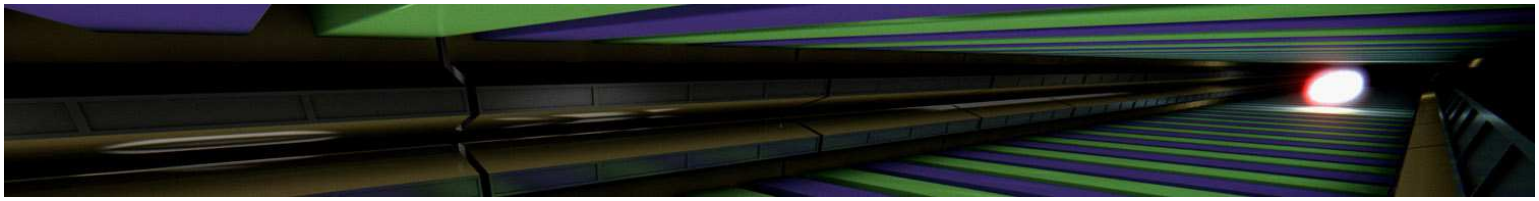


# update:
# HED science instrument
# (web version)

European XFEL Users' Meeting
January 28, 2015

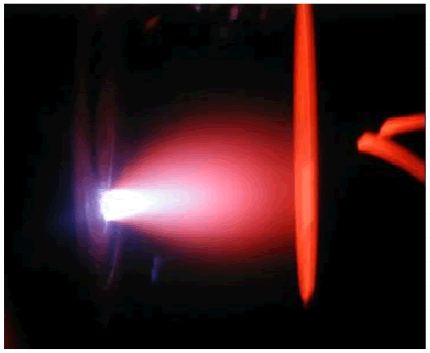
Thomas Tschentscher for HED
***thomas.tschentscher@xfel.eu***

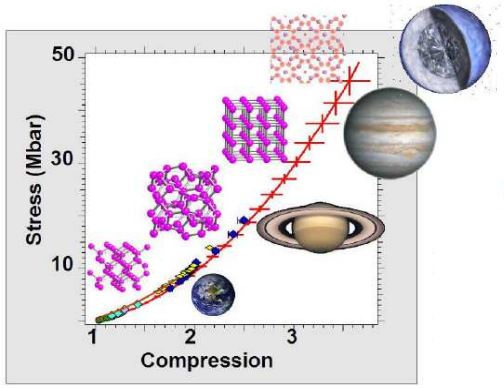
# High Energy Density Science – HED

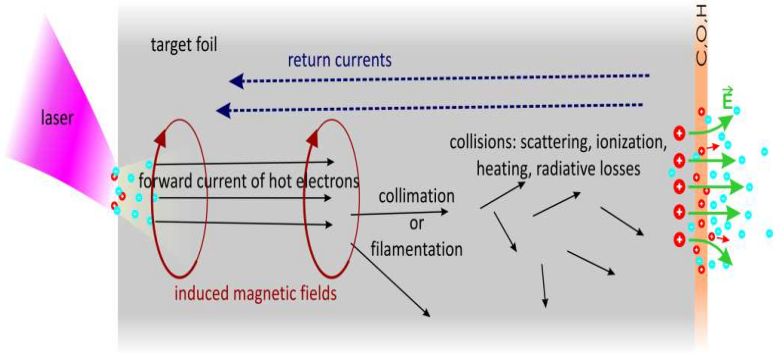


**Ultrafast dynamics and structural properties of matter at extreme states**

- Highly excited solids → laser processing, dynamic compression, high B-field
- Near-solid density plasmas → WDM, HDM, rel. laser-matter interaction
- Quantum states of matter → high field QED





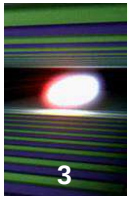

**Samples generated by pulsed excitation**

- Highly dynamic and often non-equilibrium
- Irreversible processes → sample refreshment required

**Combination of high excitation with various x-ray techniques**

- Use of various pump sources to excite samples (OL, XFEL, ext. fields)

# HED unique properties




**Integration of x-ray FEL with high power laser systems and pulsed high magnetic fields**

- 100 J, ns high-energy (HE) laser for dynamic compression *
- 4 J, 40 fs ultrahigh-intensity (UHI) laser for relativistic laser-matter interaction *
- 50 T, ~ms pulsed magnetic fields for condensed matter studies at high fields *

**Utilization of high repetition rates**

- Up to 4.5 MHz for non-destructive experiments
- Up to 10 Hz for destructive experiments

**Provision of dedicated scattering setups**

- Chamber for high energy laser-drive and various types x-ray scattering
- Setup for DAC (in air) diffraction *
- Setup for diffraction from specimen inside pulsed magnetic coil *



* external funding (HIBEF)

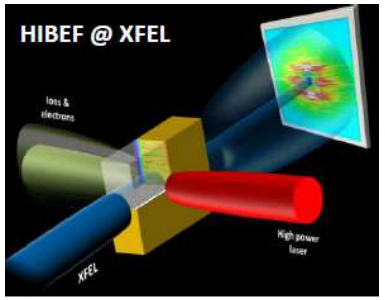
# Integration of HED and HIBEF UC



## Helmholtz International Beamline for Extreme Fields (HIBEF)

This User Consortium proposes to contribute critical instrumentation exceeding the baseline scope of the HED instrument. HIBEF is based on a wide community of users from

- → **plasma and high pressure physics**
- → **solid-state physics**
- → **material sciences**




The significant contributions are driven by the needs for the respective exps.

