and 5th harmonic radiation at 1 and 0.1 % intensity
 - radiation safety issue for harmonics & spont. radiation

Parameter	Unit	Value	Value
Wavelength	nm	0.1	0.4
Photon energy	keV	12.4	3.1
Photons per pulse	nCb	10 ¹²	1.6×10 ¹³
Pulse energy	mJ	2	8
Bandwidth	%	0.08	0.18
Coherence time	fs	0.22	0.38
Pulse duration	fs	100	100
Divergence	μrad	0.9	3.4
Source size	μm	85	55

TDR 2006
values

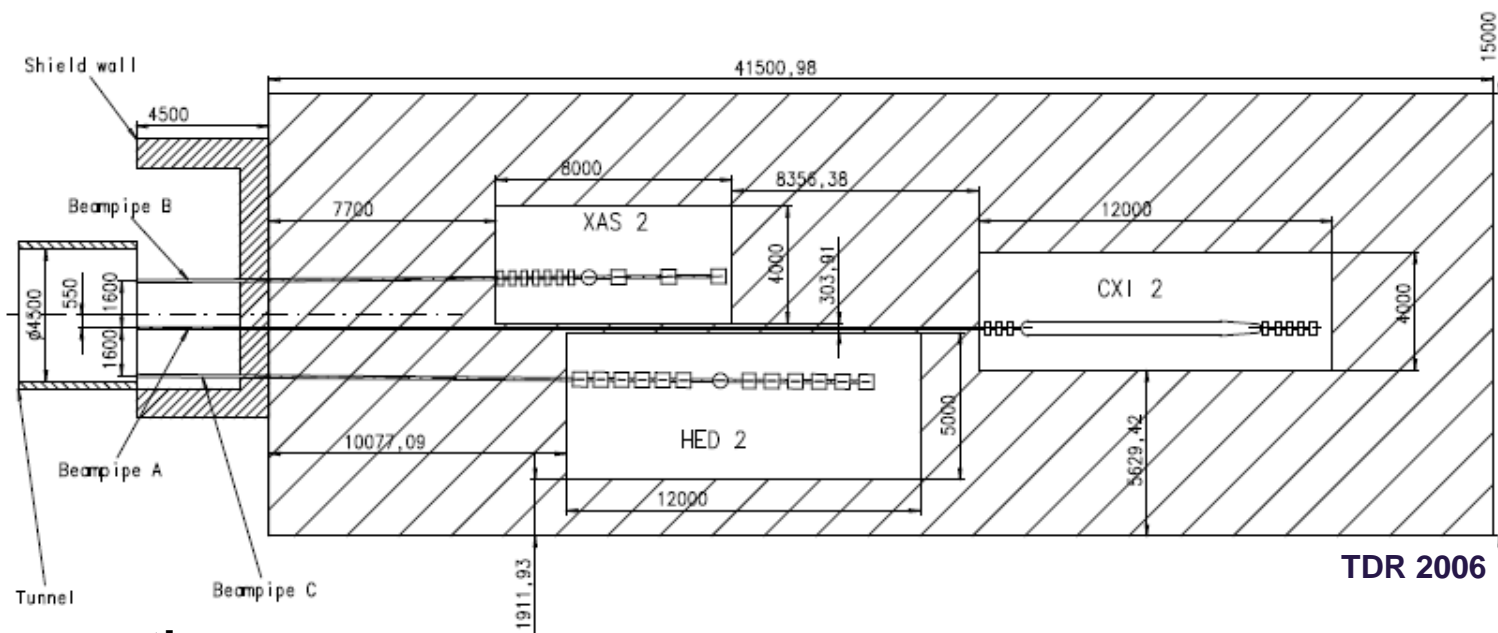
X-ray optics and beam transport has to deliver FEL beam from the source to the instrument while maintaining intensity, duration and wavefront

- steering & distribution
- monochromatization
- focusing
- suppression of high energy spontaneous/harmonic radiation



Geometry

- 3 instruments on 15×42 m² real estate inside experiments hall
- optical laser and control hutches



X-ray optics

- beam transport includes mirrors and monochromator
- special optics: focussing, split&delay, etc. require definition

Startup scenario led to combination of hard x-ray FDE and XAS instruments, as proposed in TDR-2006, into a single instrument

Science areas

- ultrafast processes in gaseous, liquid, and solid samples
- applications to (bio-)chemistry, physics, materials science

