Birthday wishes from the 'big sister'

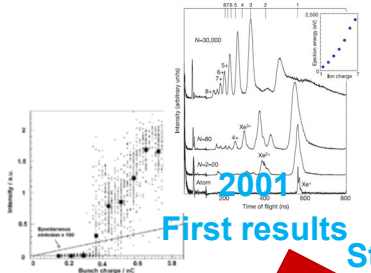
From FLASH to European XFEL

Thomas Tschentscher
European XFEL

25 years FLASH workshop, November 17 & 18, 2025

thomas.tschentscher@xfel.eu

European XFEL & FLASH – a common history and time line



2001
First results

First lasing

Start User operation
FLASH naming

FLASH 2020⁺
upgrade

FLASH

2000 2005 2010 2015 2020 2025

European XFEL

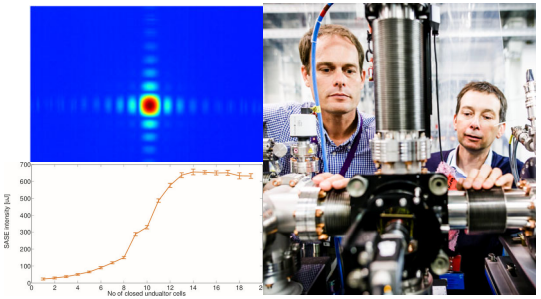
Prepare TDR

BMBF decision

2001
Proposal/TESLA event

Start construction
Foundation EuXFEL

2017
First lasing & Start User operation

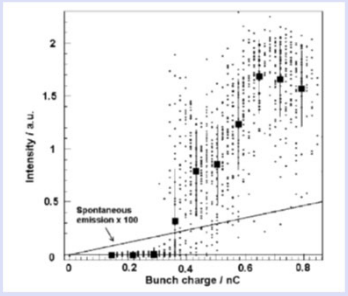


European XFEL

Direct & scientific input from FLASH to European XFEL

First lasing of a SASE FEL

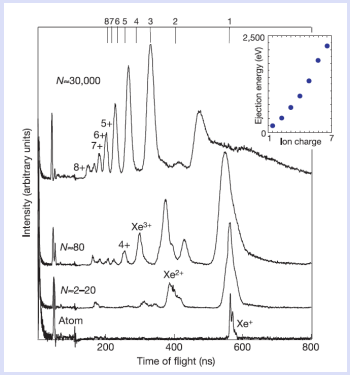
was an immense backing of the proposal to construct a hard X-ray FEL facility based on this principle.



J. Andruszkow et al.,
PRL 85, 3825 (2000)

First short-wavelength FEL science results

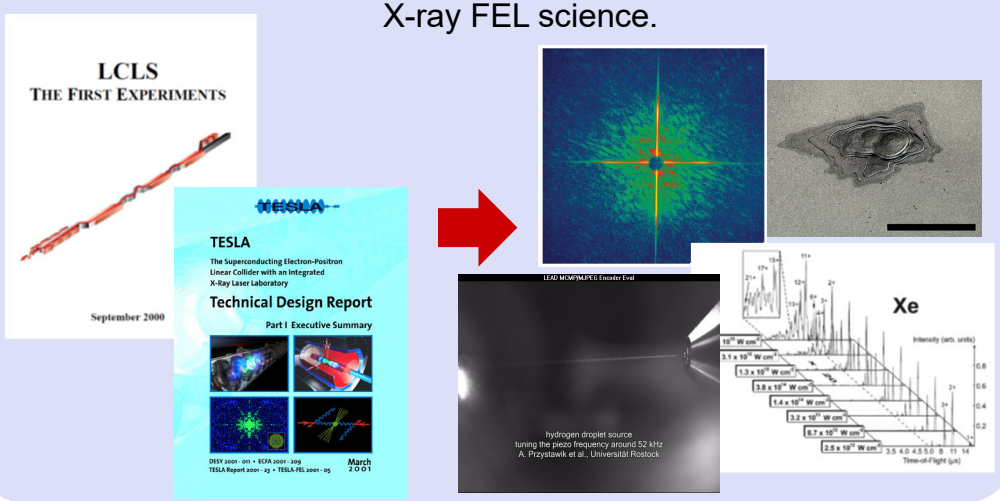
were an important input to the decision process for an X-ray FEL facility.



