HED/HIBEF satelllite meeting – WELCOME!

Ulf Zastrau
Leading scientist
Group leader of HED science instrument

European XFEL – Jan 24, 2023

Today‘s meeting

Date			
13:00	Welcome	U. Zastrau	European XFEL
13:10	Special modes of operation at SASE2	G. Geloni	European XFEL
13:40	The Climate, Astro- & Geo- Pillar in the Centre for Molecular Water Science (CMWS)	G. Gruebel	European XFEL
14:00	The operational report on the HiBEF lasers	T.Toncian	HZDR
14:20	Study of ionization dynamics in relativistic laser plasmas using XFEL	M. Mishchenko	European XFEL
14:40	Coffee break		
15:10	Pulsed laser heating combined with MHz X-ray diffraction to study partial melting in Diamond Anvil Cell	G. Morard	ISTerre, UGA
15:30	X-ray emission spectroscopy from diamond anvil cells at HED	J. Kaa	TU Dortmund
15:50	X-ray fluorescence from solid density plasmas heated by the European XFEL	G. Williams	IPFN
16:10	Status of the HIBEF UC	T. Cowan	HZDR
16:30	Open discussion		

- Join us for food & drinks & discussions in the foyer

Unique capabilities arise when:

Couple XFEL beam to powerful drivers

- Diamond Anvil Cells HiBEF
  dynamic DAC; pulsed laser heated DAC; double-stage DAC
- Powerful optical lasers
  100 J 15 ns 10 Hz (DiPOLE); 400 TW 30 fs 10 Hz (ReLaX) HiBEF
  0.2 – 2 J 15 fs 800 nm 1 MHz; 1– 40 mJ 800 fs 1 MHz (pp-laser)
- XFEL split&delay line (2025) Bundesministerium für Bildung und Forschung
  x-ray pump-probe, 0-20 ps delay
- 60 T pulsed magnetic field coil (2023) HiBEF
  cryogenic sample environment

