Welcome to DESY

Introduction to DESY Photon Science

Edgar Weckert

UXSS 2017
Hamburg, 12-15 June 2017

DESY within the Helmholtz Association

- 18 National Research Centers
- 4.45 G€ budget incl. 3rd party funding
  3.03 G€ from public sources
- 38200 employees: 21700 scientists,
  8000 PhD stud., 1700 trainees

Research fields

Energy
Earth and Environment
Health
Information
Matter
Transport and Space

Strategic forward looking evaluation every 5 years
PoF II: 2009 - 2014; PoF III: 2015 - 2019

DESY: two sites

Hamburg

two sides of DESY

Zeuthen
(near Berlin)

Nationally funded but internationally used research center

Staff: ~2350 (2110 FTE)
Users: ~3000 (> 2700 for synchrotron radiation experiments)

DESY Employees

DESY's Talents and Brains

2339 Employees

885 Scientists (41% International)
580 Engineers, Technicians
348 Administrative Personnel

169 PhD's
215 Postdocs

30 Lead Scientists
16 Joint Appointments
U Aachen, Hamburg, Berlin, Göttingen, Potsdam, Freiburg, Kiel

> 3,000 Guest Scientists / year

…providing user support, research and development

DESY International

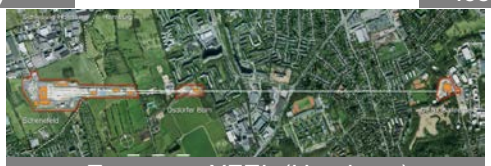
Contribution to international large-scale research infrastructures

LHC (Geneve)

CTA (in preparation)

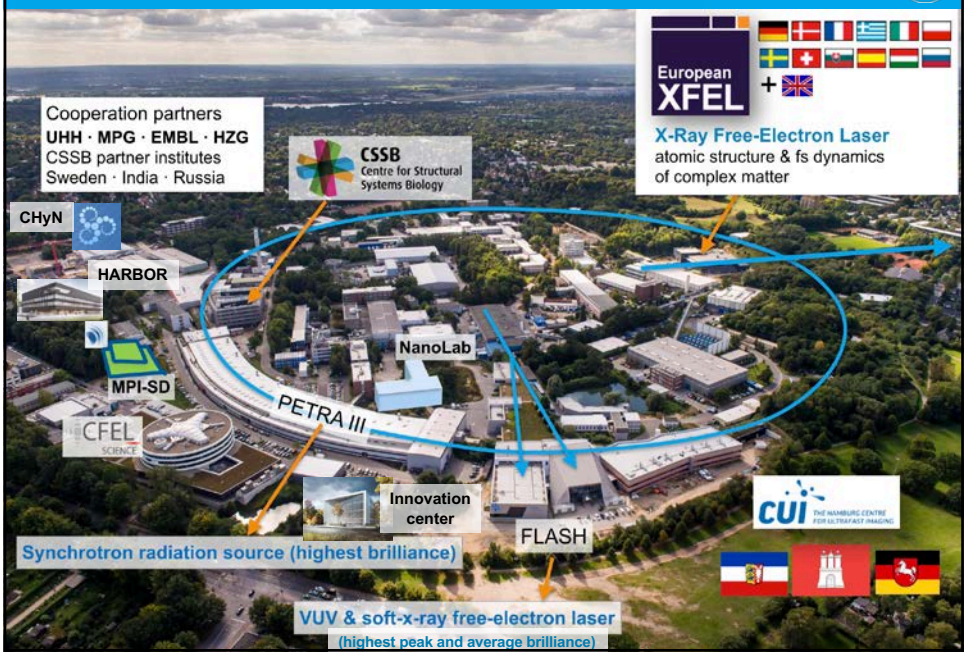
Belle II (Tsukuba)

IceCube (Southpole)

