

# 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. 3<sup>rd</sup> 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	
<b>Matter</b>	
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)**



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## 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

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## DESY International

Contribution to international large-scale research infrastructures



LHC (Geneve)



CTA (in preparation)



Belle II (Tsukuba)



IceCube (Southpole)





European XFEL (Hamburg)

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## DESY Photon Science: Campus Overview

**Cooperation partners**  
UHH · MPG · EMBL · HZG  
CSSB partner institutes  
Sweden · India · Russia

**CHyN**

**HARBOR**

**MPI-SD**

**CFEL SCIENCE**

**PETRA III**

**Innovation center**

**FLASH**

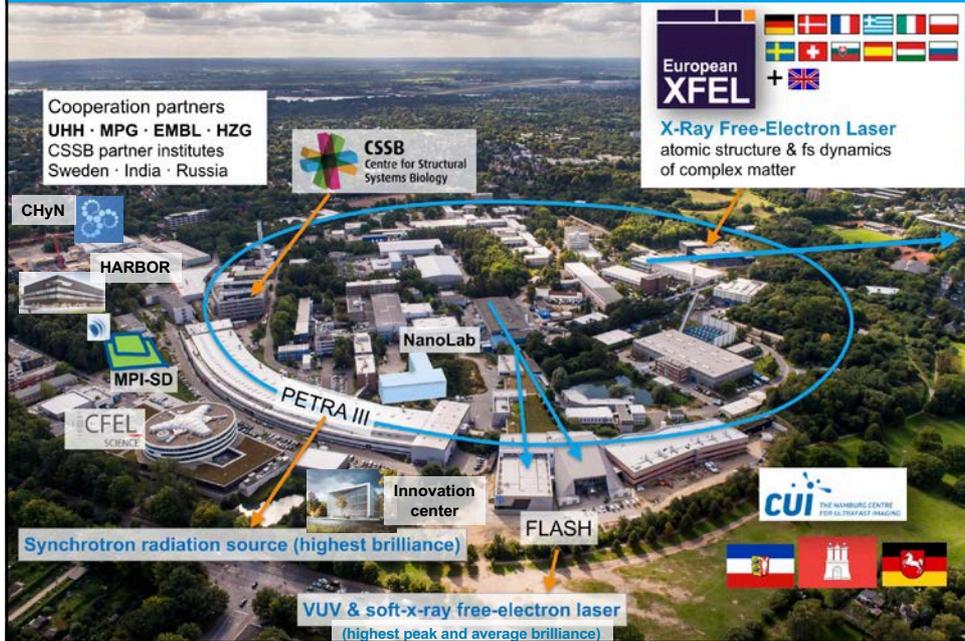
**Synchrotron radiation source (highest brilliance)**

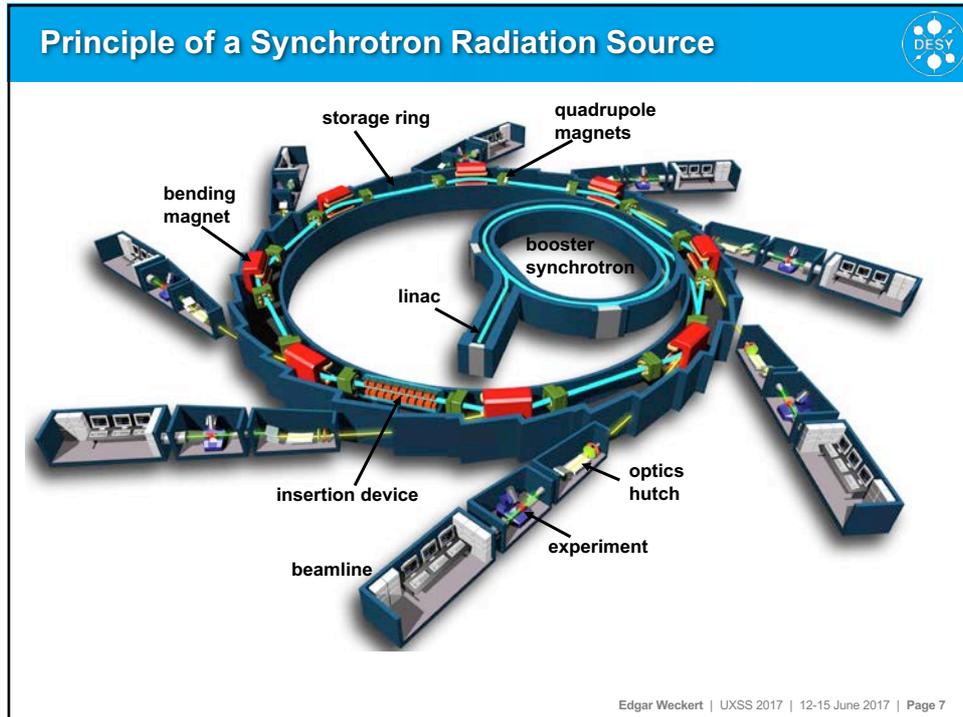
**VUV & soft-x-ray free-electron laser (highest peak and average brilliance)**