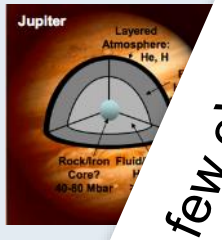
HED – research at extremes

high density $\rho > \rho_0$, T < few eV

solid density $\rho = \rho_0$, T up to keV

Laser Compression

Shock & ramp compr



XRD, IX

Long-p laser

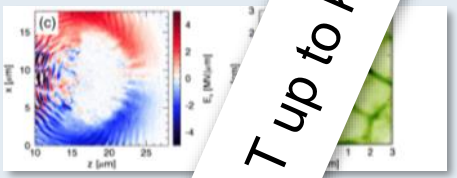
Relativistic Laser-Plasmas

Electron transpo

Instabilities and filam

Particle acceler

High EM fi



Multi-10 laser

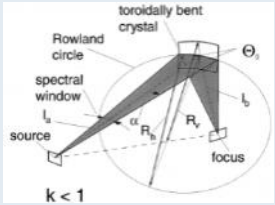
Advanced methods

Spectrometers

Advanced focusing

SAXS energy analyzer

Phase contrast imaging



Diam vil Cells

Fast piezo DAC

Puls heated DAC

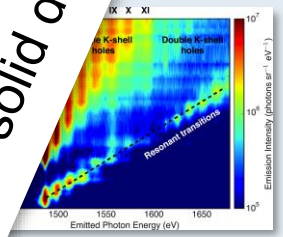
stage DAC

18 to 25 keV

Isochor excitation

Tra roperties,

H oms, rates



XES, IXS, XRD

Tight focusing

Further projects

Isobaric heating

Cryogenic jet targets

High-rep solids targets

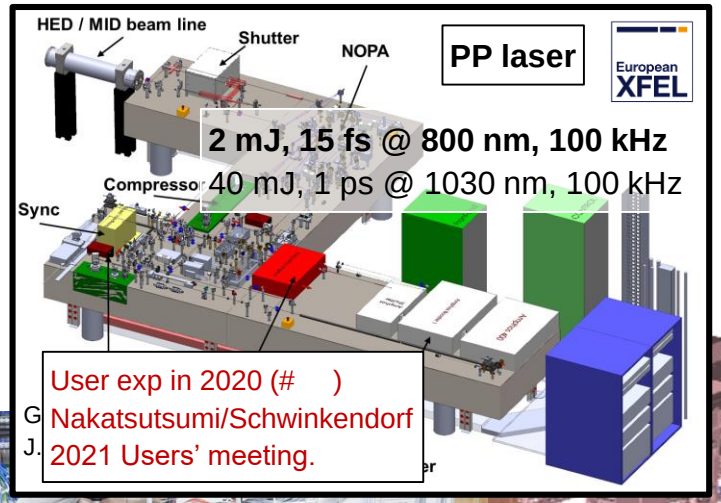
EMP-hard X-ray detectors

High-purity polarimetry

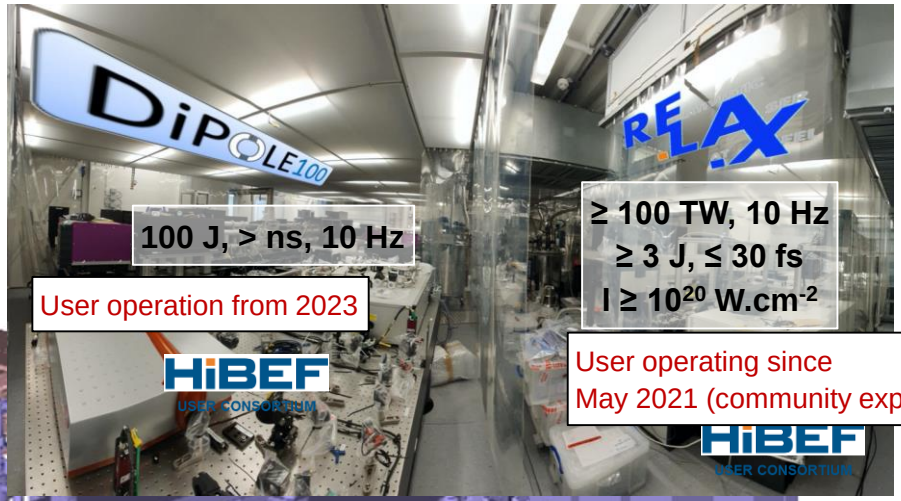
Laser-shocked DAC

GISAXS

High-energy-density (HED) instrument – large vacuum sample interaction chambers (IC1 & IC2) and many “drivers”



User exp in 2020 (#)
Nakatsutsumi/Schwinkendorf
2021 Users’ meeting.



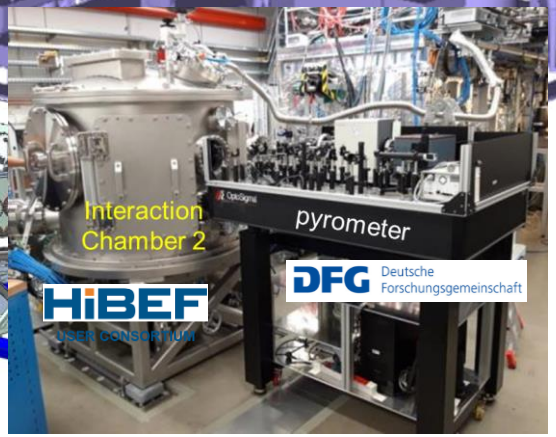
100 J, > ns, 10 Hz

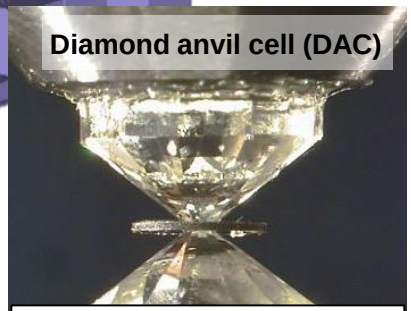
User operation from 2023

≥ 100 TW, 10 Hz
≥ 3 J, ≤ 30 fs
I ≥ 10^{20} W.cm^{-2}

User operating since
May 2021 (community expt)

User exp in 2019 (#2180)
PI: D. Kraus
2019 Users’ meeting.