- → **high energy lasers – magnetic pulser – DAC and high B setups – spectrometer**
- → **many more have been mentioned**

## Integration

- supervised & coordinated by HED
- requires HIBEF staff to be integrated
- includes future operation

**HIBEF executive**

**Coordinator: C. Baehtz (HZDR)**

**Executive board:**

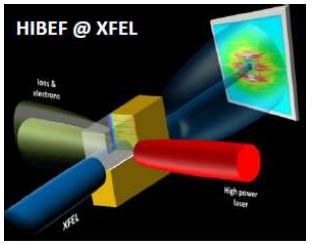
**T. Cowan (HZDR), R. Redmer (U Rostock), J. Wark (U Oxford), E. Weckert (DESY), NN**

# DIPOLE 100-X*



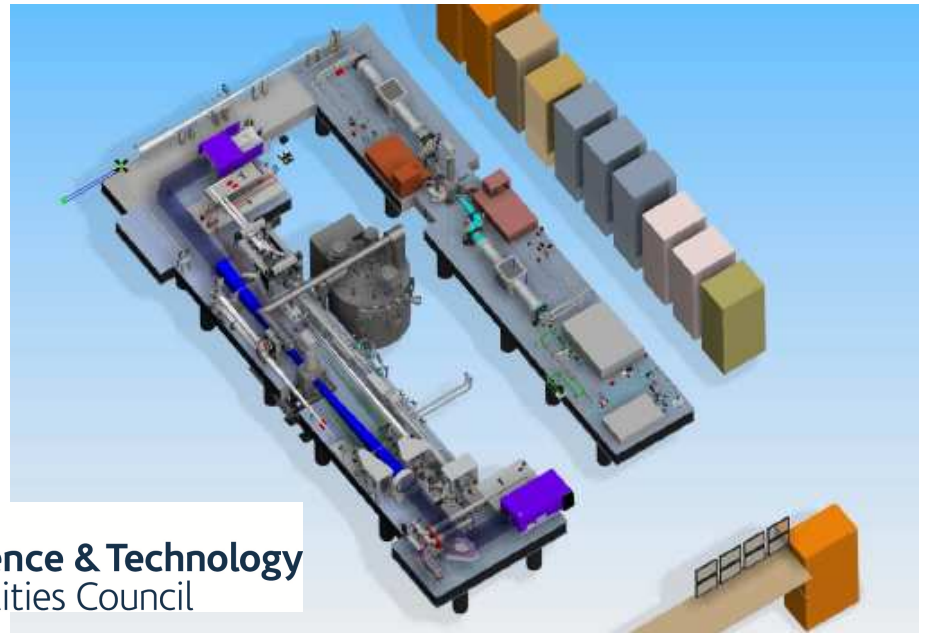
## UK contribution to HIBEF

- HE laser delivering ns pulses with ~100 J pulse energy
- Diode-pumped, cryogenic amplifier → 10 Hz capability
- Pulse-shaping capability




## Grants awarded by EPSRC and STFC to U Oxford and CLF

- Work has commenced in fall 2014
- Integration has started
- Ambitious developments ahead
  - → **Operational flexibility**
  - → **Pulse-shaping**
  - → **Frequency conversion**
  - → **Optical isolation**

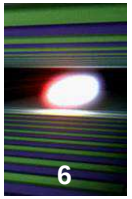


Science & Technology Facilities Council



* external funding (HIBEF)

# 2014 at HED




**Completed, reviewed and published Technical Design Report (TDR)**

- Reported at last UM, followed by User Workshop & HED-ART meeting
- XFEL.EU TR-2014-001; see www.xfel.eu/documents/technical_documents