X-ray techniques

- diffraction
- scattering
- spectroscopy
- pump-probe

Special feature : time-resolution O(10 fs)

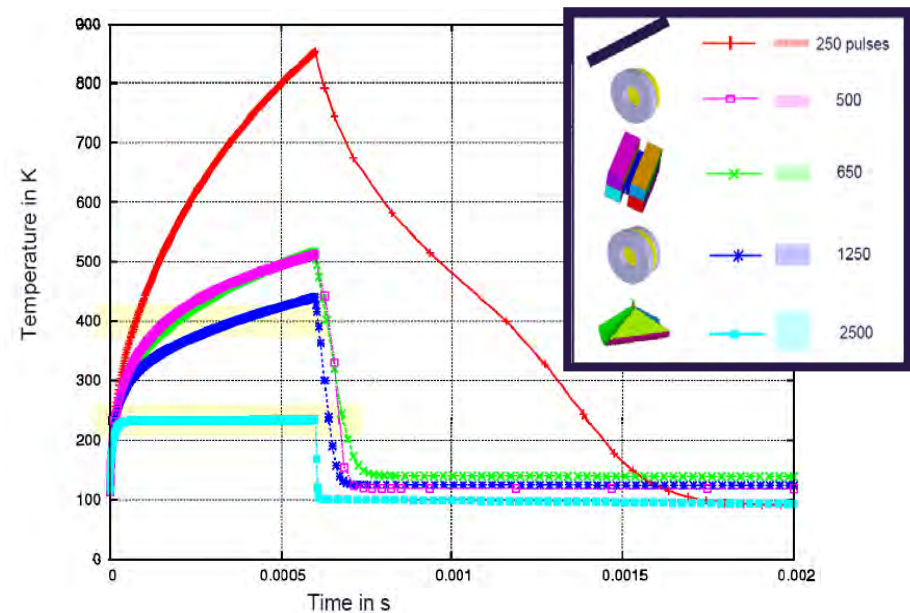
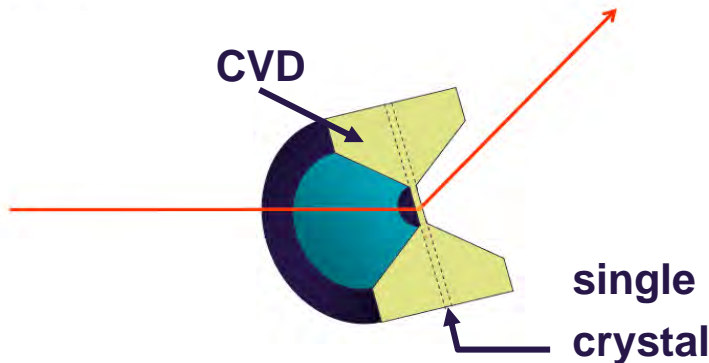
- preservation of pulse duration
- synchronization of optical laser & x-ray pulses
- time domain diagnostics: arrival/delay, duration, t_0

Mirrors

- beam transport and distribution
- grazing angle and coating determine photon energy range
- suppression of higher orders
- collimation & focusing

Monochromators

- bandwidth
- reflectivity
- heat load by pulse train



Due to the fluctuating properties of the SASE FEL sources the photon diagnostic methods in general need to be pulse resolved.

Standard diagnostics

- intensity measurement (absolute, relative, accuracy ?)
- beam position measurement (accuracy ?)

Special diagnostics

- spectral distribution
- temporal properties (distribution, width, arrival)
- polarization
- coherence / wavefronts

Jan Grünert is responsible for the task of x-ray photon diagnostics (standard components & R&D of new elements)

Challenges:

- Integrating detectors w. large dynamic range & ‘single photon sensitivity’
- frame readout rates up to 4.5 MHz

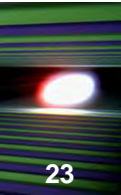
Three 2D detector developments have been started

- LPD
- AGIPD
- DSSC

After evaluating the properties of the 3 developments, the LPD detector was dedicated to liquid/amorphous diffraction at this instrument.