First user exp in 2019 (#2292)
PI: S. McWilliams
2020 Users’ meeting.

IC1

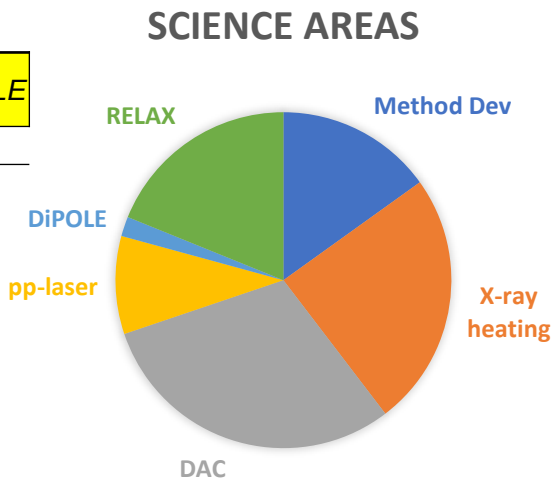
X-ray

European XFEL

Statistics

- PRP-reviewed proposals

Call	closed	Submitted proposals	allocation	Executed proposals	*Method Dev*	*X-ray heating*	*DAC*	*pp-laser*	*RELAX*	*DiPOLE*
10	Dec 2022	31	2023-II	**…**						
9	June 2022	33	2023-I	**9**	*1*	*1*	*4*	*0*	*2*	*1*
8	Dec 2021	27	2022-II	**8**		*2*	*3*	*1*	*2*	
			2022-I	**12**		*3*	*3*	*1*	*5*	
7	Dec 2020	27	2021-II	**7**	*1*	*1*	*4*	*1*		
			2021-I	**2**		*1*			*1*	
6	Dec 2019	14	2020-II	**2**		*1*		*1*		
5	June 2019	10	2020-I	**5**	*2*	*2*		*1*		
4	Dec 2018	13	2019-II	**5**	*2*	*1*	*2*			
3	June 2018	11	2019-I	**3**	*2*	*1*				



- Students at HED
  - **2** finished M.Sc. (Kaa, Wolenweber)
  - **4** finished PhDs (Biedermann, Banjafar, Plückthun, Schölmerich)
  - **6** ongoing PhDs
    - ► Wollenweber (-11/2023) high-resolution IXS
    - ► Kaa (-8/2023) XRD, IXS from Fe in DAC
    - ► Buakor (-3/2024) Minerals in shock compression
    - ► Dwivedi (-4/2024) shocked DAC
    - ► Mishchenko (-3/2024) Ionization in relativistic plasmas
    - ► Habibi (-2023) Simulations of relativistic transparency

New Colleagues

- **Valerio Cerantola** left us in July 2022,
  he is now an assistant professor in Mineralogy at the University of Milano-Bicocca

Two new instrument scientists joined us in 2022:

- **Lisa Randolph** (from U Siegen)
- **Oliver Humphries** (from HZDR)

HIBEF HZDR hired one more electric engineer:

- **Björn Näser**

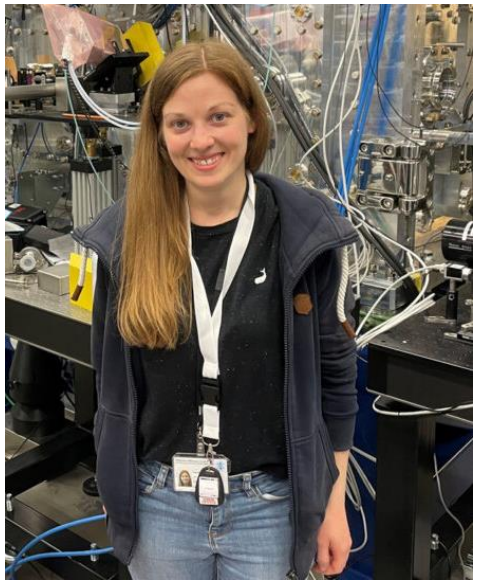


Photo copyright: European XFEL, publically availabe on the web.