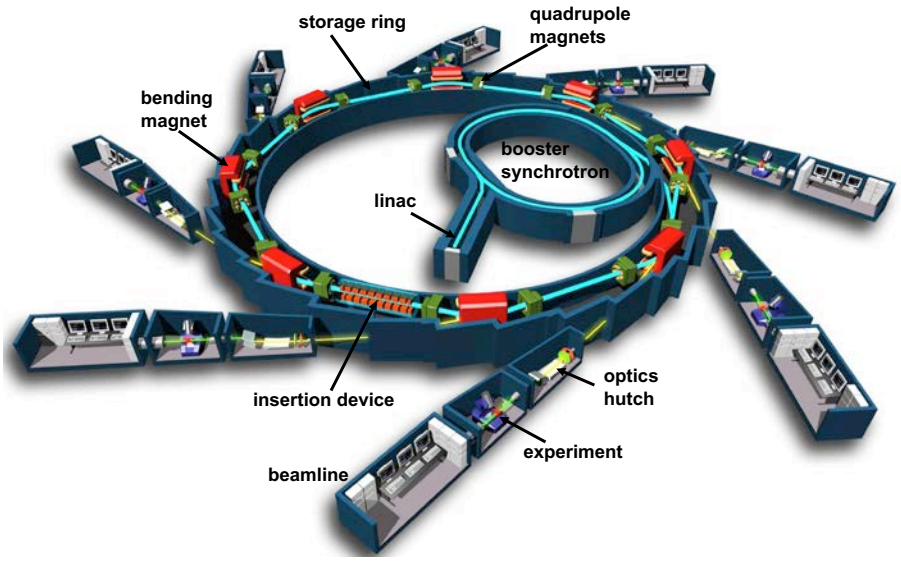


European XFEL (Hamburg)

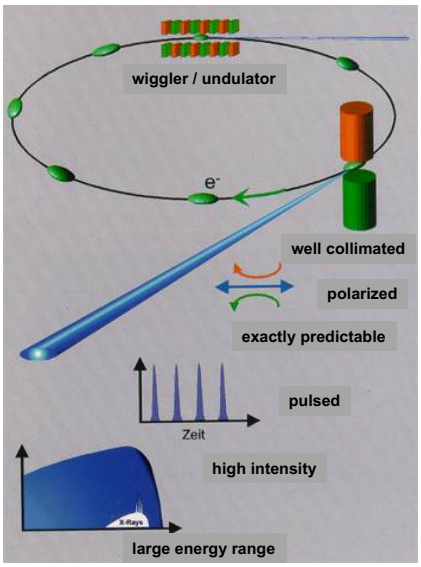
DESY Photon Science: Campus Overview



Principle of a Synchrotron Radiation Source



Properties of Synchrotron Radiation



Characteristics:

- E_c [keV] = 0.665 E^2[GeV] B[T]

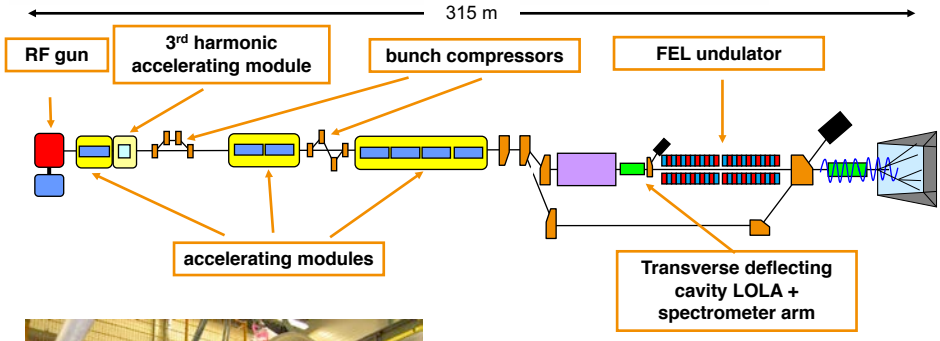
- $\gamma = E/m_e c^2$

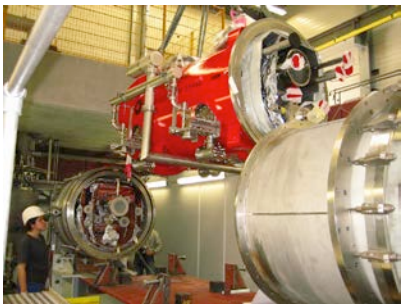
- $K = 0.934\ \lambda_u$[cm] B_0[T]

- $E_n = n\ 0.95\ E^2$[GeV]$/(1+K^2/2)/\lambda_u$[cm] (undulator)