**Civil construction of HED-EXP enclosure**

- Heavy concrete construction to enable use of ultrahigh intensity lasers

**Design of HED components**

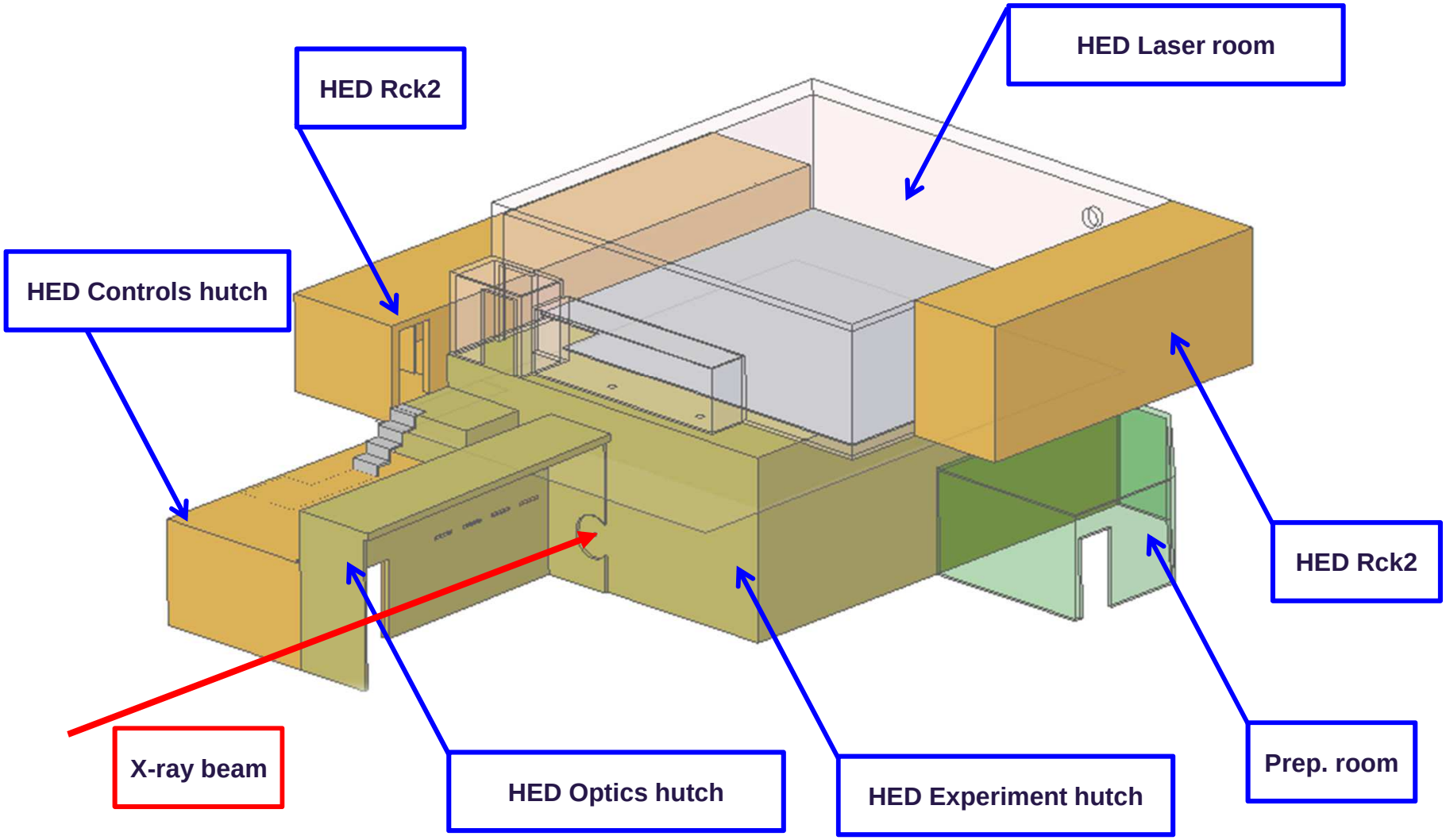
- X-ray beam delivery (attenuators, slits, CRLs → IKC by Denmark)
- Interaction chamber 1 (IA1) – main work horse
- Overall instrument layout
- Optical laser installations