**European XFEL** + 

**X-Ray Free-Electron Laser**  
atomic structure & fs dynamics  
of complex matter

**cui** THE HAMBURG CENTRE FOR ULTRAFAST IMAGING 





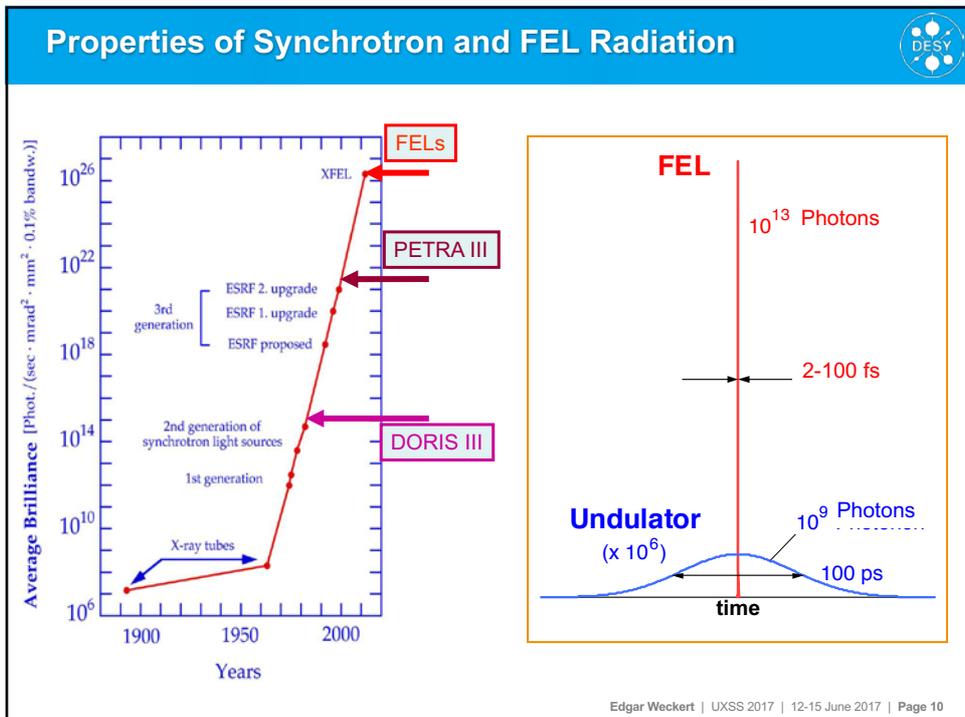
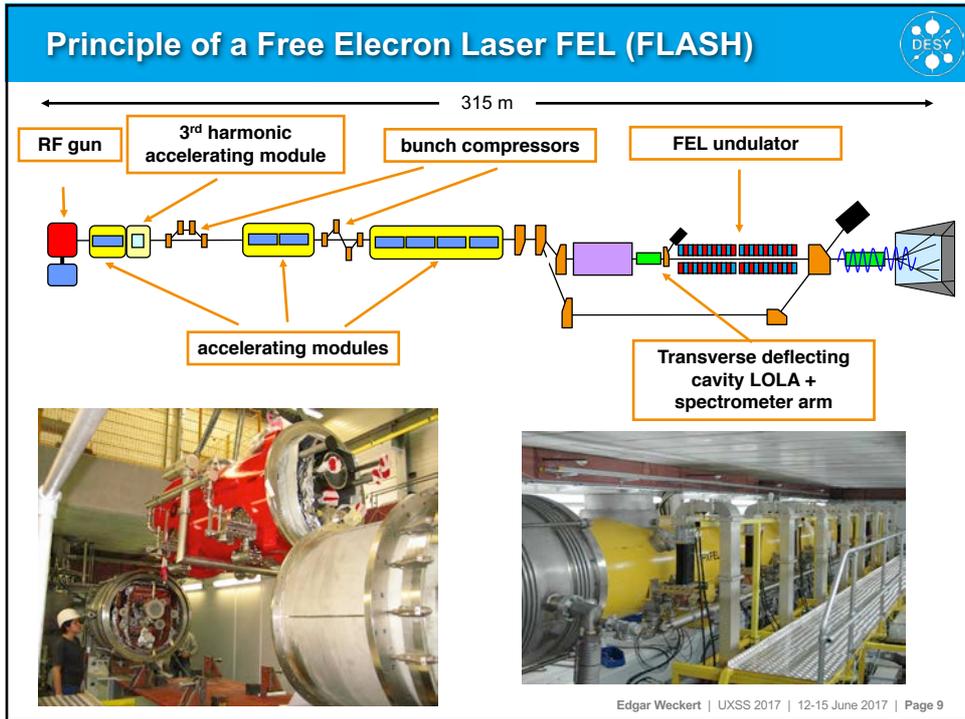
## Properties of Synchrotron Radiation