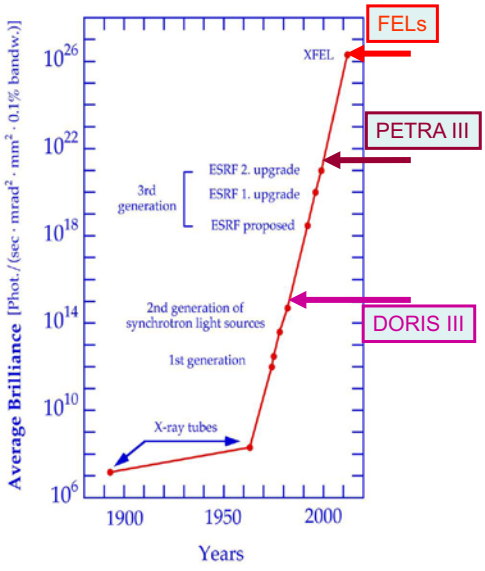
- opening angle:
  ➔ @PETRA III: $1/\gamma \sim 80\mu$rad

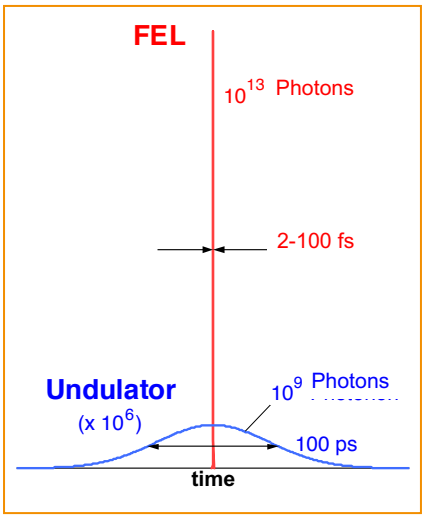
Principle of a Free Elecron Laser FEL (FLASH)