- possibilities and limitations to use this detector in other applications are to be discussed & defined

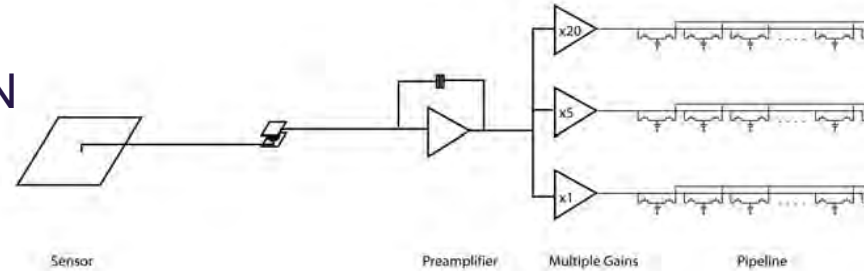
Large Pixel Detector (LPD)



Multi-Gain Concept

- offers large dynamic range: $\sim 10^5$
- Experience with calorimetry at CERN
- Relaxes ADC requirements
- Fits with CMOS complexity

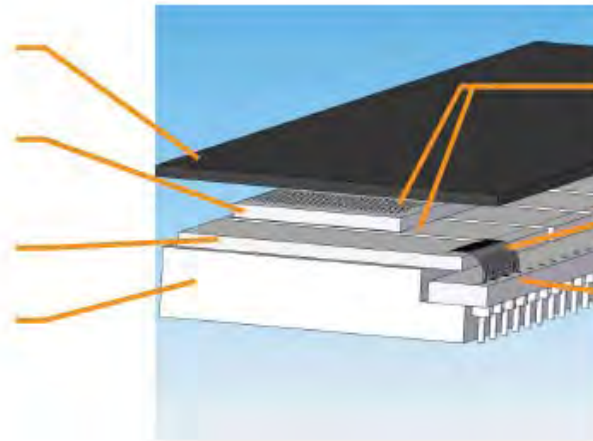
Three-fold analogue pipeline / On-chip ADC



Sensor tile detail

- 128 x 32 pixels
- 500 x 500 μm^2
- edgeless

- Sensor tile
- Silicon interposer
- ASIC Die
- Moly Metal Mount



- Area bump bonds
- Hidden wire bonds
- 'Door step' ceramic and connector

Performance

- > 6 keV (tbd)
- ~ 500 events/tr.

collaboration STFC/RAL, U Glasgow
(coordination M. French (STFC/RAL):



Science & Technology Facilities Council
Rutherford Appleton Laboratory



UNIVERSITY
of
GLASGOW

Anton Plech is the science contact for this project

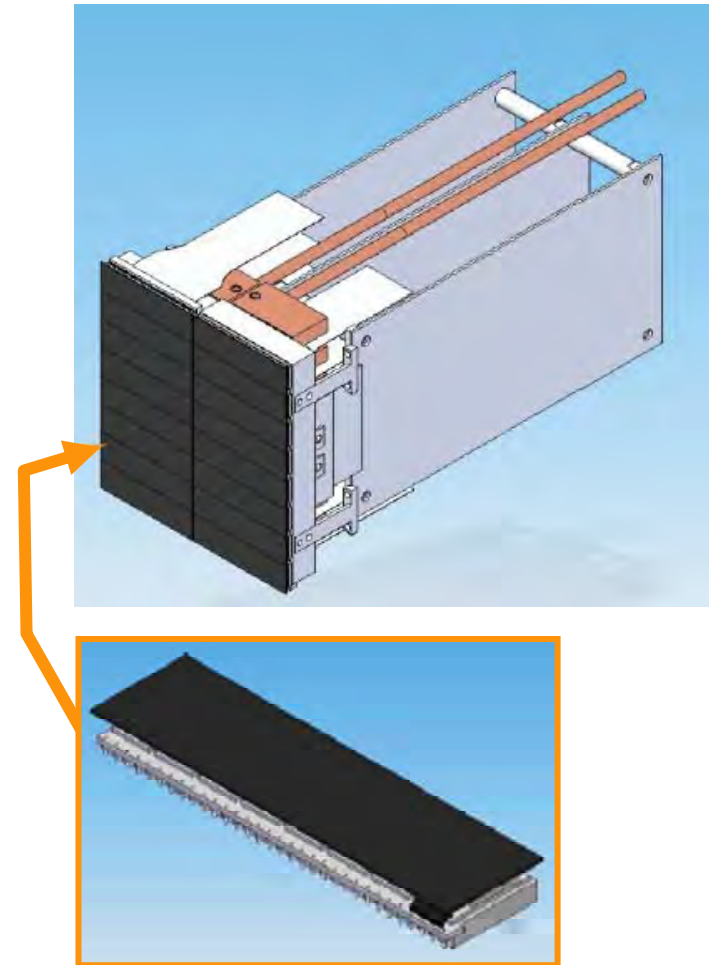
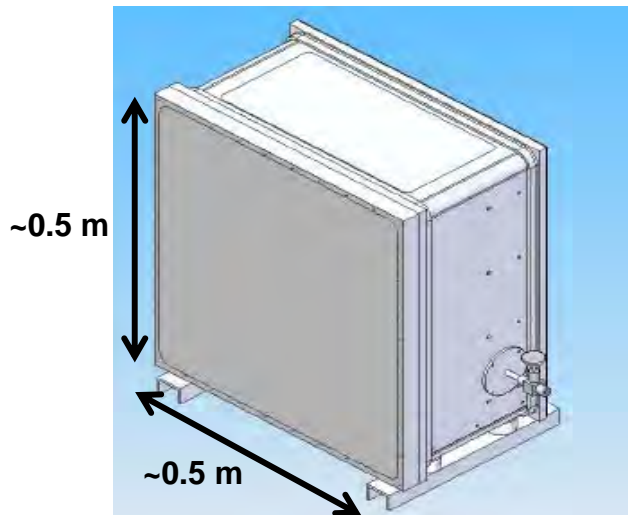
Large Pixel Detector (LPD)