H. Wabnitz et al.,
Nature 420, 482 (2002)

FLASH scientific applications

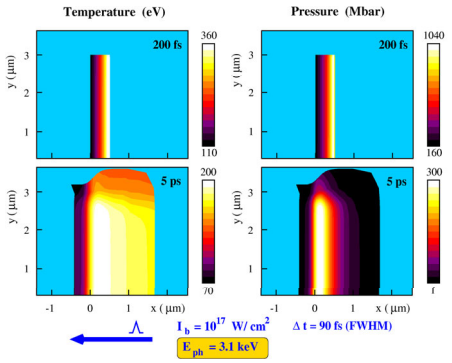
- allowed to sharpen the science case beyond the *TESLA XFEL TDR* and *LCLS First Experiments* reports,
- impacted enormously the LCLS science portfolio, and
- strengthend the German User community to take leading role in X-ray FEL science.



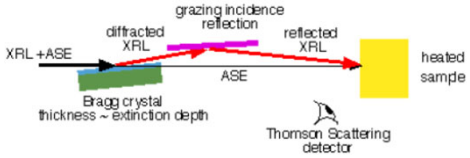
Credits: H. Chapman et al., A .Sorokin et al., A. Przystawik et al., Juha/Sobierajski et al.

Science exchange between European XFEL and FLASH

- The example of High Energy Density science



TESLA XFEL TDR (2001)



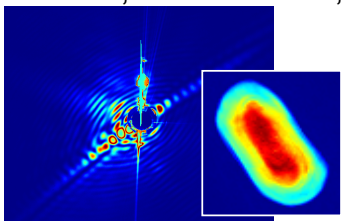
LCLS – The First Experiments (2000)

Peal Brightness Experiments collaboration
Proposal of 12 (sub-)Experiments (2002)

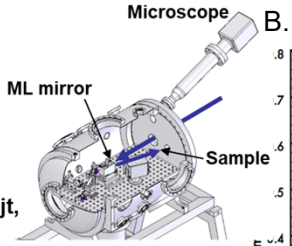
A. Nelson, S. Bajt, S. Toleikis et al.

	Experiment	Brief Description
Condensed warm matter	Warm Dense Matter Creation	Using the FEL to uniformly warm solid density samples
	EOS Measurements	Use an optical laser to heat a sample and the FEL to provide a diagnostic of the bulk
	Ablation Studies	Probe the nature of the ablation process on the sub-ps time scale
	Near Edge Absorption	Use visible laser to heat a solid and FEL to probe the structural changes that occur
Hot dense matter	Trapped, High Γ Plasmas	Use EBIT / laser-cooled trap, probe highly-charged strongly-coupled "plasmas"
	Diagnostic Development	Develop the FEL for Thomson scattering, interferometry, and radiographic imaging
	Plasma Physics Studies	Create exotic, long-lived highly perturbed electron distribution in dense plasmas
	FEL / Solid Interactions	Use the FEL to create extreme states of matter at high temperature and density
	Plasma Spectroscopy	Use the FEL to pump bound state populations and study radiation redistribution
Optics/Bio	Coulomb Explosion	Study the Coulomb Explosion process with emphasis on biological imaging
	Diffraction Imaging Studies	Validate imaging techniques. Perform microscopy beyond the current resolution
	Optics Damage	Study structural change and disintegration process in solids under FEL irradiation

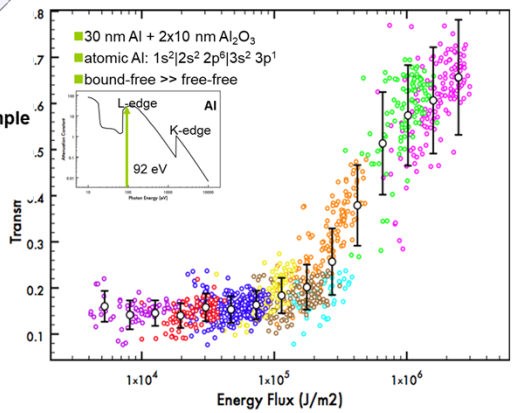
R.W. Lee, D. Riley, + 51 co-authors (…, J. Hajdu, Chapman, L. Juha, T. Möller, …S. Düsterer, S. Toleikis, TT, ….,)

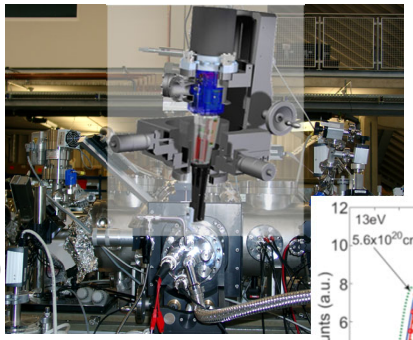


J. Hajdu, H. Chapman, F. Maia, et al.

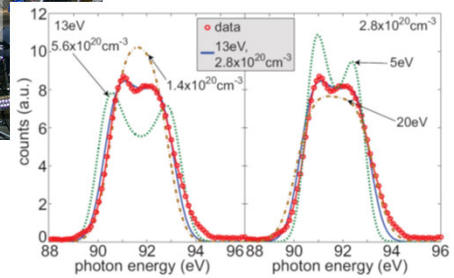


B. Nagler et al., Nat. Phys. 5, 693 (2009)





R.R. Fäustlin et al., PRL 104, 125002 (2010)