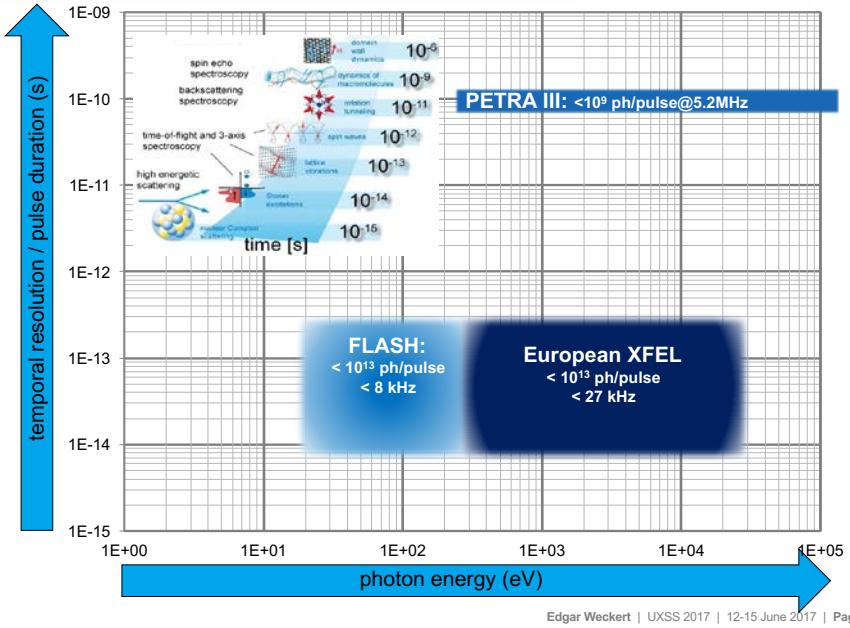


Properties of Synchrotron and FEL Radiation



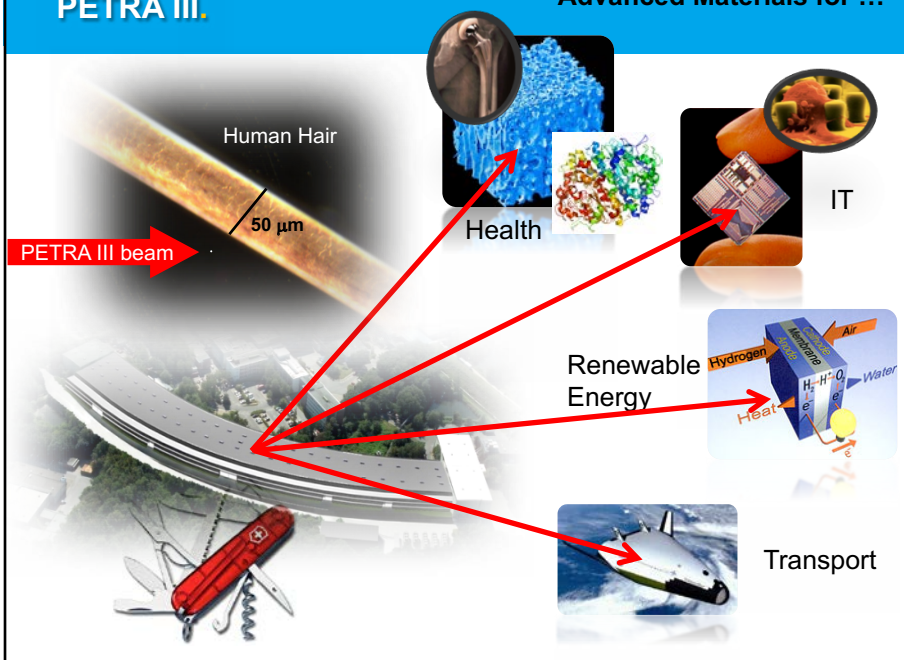


Strategy Process Facilities: Parameter space accessible by the DESY photon science facilities and EU.XFEL

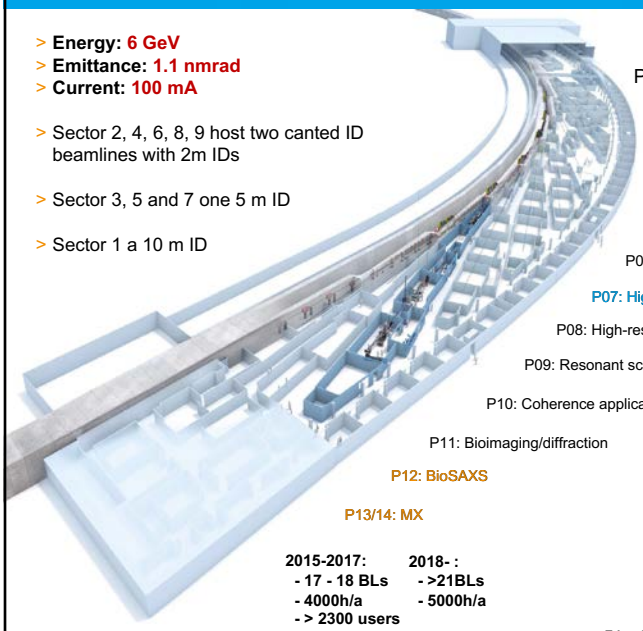


PETRA III.

Advanced Materials for …



PETRA III: Max von Laue Hall: 9 Sectors – 14 Beamlines



> **Energy: 6 GeV**
> **Emittance: 1.1 nmrad**
> **Current: 100 mA**

> Sector 2, 4, 6, 8, 9 host two canted ID beamlines with 2m IDs

> Sector 3, 5 and 7 one 5 m ID

> Sector 1 a 10 m ID

P01: Dynamics beamline, IXS, NRS

P02: Powder diffraction
extreme conditions

P03: Micro-, nano-SAXS, WAXS

P04: Variable polarization XUV

P05: Micro-, nano-tomography

P06: Hard x-ray micro-, nanoprobe

P07: High energy materials science

P08: High-resolution diffraction

P09: Resonant scattering/diffraction

P10: Coherence applications

P11: Bioimaging/diffraction

P12: BioSAXS

P13/14: MX

Partly run by HZG

Run by EMBL

2015-2017:
- 17 - 18 BLs
- 4000h/a
- > 2300 users

2018- :
- >21BLs
- 5000h/a

PETRA III: Surface Science Example

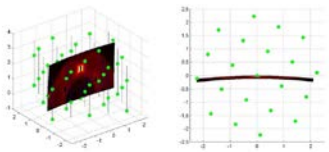
Röntgen Ångström Cluster

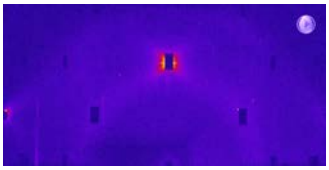
Sciencexpress

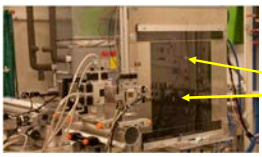
High-Energy Surface X-Ray Diffraction for Fast Surface Structure Determination