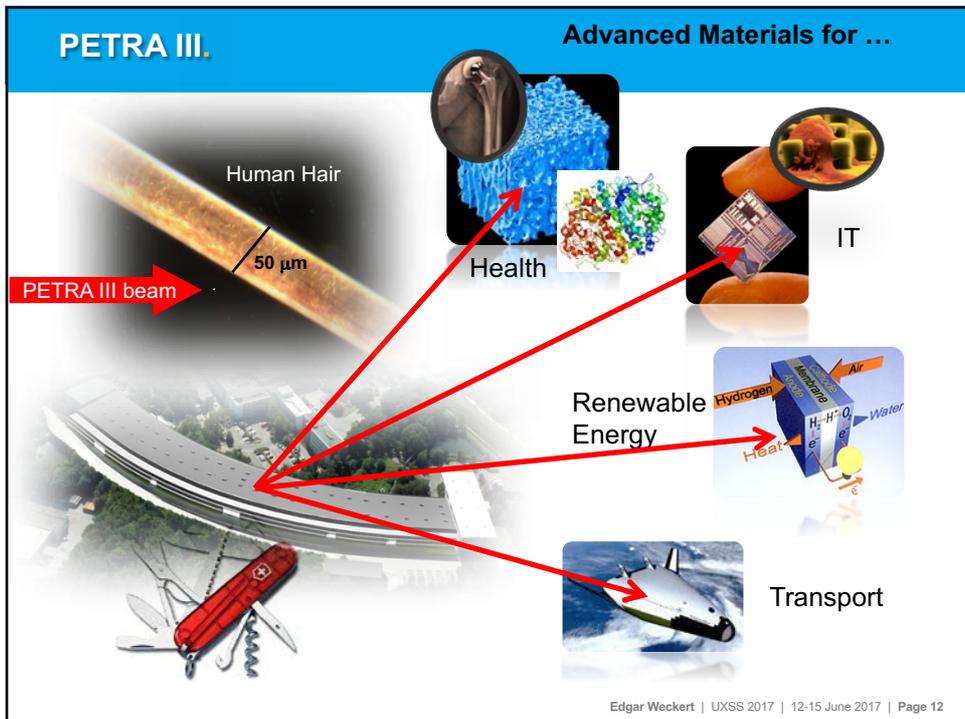
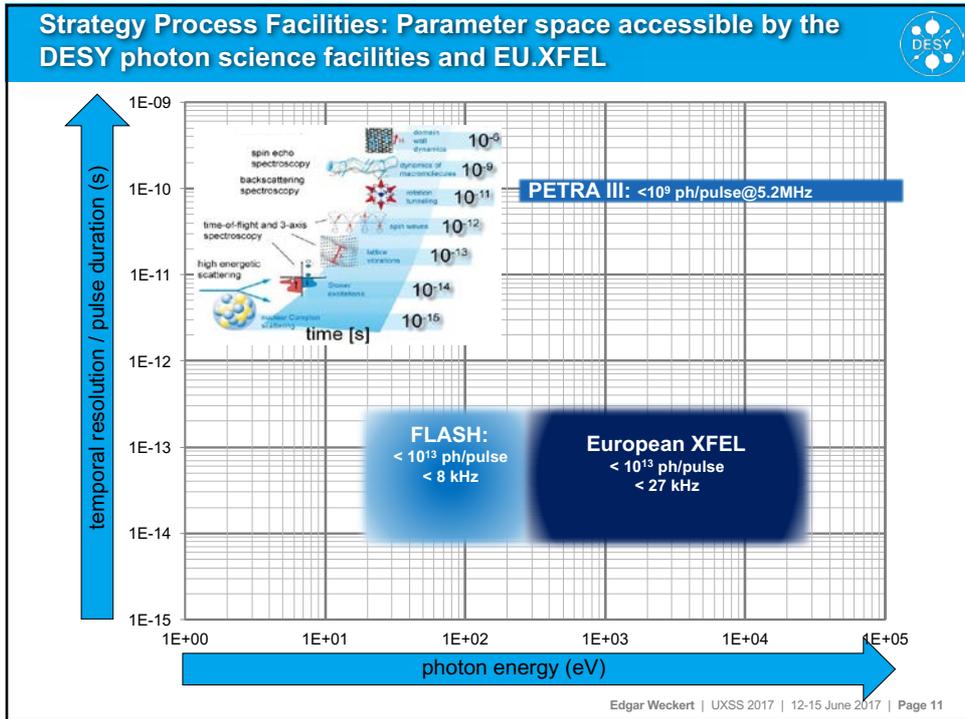
The diagram shows an electron beam ( $e^-$ ) circulating in a storage ring. A wiggler/undulator is placed in the ring to produce synchrotron radiation. The radiation is shown as a well-collimated, polarized, and pulsed beam with high intensity and a large energy range. Labels include: wiggler / undulator,  $e^-$ , well collimated, polarized, exactly predictable, pulsed, high intensity, and large energy range.