Ten publications in 2022

Absolute photon power measurements at the European XFEL instruments
Grünert, Jan ; Freund, Wolfgang ; Liu, Jia ; Maltezopoulos, Theophilos[...]
Journal of Physics: Conference Series (2380), 012083 (2022)
10.1088/1742-6596/2380/1/012083

EuXFEL data

Direct LiF imaging diagnostics on refractive X-ray focusing at the EuXFEL High Energy Density instrument
Makarov, Sergey ; Makita, Mikako ; Nakatsutsumi, Motoaki ; Pikuz, Tatiana[...]
Journal of Synchrotron Radiation, 30 (1), 1-9 (2022)
10.1107/S1600577522006245

EuXFEL data

Electron Dynamics at High-Energy Densities in Nickel from Non-linear Resonant X-ray Absorption Spectra
Engel , Robin Y. ; Alexander, Oliver ; Atak, Kaan ; Bovensiepen, Uwe[...]
10.48550/arXiv.2211.17008

Absolute keV x-ray yield and conversion efficiency in over dense Si sub-petawatt laser plasma
Ryazantsev, Sergey N. ; Martynenko, Artem S. ; Sedov, Maksim V. ; Skobelev, Igor Yu[...]
Plasma Physics and Controlled Fusion, 64 (10), 105016 (2022)
10.1088/1361-6587/ac8b33

Nanoscale subsurface dynamics of solids upon high-intensity femtosecond laser irradiation observed by grazing-incidence x-ray scattering
Randolph, Lisa ; Banjafar, Mohammadreza ; Preston, Thomas R. ; Yabuuchi, Toshinori[...]
Physical Review Research, 4 (3), 033038 (2022)
10.1103/PhysRevResearch.4.033038

Structural and electron spin state changes in an x-ray heated iron carbonate system at the Earth's lower mantle pressures
Kaa, Johannes M. ; Sternemann, Christian ; Appel, Karen ; Cerantola, Valerio[...]
Physical Review Research, 4 (3), 033042 (2022)
10.1103/PhysRevResearch.4.033042

EuXFEL data

Electron-Ion Temperature Relaxation in Warm Dense Hydrogen Observed With Picosecond Resolved X-Ray Scattering
Fletcher, L. B. ; Vorberger, J. ; Schumaker, W. ; Ruyer, C.[...]
Frontiers in Physics, 10 (2022)
10.3389/fphy.2022.838524

Off-harmonic optical probing of high intensity laser plasma expansion dynamics in solid density hydrogen jets
Bernert, Constantin ; Assenbaum, Stefan ; Brack, Florian-Emanuel ; Cowan, Thomas E.[...]
Scientific Reports, 12 (1), 7287 (2022)
10.1038/s41598-022-10797-6

Towards perfectly linearly polarized x-rays
Schulze, Kai S. ; Grabiger, Benjamin ; Loetzsch, Robert ; Marx-Glowna, Berit[...]
Physical Review Research, 4 (1), 013220 (2022)
10.1103/PhysRevResearch.4.013220