J. Gustafson,[1]* M. Shipilin,[1] C. Zhang,[1] A. Stierle,[2,3] U. Hejral,[2,3] U. Ruett,[2] O. Gutowski,[2] P.-A. Carlsson,[4] M. Skoglundh,[4] E. Lundgren[1]

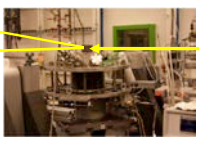
[1]Synchrotron Radiation Research, Lund University, Box 118, SE-221 00 Lund, Sweden. [2]Deutsches Elektronen-Synchrotron (DESY), D-22603 Hamburg, Germany. [3]Fachbereich Physik Universität Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany. [4]Competence Centre for Catalysis, Chalmers University of Technology, SE-412 96, Göteborg, Sweden

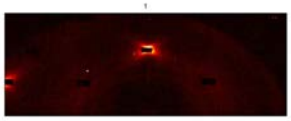


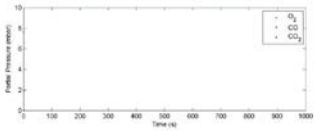




P07: photon energy: 85 KeV







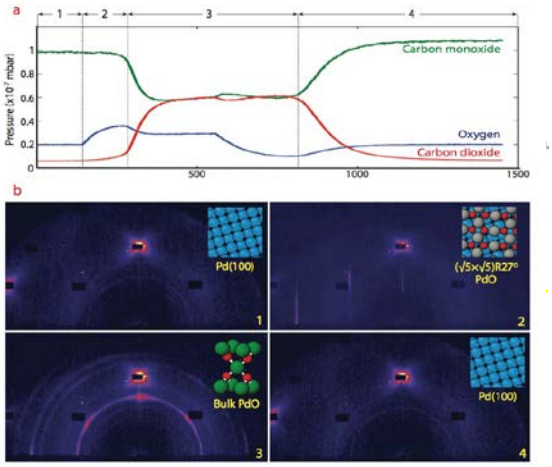
Gustafson, …, Hejral, Rutt, Gutowski, Stierle, Science 343(2014)758

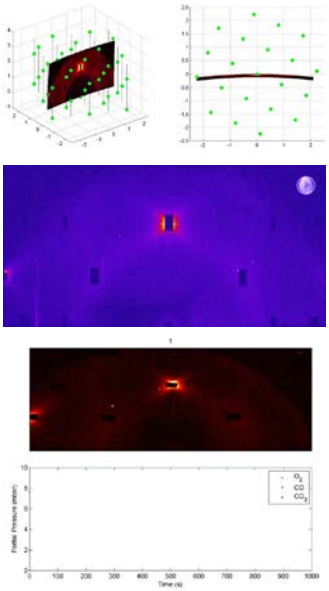
PETRA III: Surface Science Example

Röntgen Ångström Cluster

Sciencexpress

High-Energy Surface X-Ray Diffraction

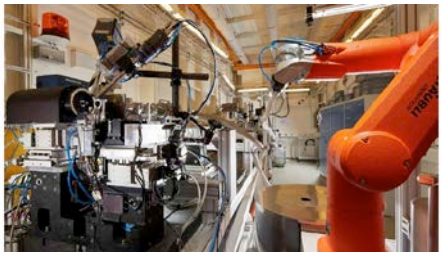


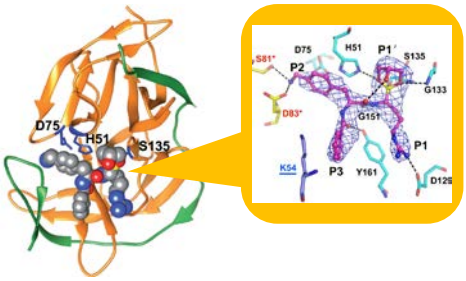


Gustafson, …, Hejral, Rutt, Gutowski, Stierle, Science 343(2014)758

Science at PETRA III: Zika Virus

Macromolecular crystallography at PETRA III (P11) → Structure determination of an enzyme responsible for the viral reproduction cycle