**Characteristics:**

- $E_c [\text{keV}] = 0.665 E^2 [\text{GeV}] B [\text{T}]$
- $\gamma = E/m_e c^2$
- $K = 0.934 \lambda_u [\text{cm}] B_0 [\text{T}]$
- $E_n = n 0.95 E^2 [\text{GeV}] / (1 + K^2/2) / \lambda_u [\text{cm}]$  (undulator)
- opening angle:  
 → @PETRA III:  $1/\gamma \sim 80 \mu\text{rad}$

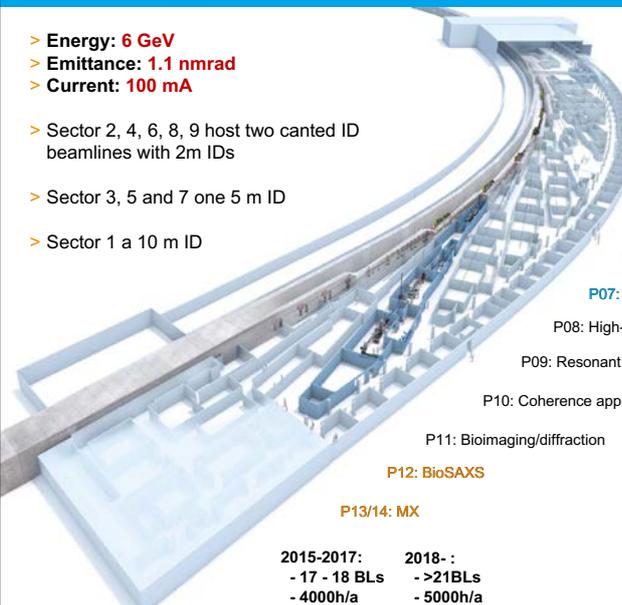
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## PETRA III: Max von Laue Hall: 9 Sectors – 14 Beamlines

- > 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

2015-2017:    2018- :

- 17 - 18 BLs    - >21BLs

- 4000h/a        - 5000h/a

-> 2300 users

Partly run by HZG

Run by EMBL

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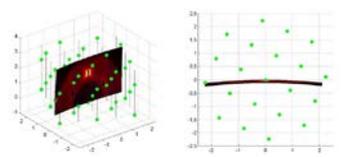
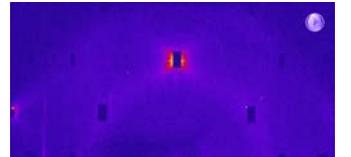
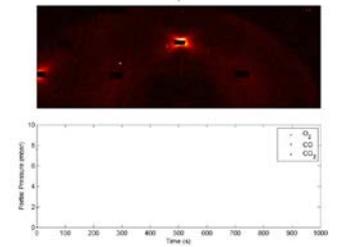
## PETRA III: Surface Science Example