European XFEL

Science exchange between European XFEL and FLASH

- The example of High Energy Density science

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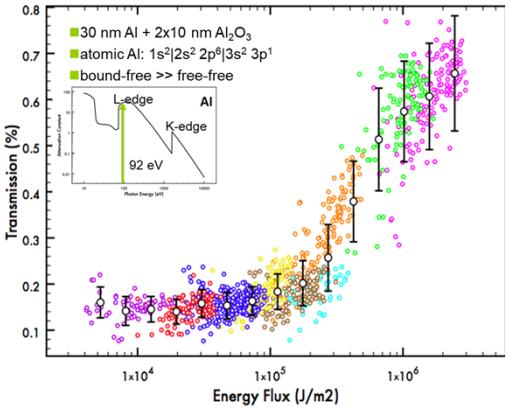
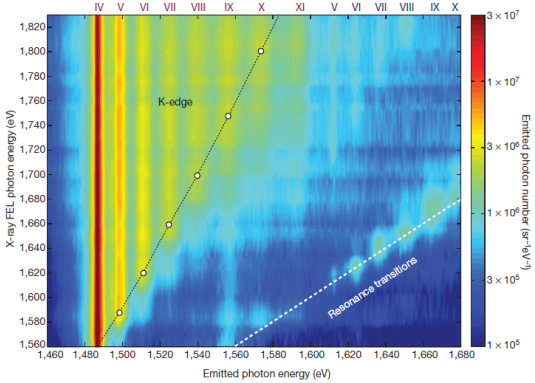
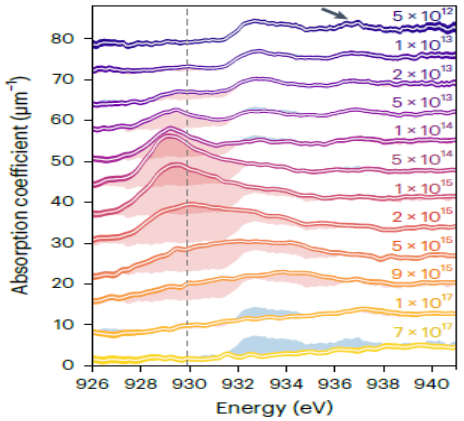


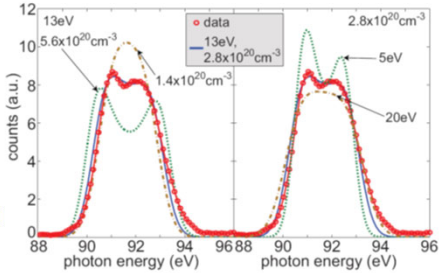
S.M Vinko et al., Nature. 482, 59 (2012)

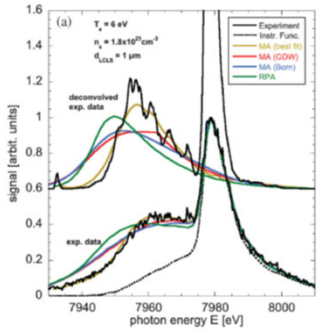


L. Mercadier et al.,
Nat. Phys. 20, 1564 (2024)



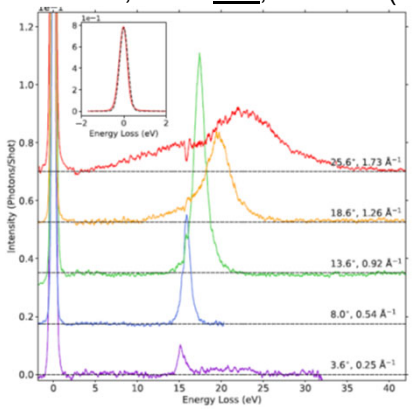
R.R. Fäustlin et al.,
PRL 104, 125002 (2010)