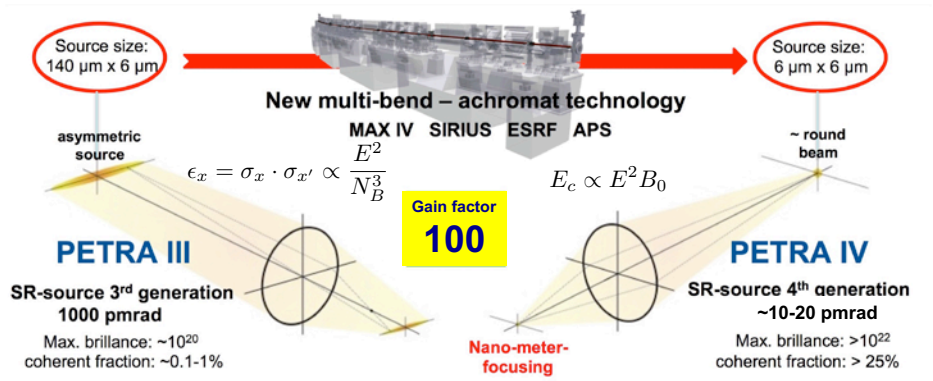
Crystal structure of Zika virus NS2B-NS3 protease in complex with a boronate inhibitor
J. Lei, …, R. Hilgenfeld
Science **353,** 6298 (2016)

„With the known 3D structure of the protease it will be possible to produce highly specialized compounds to block the reproduction fo the virus.“
(Rolf Hilgenfeld)

PETRA III Extension: More beamlines (ongoing project)

Presently (June 2017):
Three experimental halls
18 independent stations
40 different instrument

PETRA IV: scope / motivation / design



PETRA IV

- New multibend-achromat-technology +
- 2,3 km circumference
  source size scales with 1/(circumference)^3
- ⟹ ~ for 1 Å wavelength at the diffraction limit !!
  („Ultimate Storage Ring")

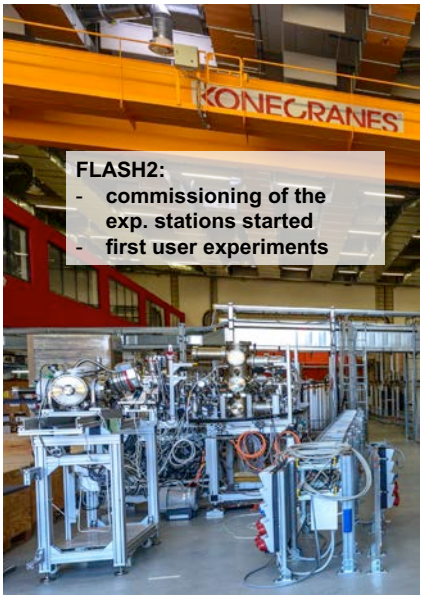
Quantum leap in SR based analytics

In-situ nm-3D-microscopy of covered structures

Nano-imaging (operando) of

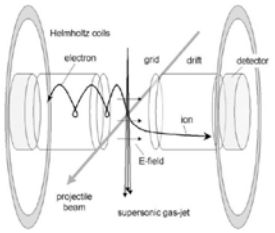
- structural details
- electronic properties
- pico-second dynamics

FLASH: VUV and soft X-ray FEL

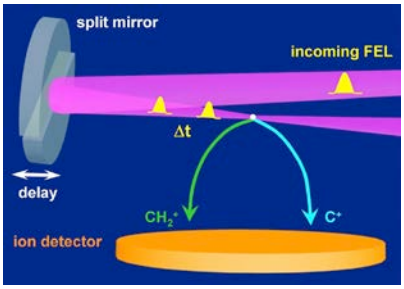


FLASH: Femtosecond Chemical Dynamics

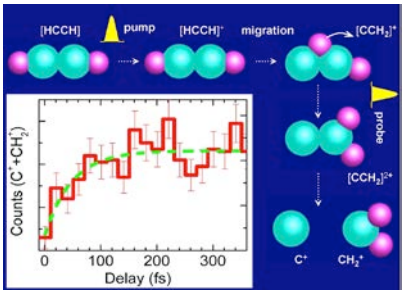
Isomerization of acetylen cations



Reaction microscope
Ullrich et al., Rep. Prog. Phys. (2003)