**Continued definition of HIBEF User Consortium contributions**

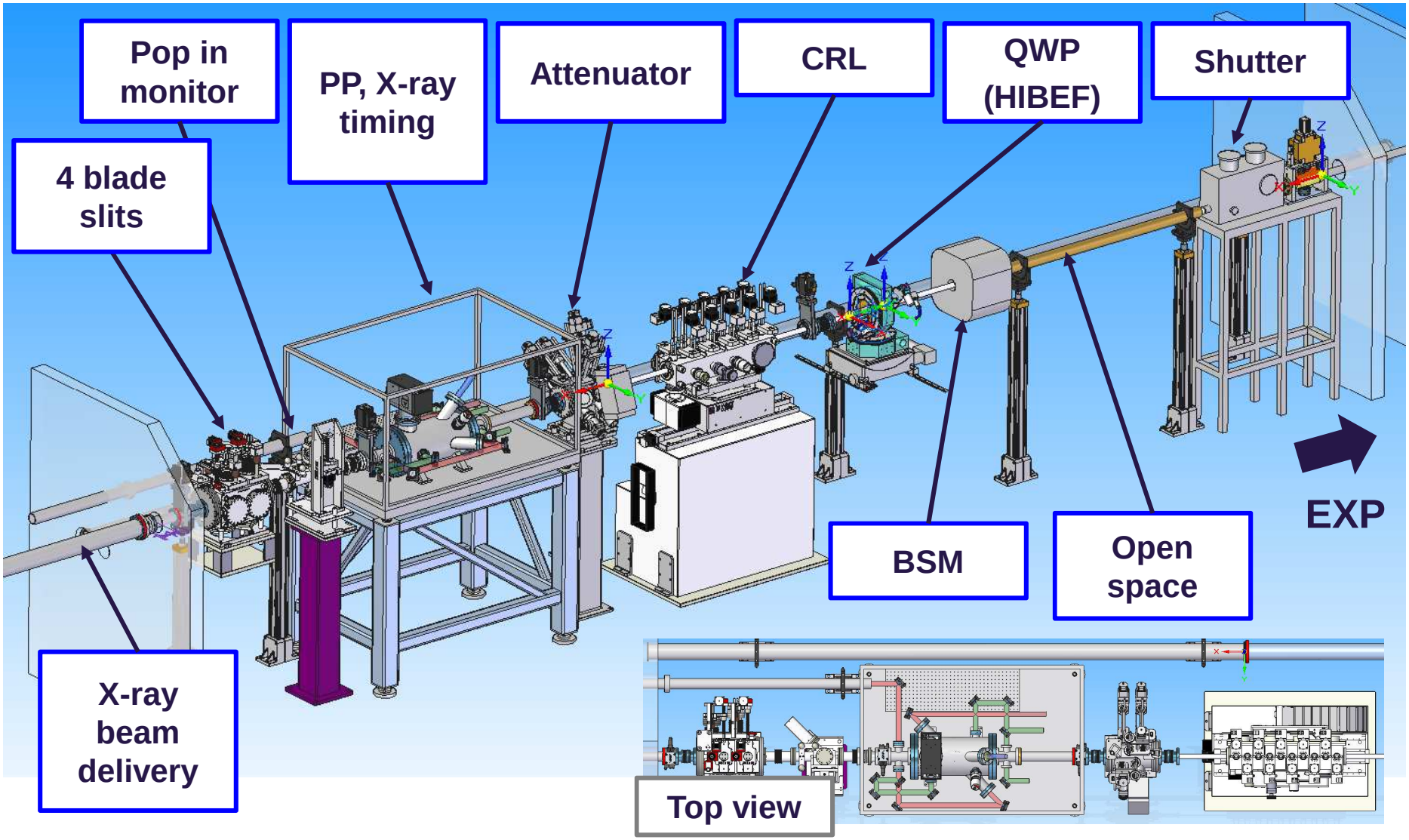
- Work on DIPOLE 100-X started
- Other contributions still under definition

# Refined HED model (3D)





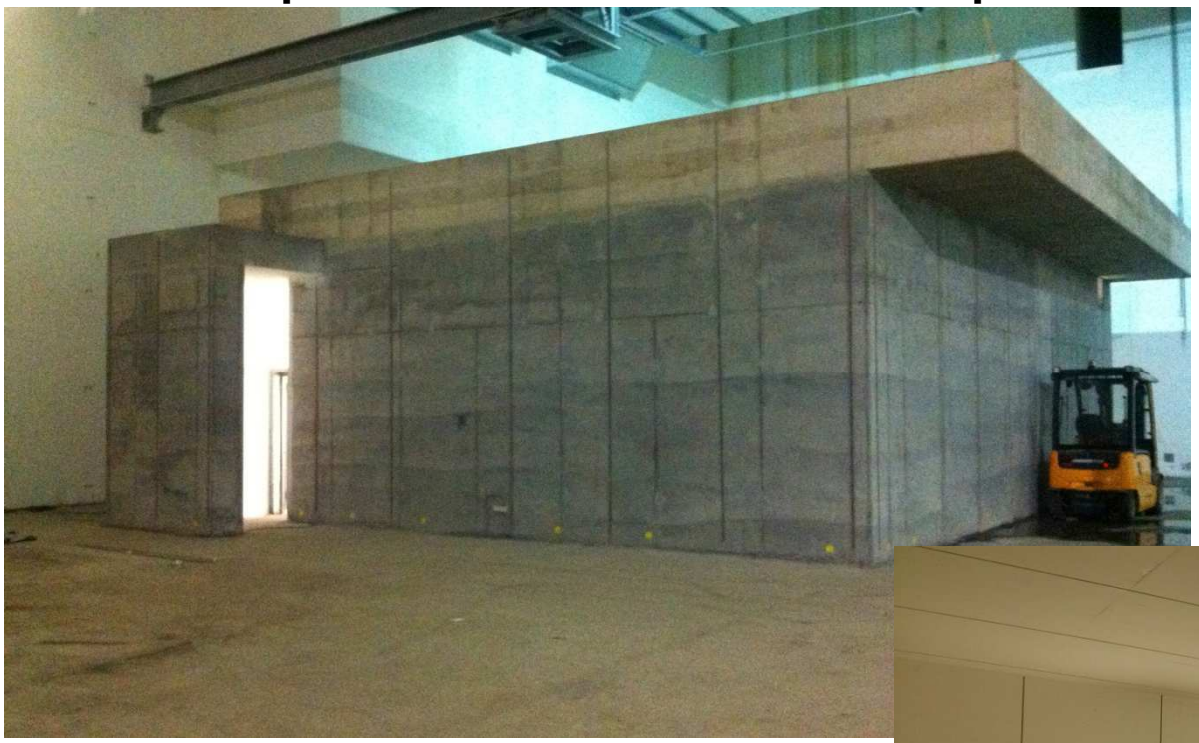
# X-ray optics hutch (HED-OPT)