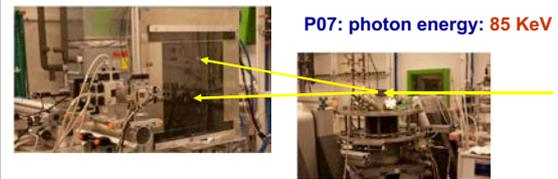
### High-Energy Surface X-Ray Diffraction for Fast Surface Structure Determination

J. Gustafson,<sup>1\*</sup> M. Shipilin,<sup>1</sup> C. Zhang,<sup>1</sup> A. Stierle,<sup>2,3</sup> U. Hejral,<sup>2,3</sup> U. Rutt,<sup>2</sup> O. Gutowski,<sup>2</sup> P.-A. Carlsson,<sup>4</sup> M. Skoglundh,<sup>4</sup> E. Lundgren<sup>1</sup>

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

**P07: photon energy: 85 KeV**



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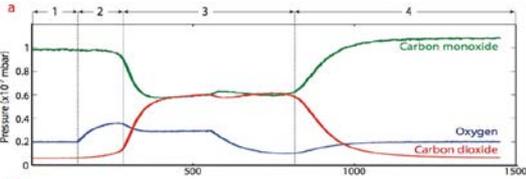
Röntgen Angström Cluster  
DESY

## PETRA III: Surface Science Example

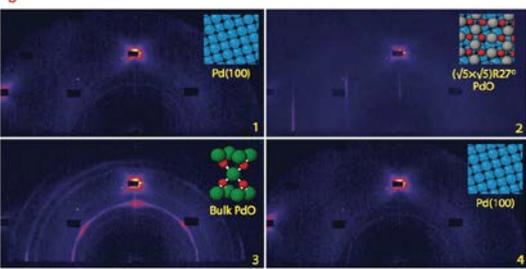


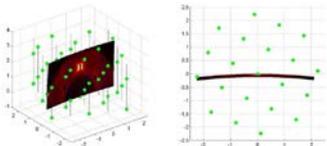
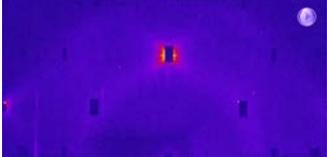
### High-Energy Surface X-Ray Diffraction

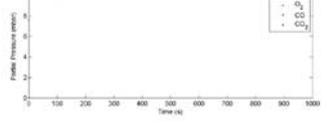
**a**



**b**





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

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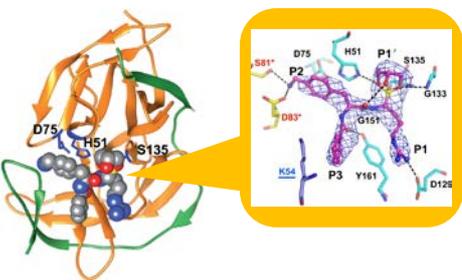
DESY

## 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 of the virus.“  
 (Rolf Hilgenfeld)

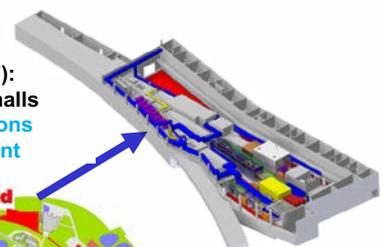
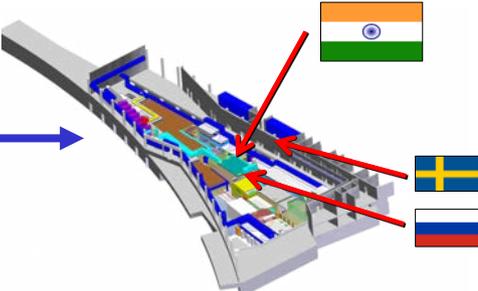
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### PETRA III Extension: More beamlines (ongoing project)

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





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### PETRA IV: scope / motivation / design