- **VUV-pump – VUV-probe experiment**
- **VUV beam: 20 µm focus**
- **38 eV**
- **10^{13} W/cm^2**
- **mean isomerization time: 52(15) fs**

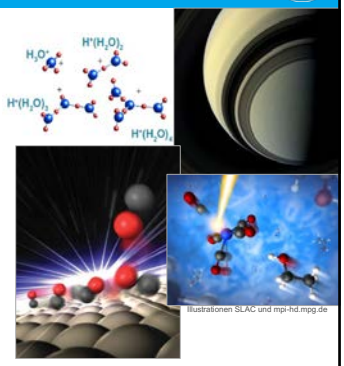


Jiang at al., PRL 105 (2010) 263002

FLASH2020

Investigation of ultrafast dynamic processes in

- Samples of extremely low densities like gas phase reaction of state prepared molecules, atmospheric and outer space chemistry or
- ‚Quantum Molecular Movies': determination of the dynamics of electrons and atoms during chemical reactions (e.g. catalysis) by coincidence measurements



Illustrationen SLAC und mpi-hd.mpg.de

require an extremely high repetition rate due to very low signal strengths

➔ **FLASH2020: towards a CW – operation mode at 100 - 1000 kHz repetition rate**

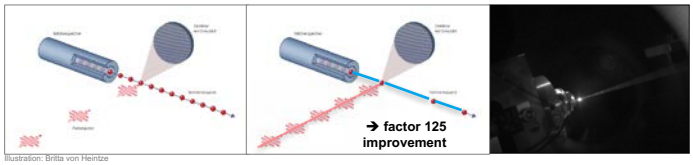
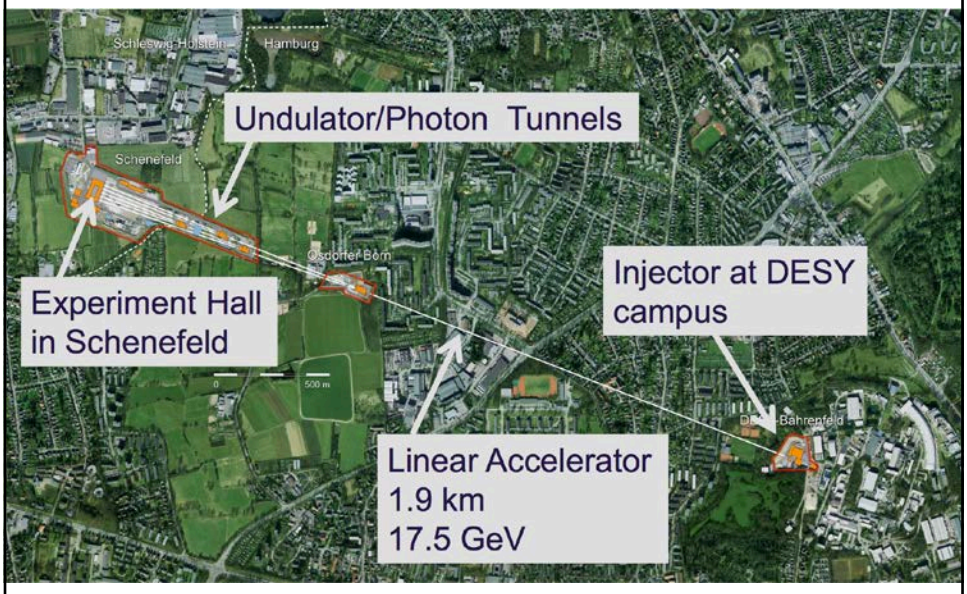