Super-module

- 8 x 2 tiles
- 256 x 256 pixel

The MegaPixel module

- 4 x 4 supermodules
- 1024 x 1024 pixel



collaboration STFC/RAL, U Glasgow
(coordination M. French (STFC/RAL):



Science & Technology Facilities Council
Rutherford Appleton Laboratory



UNIVERSITY
of
GLASGOW

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1D detector development

- offer higher spatial resolution and storage capacity, but provide less information

These detectors usually cannot provide spectroscopic information

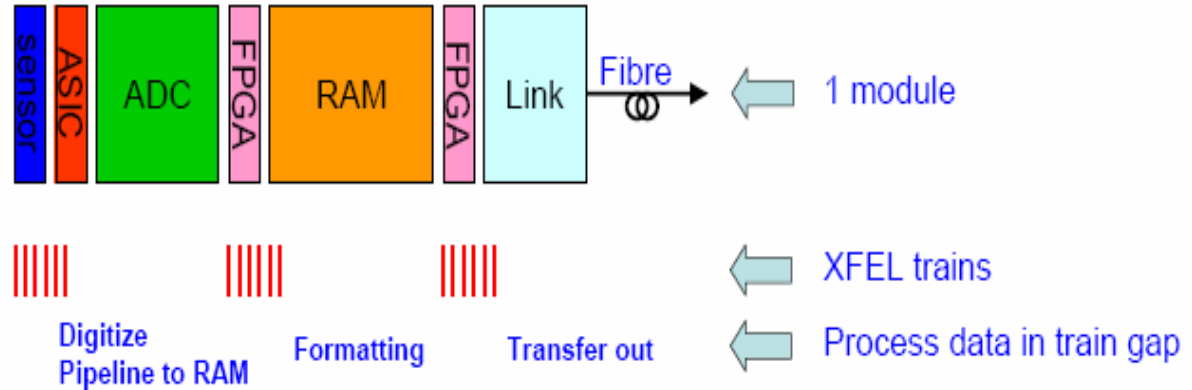
- issue of multiple hits on pixel & resolution

Data acquisition, storage and instrument control

Data acquisition

- 2 Mb per frame
- 1500 × 10 frames/s
- 30 Gb/s

collaboration:
DESY, STFC/RAL



Data storage

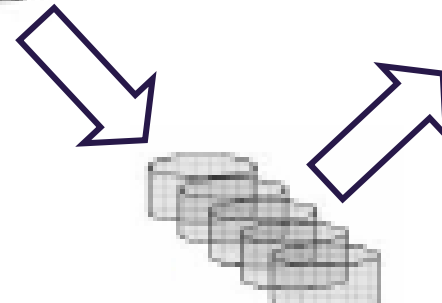
- large amounts of data
- ~10 PB archive (scaleable to 100 PB)
- off-line access