Source size:  
140 μm x 6 μm

asymmetric source



Source size:  
6 μm x 6 μm

~ round beam

**New multi-bend – achromat technology**

MAX IV SIRIUS ESRF APS

**PETRA III**

SR-source 3<sup>rd</sup> generation  
1000 pmrad

Max. brilliance: ~10<sup>20</sup>  
coherent fraction: ~0.1-1%

Gain factor  
**100**

**PETRA IV**

SR-source 4<sup>th</sup> generation  
~10-20 pmrad

Max. brilliance: >10<sup>22</sup>  
coherent fraction: > 25%

**PETRA IV**

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

**Quantum leap in SR based analytics**

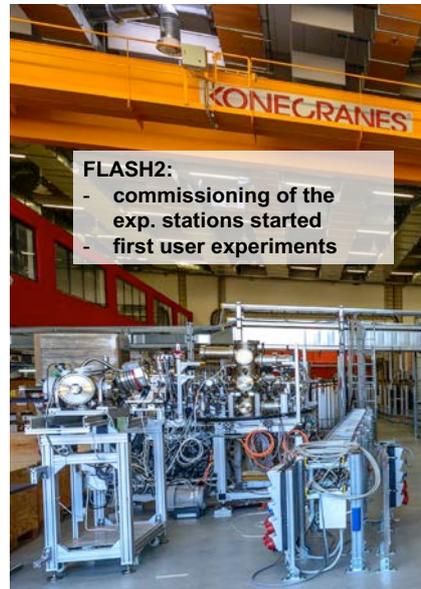
**In-situ nm-3D-microscopy of covered structures**

Nano-imaging (*operando*) of

- structural details
- electronic properties
- pico-second dynamics

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## FLASH: VUV and soft X-ray FEL

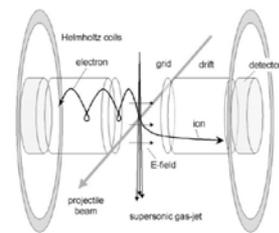


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## FLASH: Femtosecond Chemical Dynamics



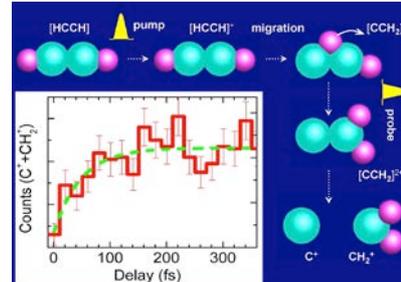
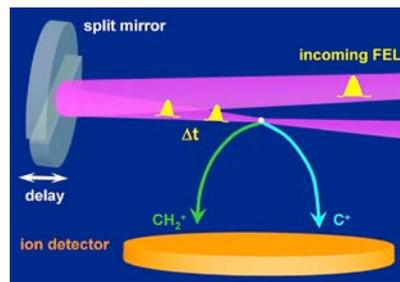
## Isomerization of acetylen cations



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

- VUV-pump – VUV-probe experiment
- VUV beam: 20  $\mu\text{m}$  focus
- 38 eV
- $10^{13}$  W/cm<sup>2</sup>
- mean isomerization time: 52(15) fs

Jiang et al., PRL 105 (2010) 263002



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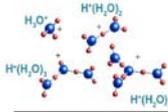
## FLASH2020



### 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

require an extremely high repetition rate due to very low signal strengths  
 → FLASH2020: towards a CW – operation mode at 100 - 1000 kHz repetition rate