P. Sperling et al.,
PRL. 115, 115001 (2015)

T. Gawne et al., PRB. 109, L241112 (2024)

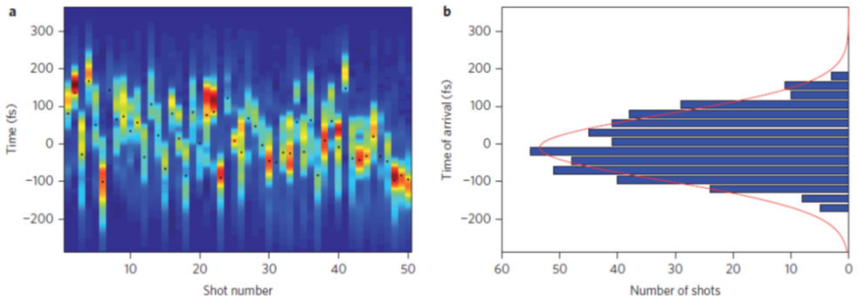


Technology development – benefits to both facilities

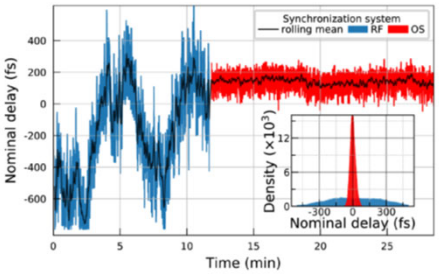
- FLASH as prototype
  - **Superconducting accelerator technology**
  - **Controls (hw & sw)**
  - **Prototyping & costing**
  - **Construction & installation**
  - **Operation of a FEL User facility**

- Further development
  - **Synchronization & pulse arrival measurement**
  - **Photo-injector & gun laser**
  - **Photo-electron spectroscopy**

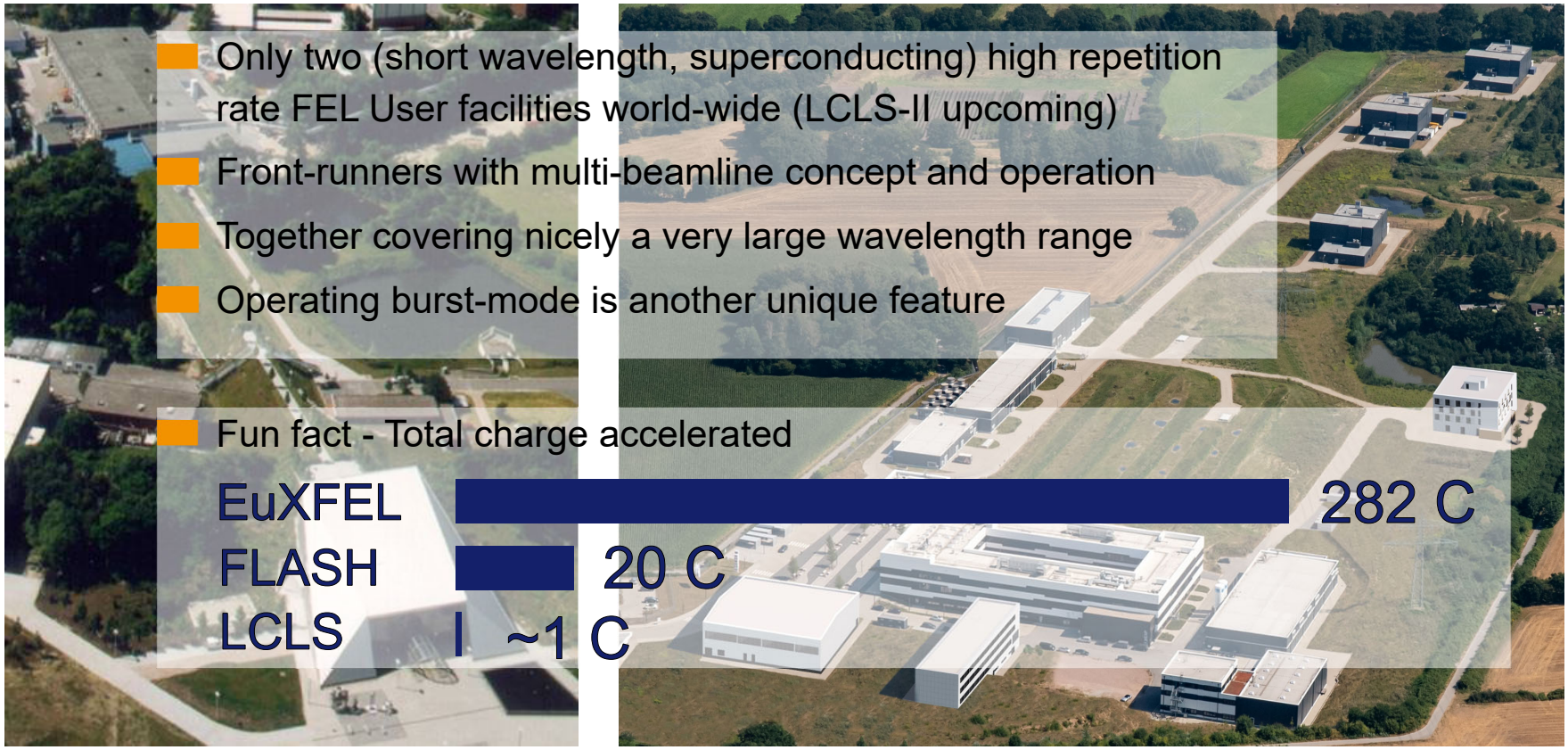
I. Grguras et al., Nat. Phot. 6, 852 (2012)