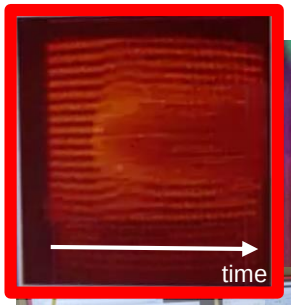
EuXFEL data

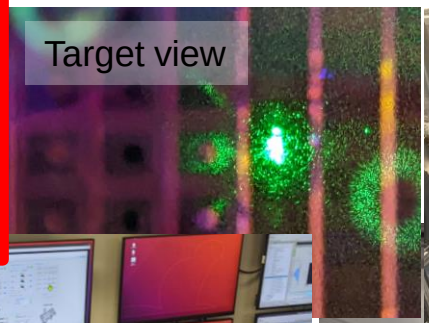
In situ x-ray diffraction study of dynamically compressed α -cristobalite using a dynamic diamond anvil cell
Schoelmerich, M. O. ; Mendez, A. S. J. ; Plueckthun, C. ; Biedermann, N.[...]
Physical Review B, 105 (6), 064109 (2022)
10.1103/PhysRevB.105.064109

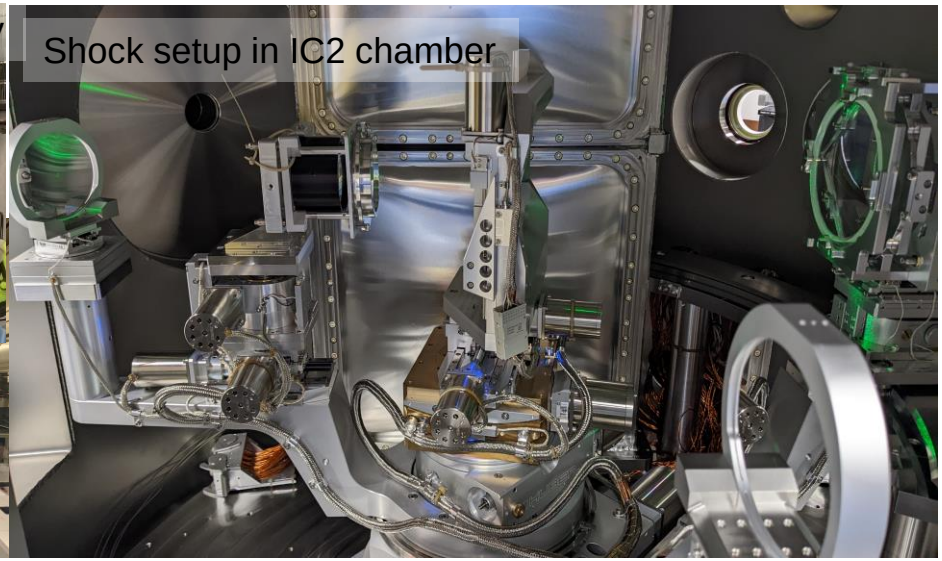
Successful first shots at the dynamic shock platform at HED/HiBEF combining DIPOLE-100X laser with Interaction chamber 2 and VISAR diagnostic

Many thanks: E. Brambrink, A. Pelka, H. Höppner, C. Strohm, M. Röpert, M. Tang, S. Di Dio Cafiso, M. Hassan, M. Masruri, M. Toncian, T. Toncian, J. Philips, P. Mason, T. Butcher and many more from DESY, HZDR, LULI, CLF and EuXFEL