collaboration: DESY

Computing TDR

- available on the XFEL website

experiment

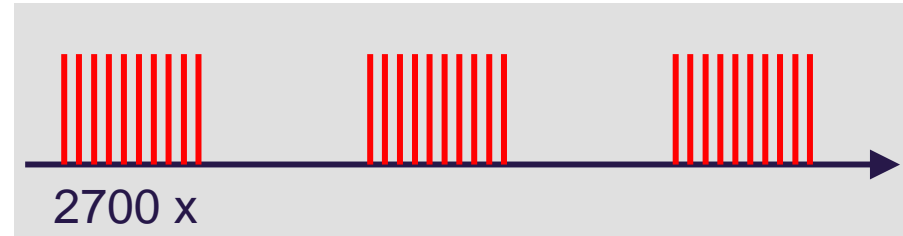


archive

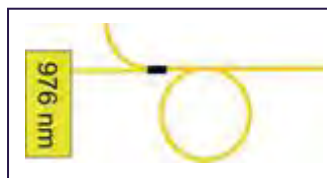
intermediate storage

Challenge

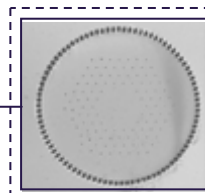
- burst-mode operation
- high average power (>100 W)
- ultrashort pulse duration
- synchronization



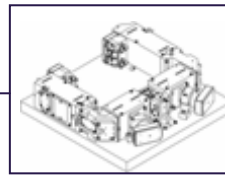
layout & test of pump laser



fiber preamplifier
 $G=10^3$



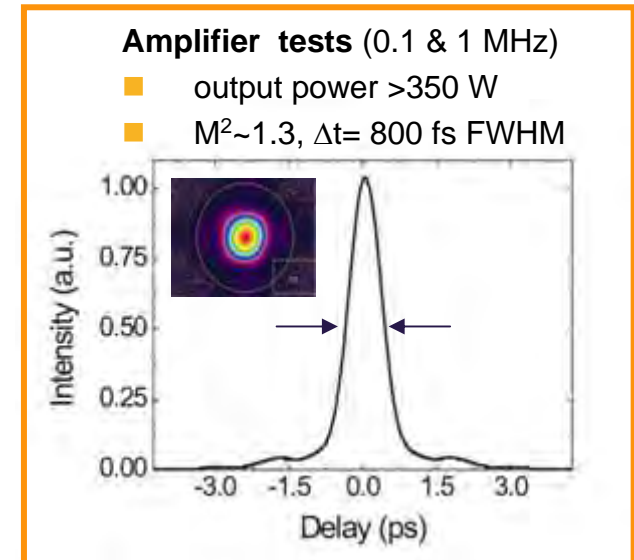
CPA fibre
amplifier
 $G>10^4$



Yb:YAG slab
amplifier
($G=100$) 400W



Yb:YAG
thin disk
multipass



F. Tavella, S. Düsterer (DESY);

collaboration: DESY, HI Jena, ILT Aachen, MBI Berlin

Due to intense beams the interaction of the x-ray beam with the sample cannot be neglected:

- direct beam
 $\sim 10^{16} \text{ W/cm}^2$ (10 μm); $\sim 10^{18} \text{ W/cm}^2$ (1 μm); $\sim 10^{20} \text{ W/cm}^2$ (0.1 μm)
- monochromatic beam (2% eff.)
 $\sim 2 \times 10^{14} \text{ W/cm}^2$ (10 μm); $\sim 2 \times 10^{16} \text{ W/cm}^2$ (1 μm); $\sim 2 \times 10^{18} \text{ W/cm}^2$ (0.1 μm)
- split & delay unit (0.1% eff.)
 $\sim 10^{13} \text{ W/cm}^2$ (10 μm); $\sim 10^{15} \text{ W/cm}^2$ (1 μm); $\sim 10^{17} \text{ W/cm}^2$ (0.1 μm)
- unfocussed beam
 $\sim 2 \times 10^{12} \text{ W/cm}^2$ (full); $\sim 5 \times 10^{10} \text{ W/cm}^2$ (mono.); $\sim 2 \times 10^9 \text{ W/cm}^2$ (split&delay)

In addition high rep. rates lead to heat load on the sample.

What are the needs and possibilities for sample exchange ?