T. Sato et al., Optica. 7, 716 (2020)



Different wavelength – many common facility aspects



- Only two (short wavelength, superconducting) high repetition rate FEL User facilities world-wide (LCLS-II upcoming)
- Front-runners with multi-beamline concept and operation
- Together covering nicely a very large wavelength range
- Operating burst-mode is another unique feature
- Fun fact - Total charge accelerated

European XFEL at a glance

European XFEL

3 FEL sources (perm. Magnets, planar)
SASE1 – Hard x-rays 5 – 30 keV
SASE2 – Hard x-rays 5 – 30 keV &
Self-seeding (8 – 14 keV)
SASE3 – Soft & Tender x-rays (0.27 – 3 keV) &
var. polarisation afterburner

7 scientific instruments
SPB/SFX – SFX,SPB,imaging
FXE – XRD,XAS,XES,EXAFS
MID – imaging,XRD
HED – XRD,XES,SAXS
SQS – part.spectros.,imaging
SCS – XAS,RIXS,XRD,imaging
SXP – open port,XPS,EBIT

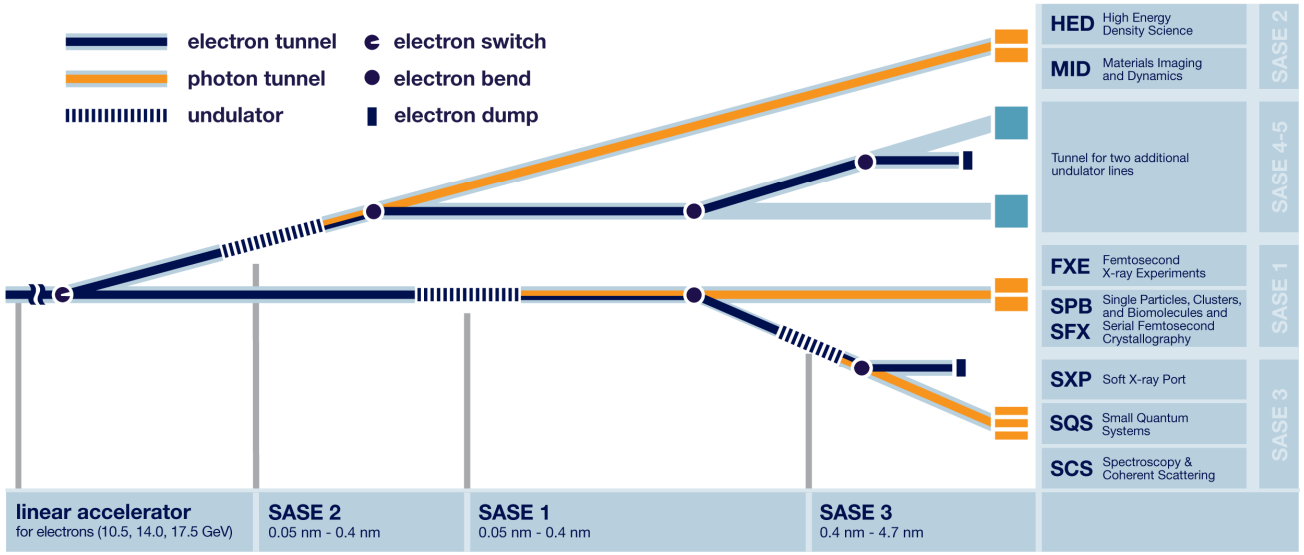
500 m

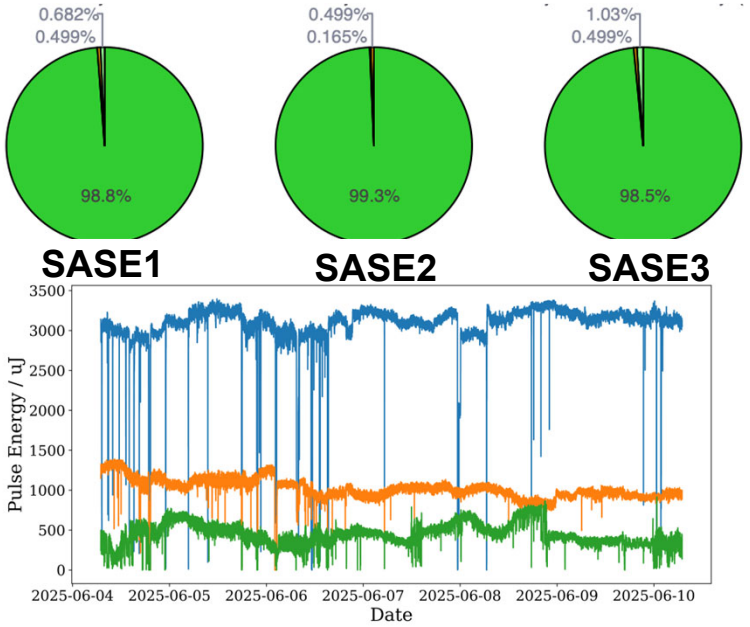
Superconducting electron accelerator
17.5 GeV, 1.3 GHz,
4.5 MHz, 10 Hz burst-mode
0,6% duty cycle
Highly flexible electron distribution

International User Facility
~ 1200 users/yr, ~2000 user visits/yr, 90 – 100 experiments
Start of operation: 2017

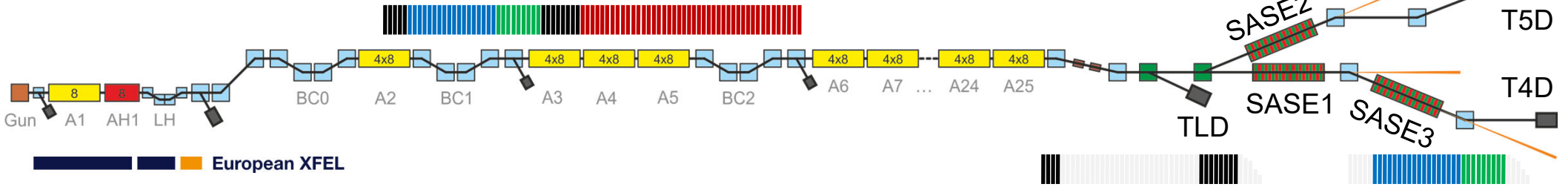
DESY.

European XFEL as a Multi-user facility



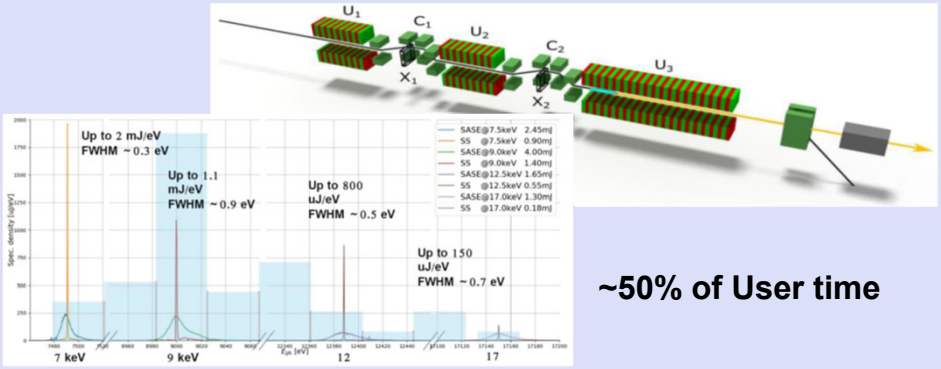


Distributing electron bunches to FELs/experiments (1/2,25/4,5 MHz, 600 µs)



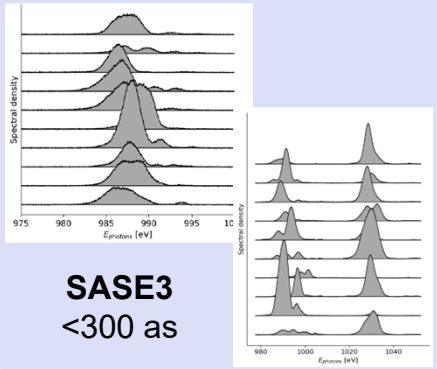
Going beyond standard operation

Hard X-ray Self-seeding (SASE2)