23.11 VISAR trace of shock compressed Al by a 28 J 515 nm 10 ns square pulse

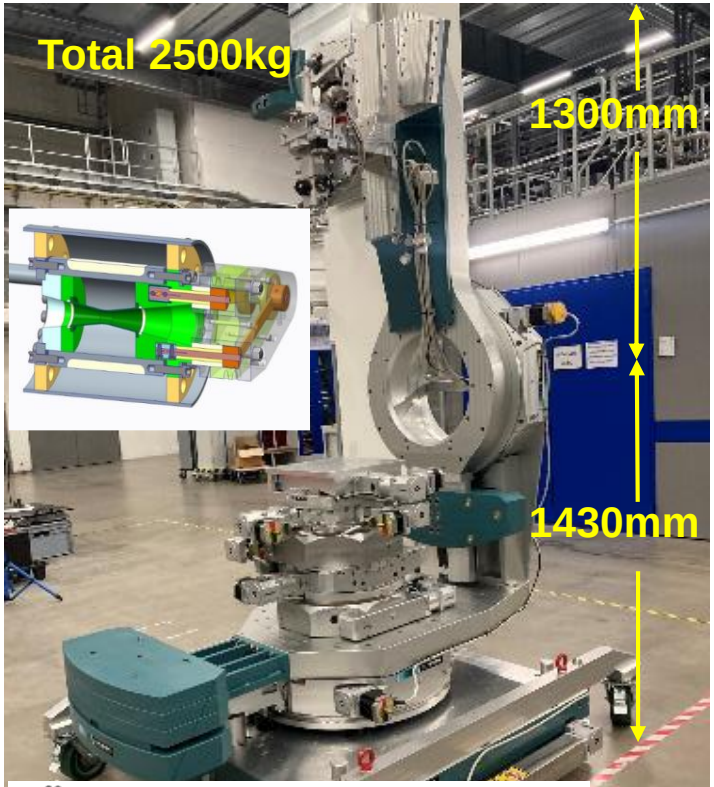


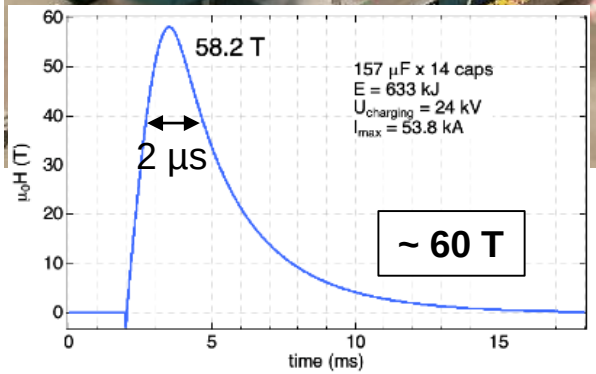




Pulsed magnetic field (PMF)

Spokesperson: T. E. Cowan (HZDR, HIBEF)





Scientific questions

- emergence of superconductivity from the ground state
- frustration and novel magnetic states of matter
- interplay between magnetic order and strcutural symmetries
- electronic structure of strongly correlated materials

Unique facility

- aim at highest non-destructive fields available at X-ray source
- ability to record field dependencies by matching ms rise time of coils with 550 µs Eu.XFEL pulse train and AGIPD MHz detector
- diffraction: 12keV to 30 keV
- resonant scattering, absorption, and dichroism 5 keV to 15 keV (3d K-edges to 4f and 5d L-edges).

Status and plan

- heavy load diffractometer: delivered
- magnets: testing (coils) successful, integration (cryostat) ongoing
- onsite construction work ongoing (F90 enclosure ‘pulser room’)
- installation (pulser) starts Q4 2022
- installation (magnet and cryostat) 2023
- test / commssioning from Q3/Q4 2023 onwards

Instrument papers

- General overview of the HED instrument
  - Zastrau, Appel, Baehtz et al., J. Synchrotron Rad. (2021). 28, 1393–1416
- Details and performance of the HAPG von-Hamos spectrometers
  - Preston et al., Journal of Instrumentation, Volume 15 (2020)
- Design and performance of the meV high resolution setup
  - Wollenweber et al., Review of Scientific Instruments 92, 013101 (2021)
- The experimental platform for XRD from Diamond Anvil Cells
  - Liermann et al., J. Synchrotron Rad. (2021). 28, 688-706
- ReLaX: the HiBEF high-intensity short-pulse laser driver:
  - Laso Garcia et al., High Power Laser Science and Engineering, 1.5 (2021)
- Design and performance of the SAXS mirror:
  - Smid, Baehtz, Pelka et al., Review of Scientific Instruments 91, 123501 (2020)
- New frontiers in extreme conditions science at synchrotrons and free electron lasers
  - Cerantola et al., K. *Phys.: Condens. Matter* **33** 274003 (2021)