Illustration: Britta von Heintze

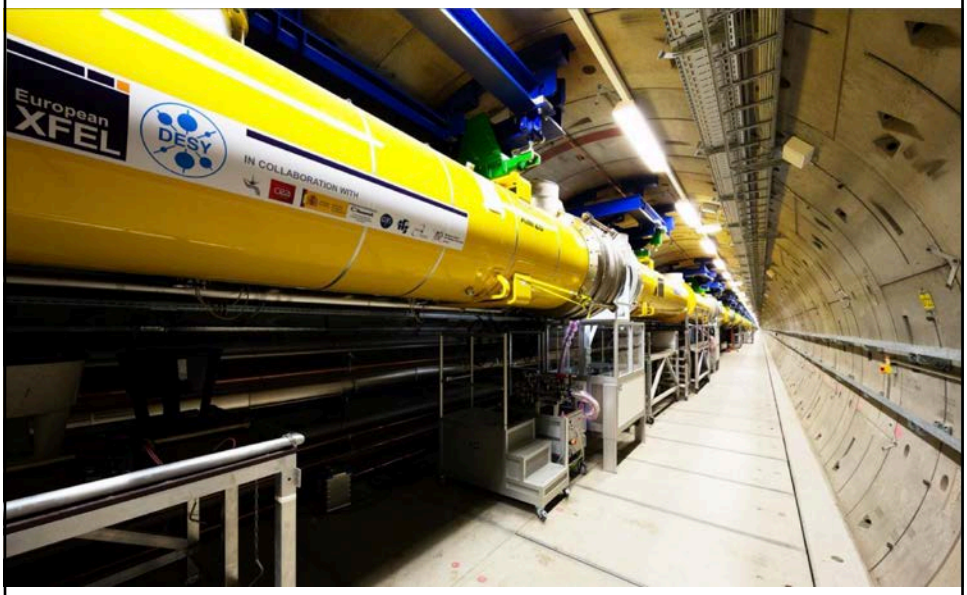
FLASH 2020:
Experiments with high repetition rate at highly dilute systems or of weak signal strength

Contact: wilfried.wurth@desy.de

European XFEL



European XFEL



European XFEL

European XFEL

First lasing at 0.9 nm

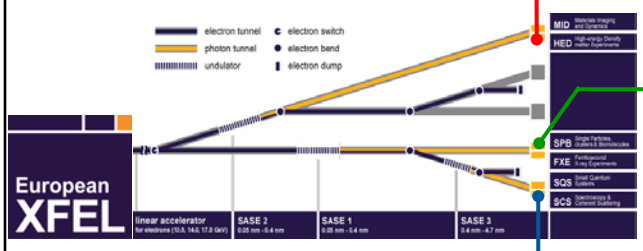
Robert Feidenhans'l new XFEL DG

- First beam in the injector: Dec. 2015
- Start cool down of the linac: Nov. 2016
- First electron beam: Jan. 2017
- First lasing at 0.9 nm: 4 May 2017
- Lasing at 0.2 nm, 1 mJ (commissioning goal) 25 May 2017
- First (friendly) user experiments: September 2017

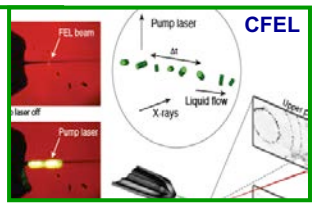
Helmholtz International User Consortia at XFEL.EU

HIBEF: Laser Systems (0.1-10 Hz) (HZDR, STFC, DESY, …)
~PW, 30 J/30 fs (Ti:Sapphire)
~kJ, 2-20 ns shaped (Diode)
Pulsed Magnets (60 T, 1 ms)

T. Cowan (HZDR), H.-P. Liermann, M. v. Zimmermann, J. Strempfer, C. Schroer, …



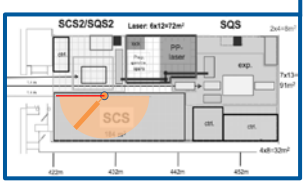
(DESY, Welcome T., …)
H. Chapman, A. Meents, H. Graafsma, …
SFX – permanent setup for biomolecule imaging



DataExpress
A. Barty

COMO
J. Küpper

TR-XPES
K. Rossnagel (CAU), W. Wurth, ...



hRIXS
High resolving power
E/ΔE = 30000
(DESY, U. Potsdam, …)
A. Föhlisch (U. Potsdam), T. Laarmann, S. Techert, W. Wurth, …

DESY / Bahrenfeld Campus development

UHH: University of Hamburg