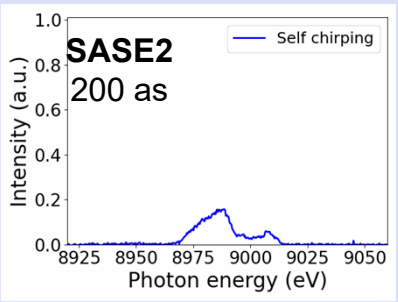


~50% of User time

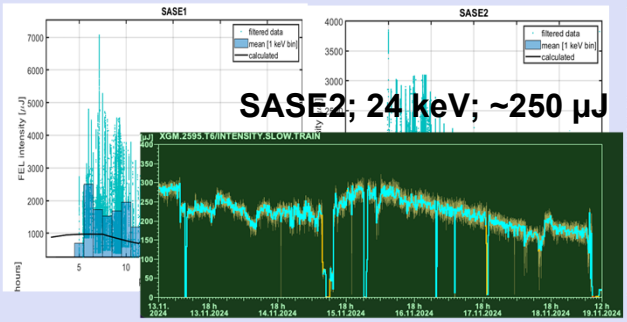
Attosecond pulse delivery (SASE3 & SASE2)



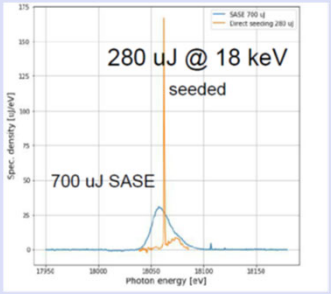
SASE3
<300 as



High photon energy X-ray FEL operation (SA2)



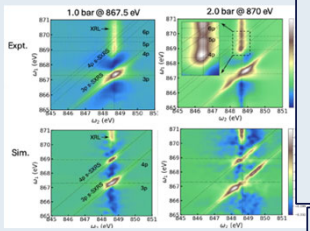
HXRSS



Enabling very high FEL beam power (SASE3)

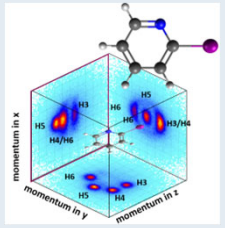
Scientific applications

Super-resolution Stimulated X ray Raman Spectroscopy



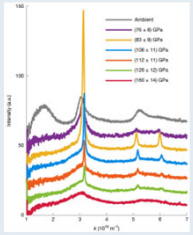
Li Nature

Imaging collective quantum fluctuations of the structure of a complex molecule

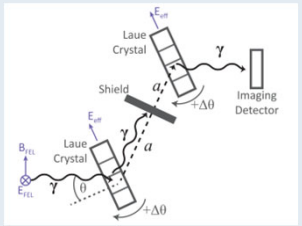


Richard Science

The structure of liquid carbon elucidated by in-situ X-ray Diffraction

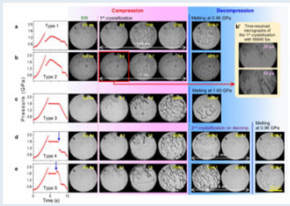


Bounds on heavy axions with a X-ray Free Electron Laser



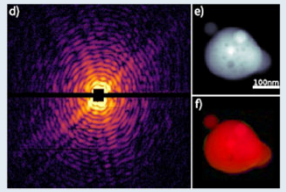
Halliday Phys. Rev. Lett.

Multiple freezing-melting pathways of high density ice at room temperature



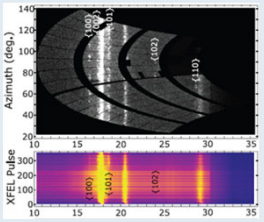
Lee Nat. Materials

SPRING, an effective and reliable framework for image reconstruction in single particle CDI



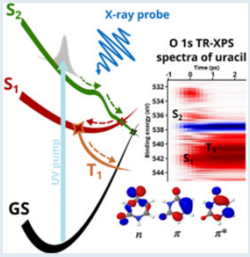
Colombo npj Comp. Mat.

Synthesis of Gold Hydride at High Pressure and High Temperature



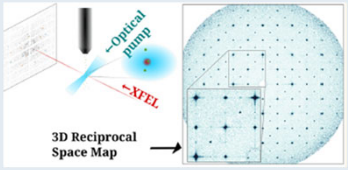
Frost Angew. Chem. Int. Ed.

Unraveling the relaxation dynamics of Uracil



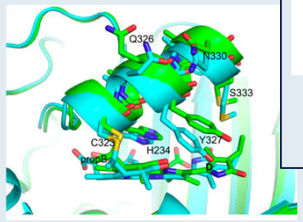
Faccialà JACS

Direct observation of the exciton-polaron in single $CsPbBr_3$ quantum dots



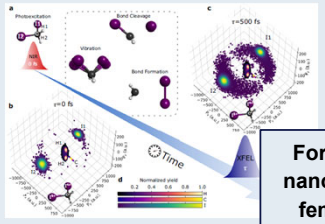
Shen ACS Nano

Pr and Pfr structures of plant phytochrome A



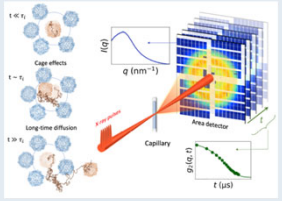
Nagano Nat. Comm.