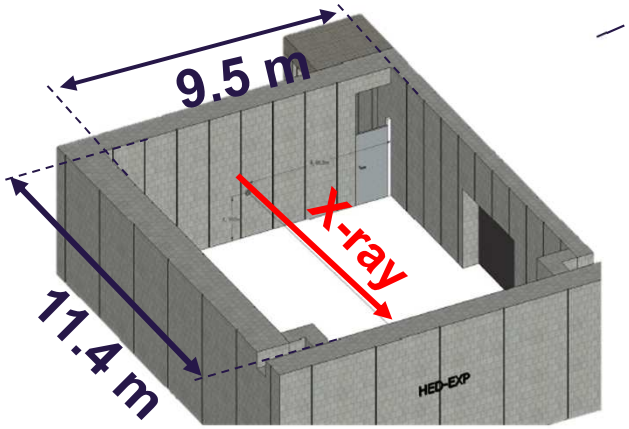


# HED-EXP



## HED experiments enclosure 95% completed



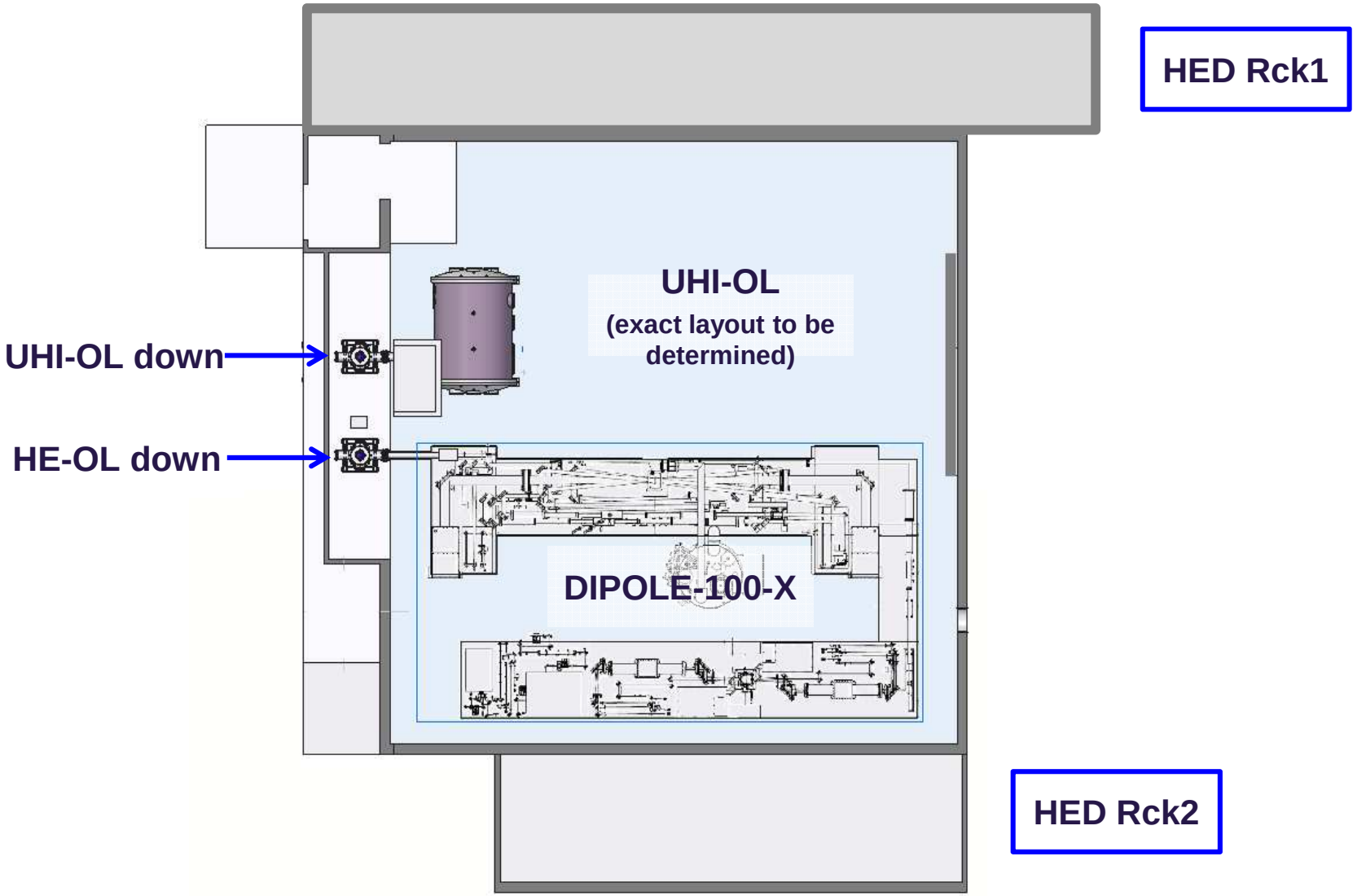