→ factor 125 improvement

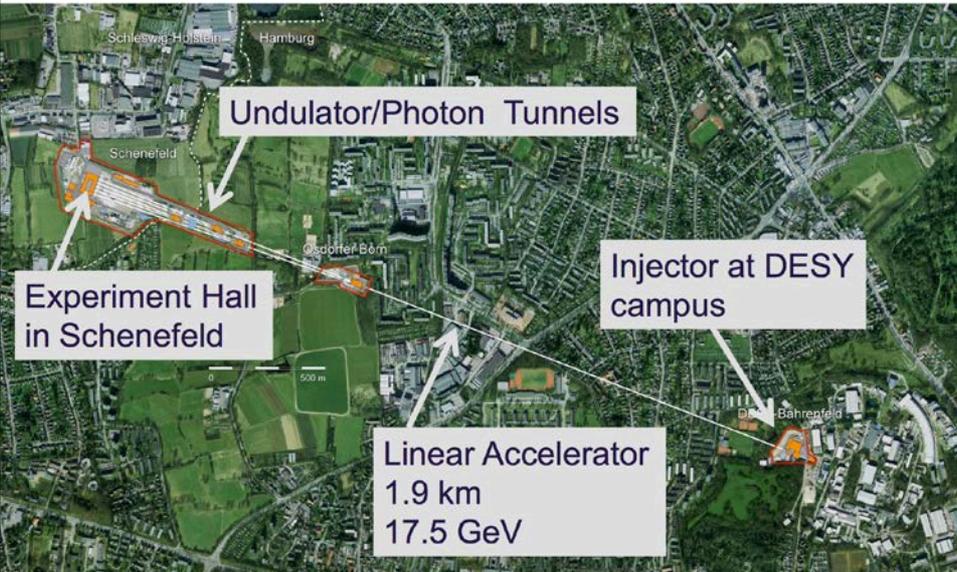


**FLASH 2020:**  
 Experiments with high repetition rate at highly dilute systems or of weak signal strength

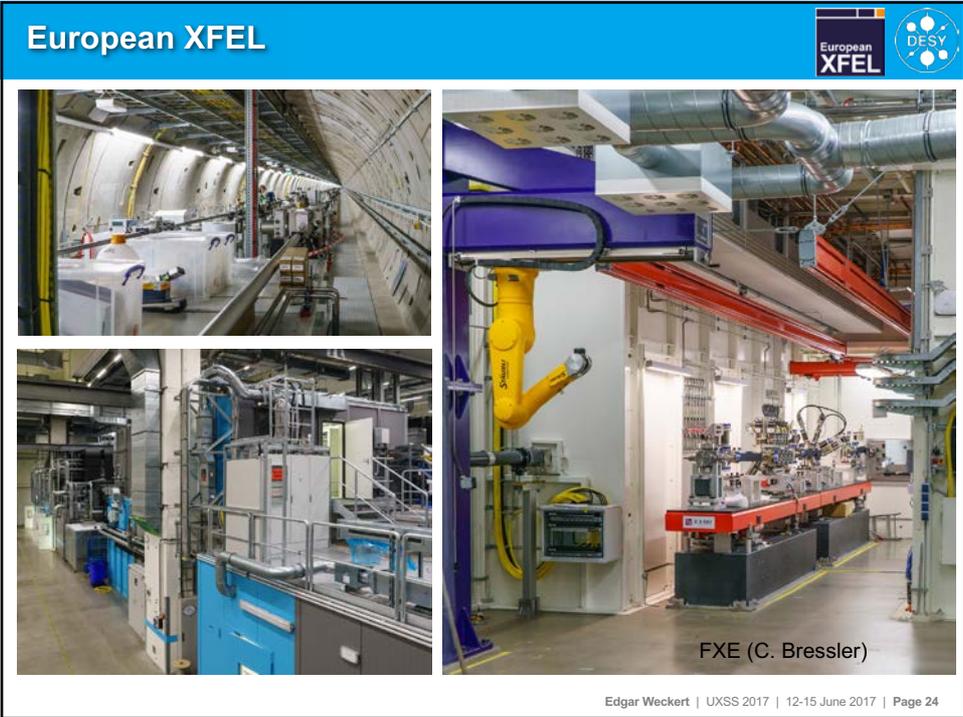
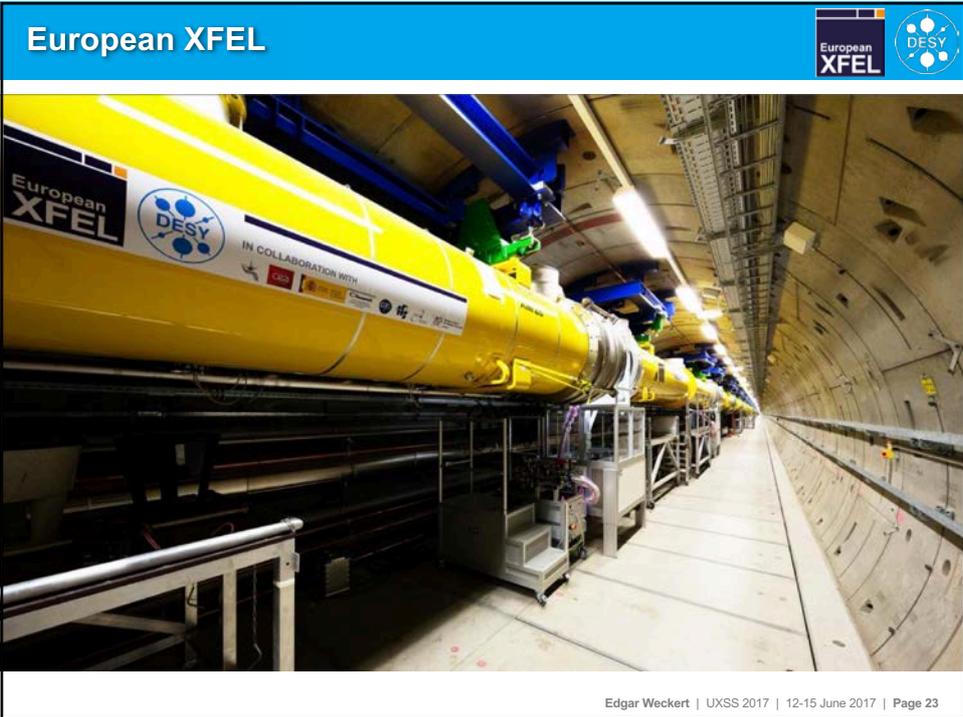
Contact: wilfried.wurth@desy.de
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## European XFEL