Imaging a light-induced molecular elimination reaction with an XFEL



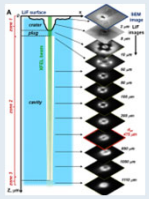
Li Nat. Comm

Coherent X-rays reveal anomalous molecular diffusio and cage effects in crowded protein solutions



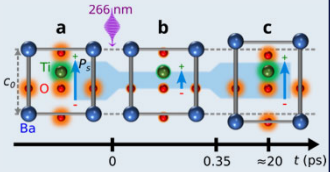
Girelli Nat. Comm.

Formation of nanocavity in femtosecon



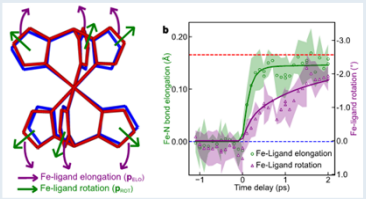
Makarov Nat. Comm.

Ultrafast decoupling of polarization and strain in ferroelectric BaTiO3



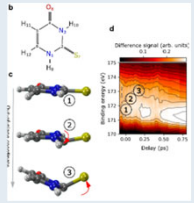
Hoang Nat. Comm.

Capturing the ultrafast dynamics with atomic resolution in spin-crossover materials



Vinci Nat. Comm.

Direct observation of ultrafast symmetry reduction during internal conversion of 2-thiouracil

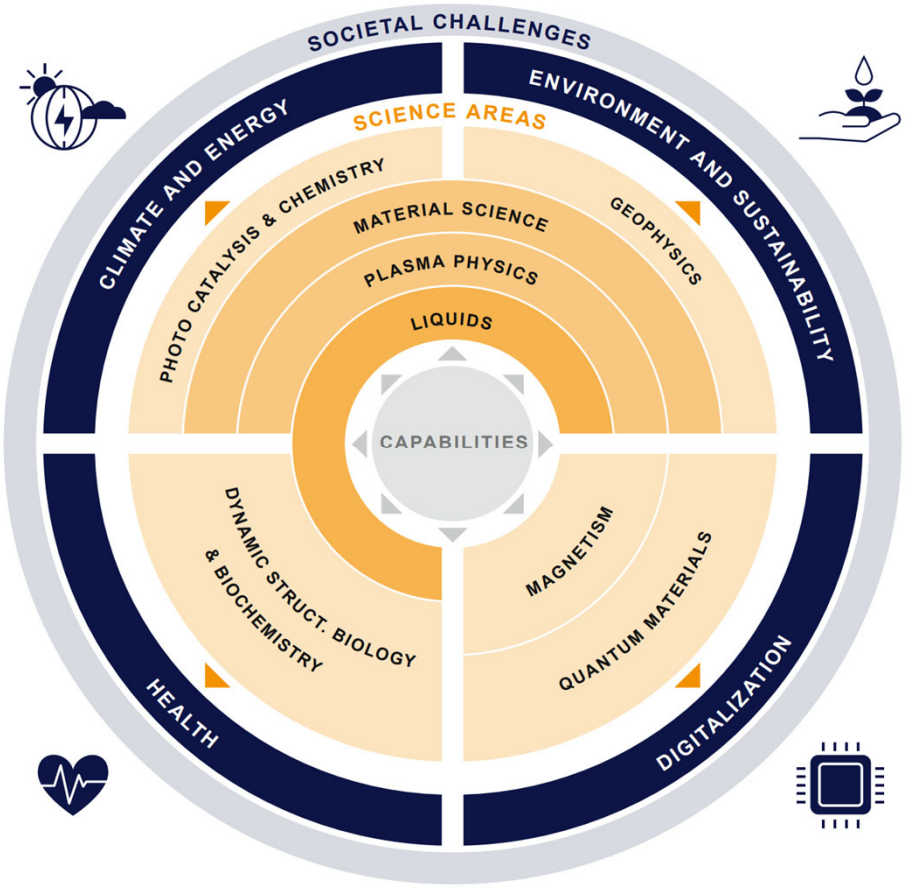


Jahnke Nat. Comm.

European XFEL

European XFEL contributing to societal challenges

- Major impact to:
  - **Climate & Energy**
    - ► Photo-chemistry
    - ► Materials
  - **Environment & Sustainability**
    - ► Materials
    - ► Geophysics
  - **Health**
    - ► Structural biology
    - ► Biochemistry
  - **Digitalization**
    - ► Complex materials
    - ► Quantum materials
- Largely through basic research efforts



To many more years of fantastic collaboration, ‘little sister’ !

Thank you for your attention