**To come:**

- crane
- chicanes

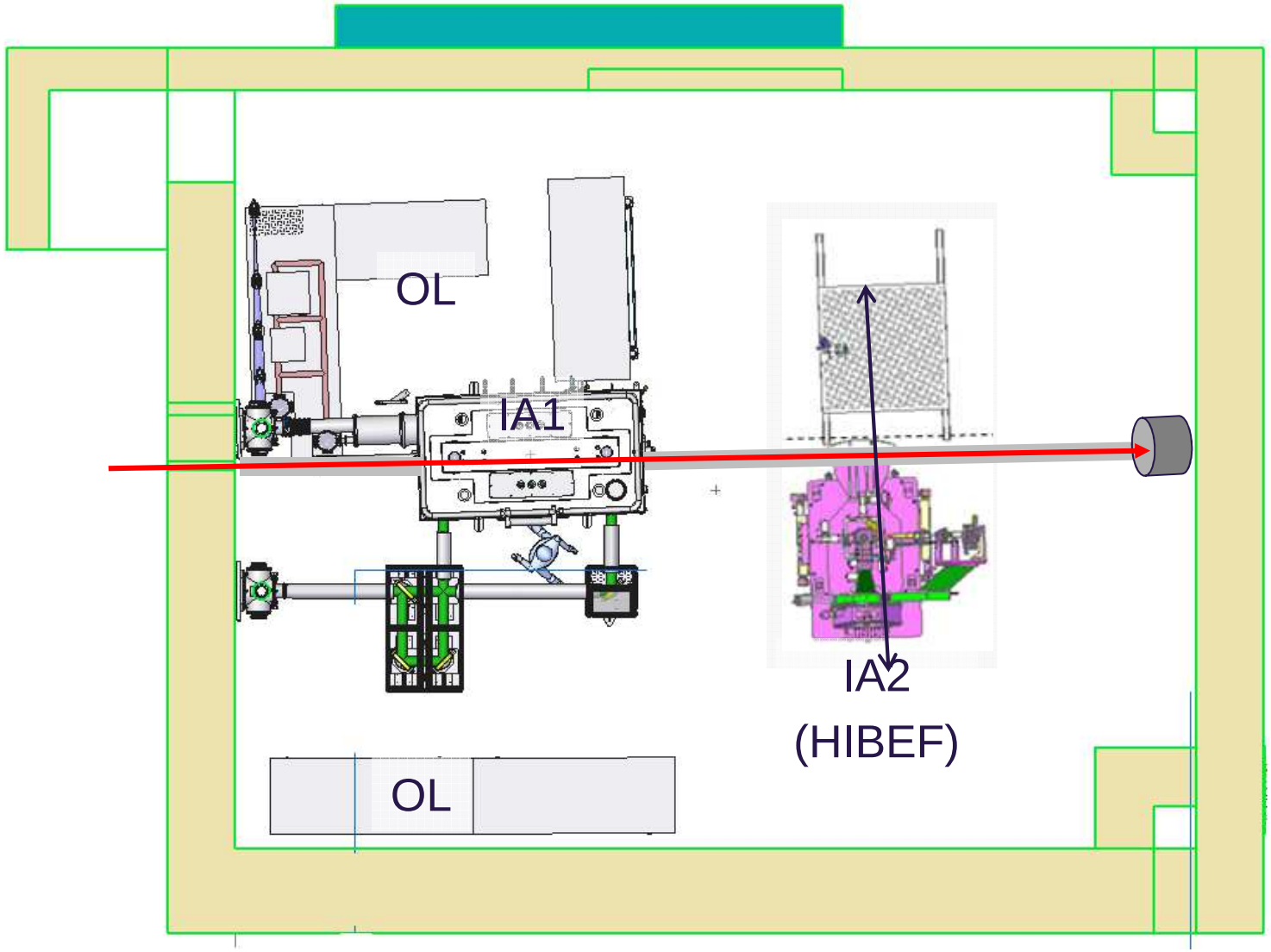
# HED-Laserroom (DIPOLE-100-X & UHI model)