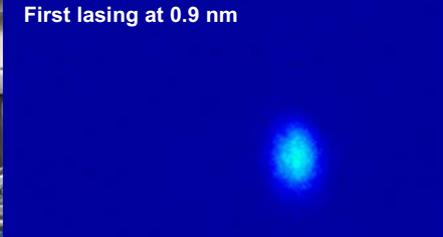
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## European XFEL




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

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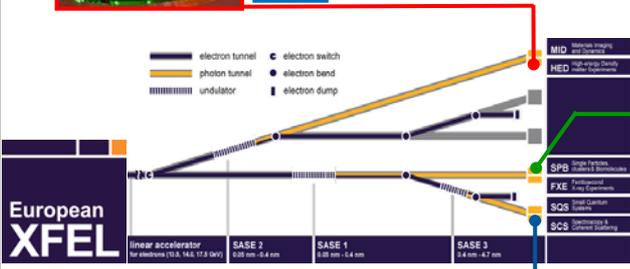
## Helmholtz International User Consortia at XFEL.EU



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

**(HZDR, STFC, DESY, ...)**  
T. Cowan (HZDR),  
H.-P. Liermann,  
M. v. Zimmermann,  
J. Stremper,  
C. Schroer, ...

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

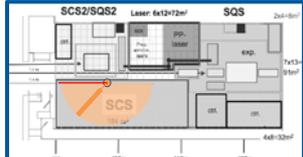


**European XFEL**  
linear accelerator for electrons (13.5, 14.5, 17.3 GeV)  
SASE 2 0.85 nm - 0.4 nm  
SASE 1 0.85 nm - 0.4 nm  
SASE 3 0.4 nm - 0.7 nm

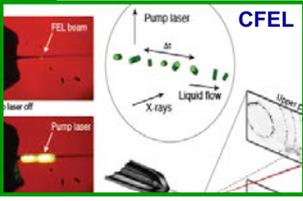
**DataExpress**  
A. Barty

**COMO**  
J. Küpper

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



**hRIXS**  
High resolving power  
 $E/\Delta E = 30000$   
**(DESY, U. Potsdam, ...)**  
A. Föhlich (U. Potsdam), T. Laermann, S. Techert, W. Wurth, ...



**CFEL**  
Pump laser  
FEL beam  
Liquid flow  
X-rays  
User

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**DESY / Bahrenfeld Campus development**

The map shows the layout of the DESY Bahrenfeld Campus. Key areas and buildings are labeled: PETRA IV (two locations), H<sub>2</sub>O Institut, Theory DESY-UHH, CSSB 2.0, Innovation center, MPSD, MINT UHH, Harbor, CHyN, Chemistry, FhI, Conference Center, and Guesthouses. The DESY logo is prominently displayed in the center of the map.

UHH: University of Hamburg

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**Thank you for your attention**

The image is an aerial photograph of the DESY Bahrenfeld Campus, showing the various buildings and green spaces. The text "Thank you for your attention" is overlaid in large, bold, blue letters across the center of the image.

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