Preparing conceptual designs for beam transport and scientific instruments

Instrument workshops

- consolidate science case and define requirements for design of beam transport and instruments
- SQS – Nov '08, Aarhus
- SPB – Nov '08, Uppsala
- HED – Mar '09, Oxford
- SCS – Jun '09, Villigen
- MID – Oct '09, Grenoble
- FDE – Dec '09, Budapest

1st meeting European XFEL SAC/MAC

- Jan 25/26, 2010, Hamburg

4th European XFEL Users' Meeting

- Jan 27-29, 2010, DESY, Hamburg

International workshop series on the science and instrumentation at the European XFEL:
Femtosecond X-Ray Experiments

9 – 11 December 2009
KFKI Research Institute
Budapest, Hungary

Local organizers
György Vanko, Denes Nagy
KFKI Research Institute, Budapest, Hungary

International programme committee
Matias Bargheer, University of Potsdam, Germany
Christian Brei, Hamburg, Germany
Gyula Faigel, Hungary
Pieter Glatzel, Steven Johns, Switzerland
Martin Nielsner, Alexander Sol, Federation
Simone Techner

The Instrument for Femtosecond X-Ray Experiments (FDE) will exploit the unique time structure and intensity of the European XFEL for structural dynamics studies of molecules, biological species and solid state materials. This instrument will allow new investigations of electronic and atomic structure changes that are not possible today. It will thus supplement to several fields of contemporary research including chemical and biological dynamics and solid state physics. Advanced X-Ray Spectroscopies and Scattering will be implemented with femtosecond time resolution, but also techniques that require the intense average XFEL flux are foreseen.

This meeting forms part of a series of workshops aiming to discuss scientific cases and designs of the European XFEL instruments. It features a number of invited lectures on scientific and technical aspects, followed by group sessions providing opportunities for extended discussions from broad user communities on the construction of the FDE instrument and its capabilities.

Young scientists bursaries
Deadline: 15 Oct 2009
(for details see website)

The workshop is co-funded by the European Commission through the Pre-XFEL grant. This will allow free of charge access to the workshop.

Hosting the workshop and support by the KFKI Research Institute, Budapest, Hungary, is gratefully acknowledged.

www.xfel.eu

4th European XFEL Users' Meeting
27 - 29 January 2010 at DESY, Hamburg, Germany

The European XFEL Users' Meeting is an annual opportunity to strengthen the interaction between the European XFEL project and the scientific user community. This year it will focus on:

- Selected science applications
- Progress and current status of the European XFEL
- Results of 2009 technical and scientific workshops
- Current developments in the field of XFEL facilities
- Job opportunities at the European XFEL

Registration: www.xfel.eu/4th-users-meeting

Bursaries for young scientists
Thanks to the support by the European Commission, we are able to offer a financial contribution of up to 600 €, depending on distance, towards travel and living expenses to a limited number of young scientists. Eligible are all science graduate students or recent PhDs (doctorate granted after Jan 01, 2009). To apply, send a request to secretaries@xfel.eu before January 4, 2010, with a CV including the topic, the name of the thesis advisor and the University of your PhD work, as well as the date of completion of your doctorate (or the expected date, if you did not complete it yet).

Organizing committee:
Henry Chapman (CFEL/DESY), Gyula Faigel (DESY, Budapest), Josef Fransson (DESY), Massimo Albarelli, Christian Brezner, Imke Gemballa, Serguei Molodtsov, Andreas Schwane, Thomas Tschentscher, Karl Witte (European XFEL)

www.xfel.eu

Programme

27 January 2010
Plenary sessions with project status and workshop reports
Science session with special topic: Coherence applications

28 January 2010
Joint session with HASYLAB Users' Meeting:
Soft X-ray FEL / FLASH experiments

29 January 2010
Poster session



This meeting is supported by the European Commission within Framework Programme 7



Refine science scope of FDE instrument

- application areas
- Are there synergies of the various techniques ?

Discuss requirements for FDE instrument

- beam delivery (coherence, focal spots, monochromaticity, split & delay, temporal properties, rep. rates, pulse patterns)
- photon diagnostics
- instrumentation (sample environment, diffractometer, spectrometers)
- detectors and their geometry (2D, 1D (?), streak cameras)
- optical lasers (wavelength, pulse energies)

Sample issues

- sample classes & exchange schemes

FDE instrument layout

- overall concept
- diffraction and scattering
- absorption spectroscopy & Co.

The European XFEL project is up and running.



The European XFEL foresees to build an instrument for femtosecond time resolved investigations of a wide class of samples and systems.



Early European XFEL experiments are scheduled for 2015. But preparation of the instrument starts now.

Time-resolutions of few femtoseconds seem to be in reach.



The European XFEL team is looking forward to working with you over the next years on defining and building this instrument.