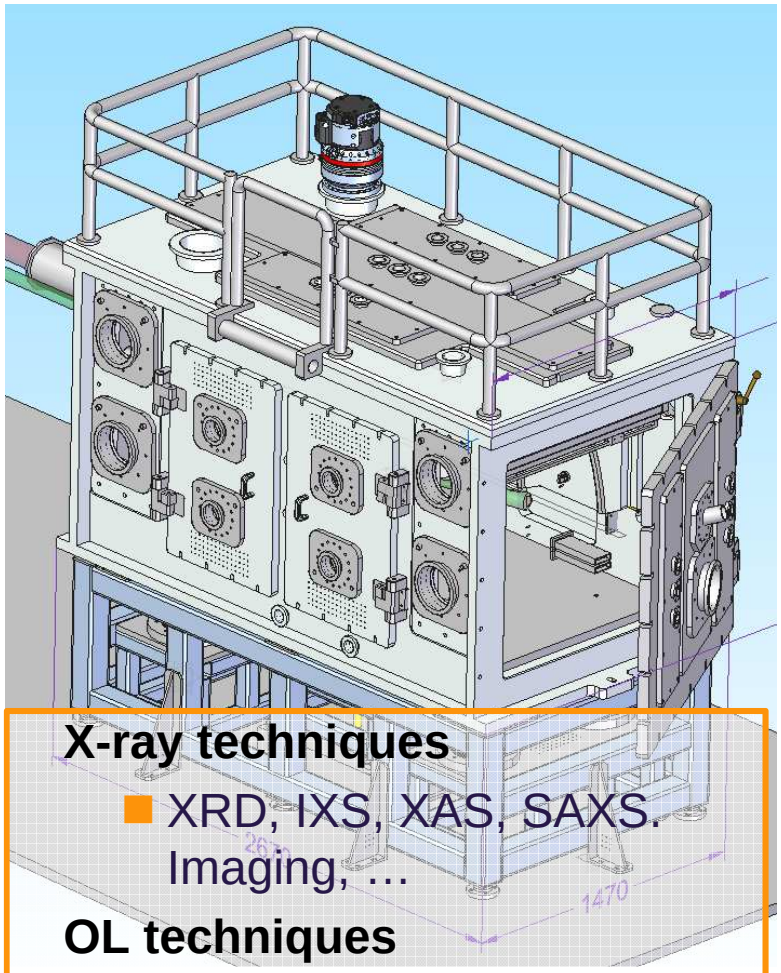
# HED experiment hutch





# Interaction chamber 1 (IA1)



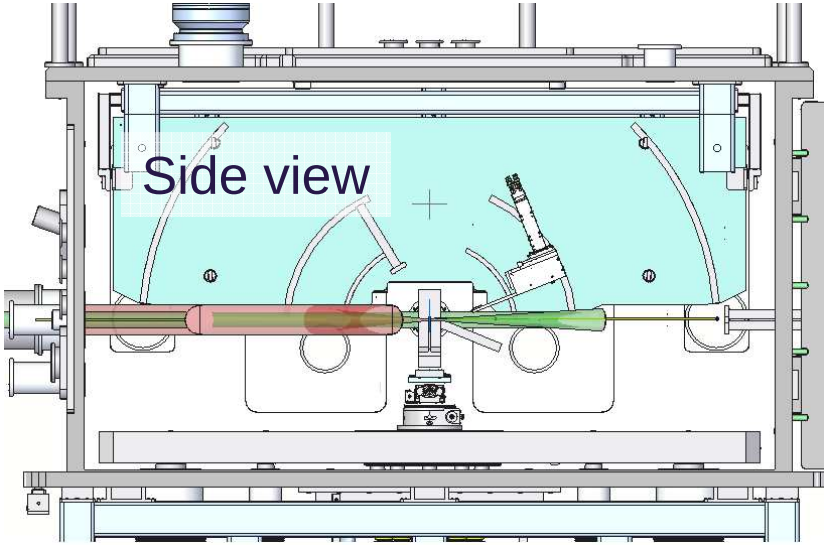


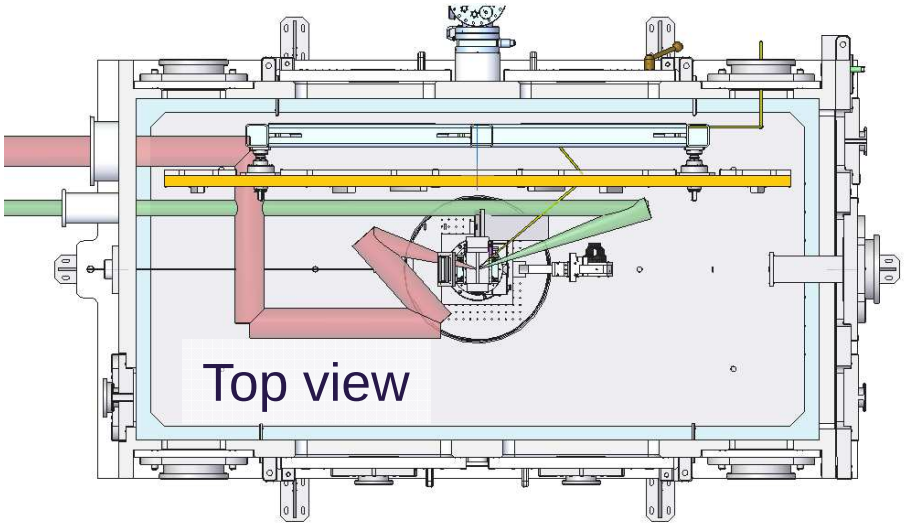
**X-ray techniques**

- XRD, IXS, XAS, SAXS. Imaging, …

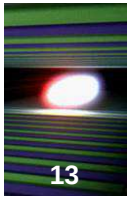
**OL techniques**

- VISAR, FDI, microscopy, …



# Area detector issues




**Several experimental techniques require (large) area detectors**

- Spectroscopy (XAS, IXS (hr, plasmon,Compton)) – 2D improves selectivity
- Imaging (Ptychography, PCI, Coh-Imaging) – distance requirements
- Diffraction (crystals, powders, liquids/amorphous) – Large θ angle coverage

⇒ **High expectation by user community**

**Specific issues**

- Forward scattering: detectors/windows vs. intense FEL beam
- Debris from sample expansion
- EMP from laser pulses

⇒ **Conflicting requirements**

# Forward diffraction experiments

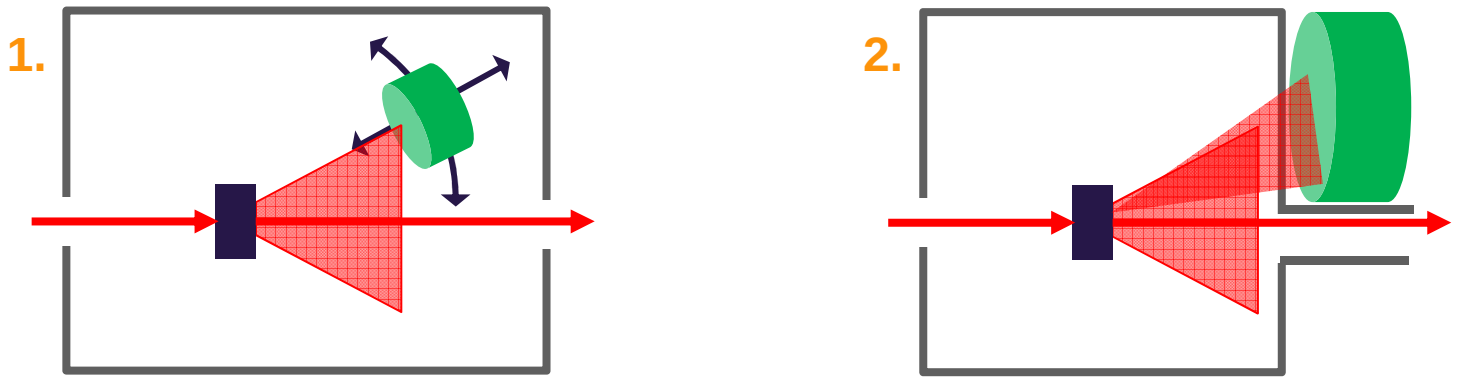


**Typical requirements (**for class of exps.**)**

- large area detectors
- close to the sample (scatterer) to provide max. coverage of θ angle/Q-space
- cover min. 90˚ , better 180˚ in φ (azimuthal angle)
- often mounted on x-ray axis to cover 360˚ in φ

**Two scenarios**

1. mount tile(s) in-vacuum → 1st priority
2. Put large area outside vacuum & off-axis → 2nd priority



# Area detector issues



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**Specific issues**

- Forward scattering: detectors/windows vs. intense FEL beam
- Debris from sample expansion
- EMP from laser pulses

⇒ **Conflicting requirements**

**Start of operations**

- Abandon idea to include large area, in-vacuum, full-reprate detector
- Place ‘smallish’ area detectors inside vacuum; EMP tested
- Continue search for possible large area detector solutions

# Concrete detector choices



## AGIPD

+ Full rep-rate capability
– Weight & complexity
– Pixel size (220 µm)

## Jungfrau

+ 1MHz/16-pulse capability
+ Pixel size (75 µm)
– Vacuum capability

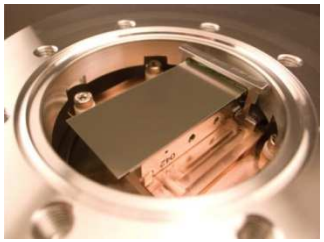
## MPCCD

+ Pixel size (50 µm)
+ EMP tests (SACLA)
– max 10 Hz rep rate
– red. dyn range
– red. sensitivity

| Para-meter | AGIPD | Jungfrau | MPCCD |
|---|---|---|---|
| **Sensor** | 500 µm Si | 500 µm Si | 300 µm Si |
| **Dyn. range** | 10^4 | 10^4 | 10^3 |
| **Noise** | ~300 $e^-$ | ~180 $e^-$ | ~300 $e^-$ |

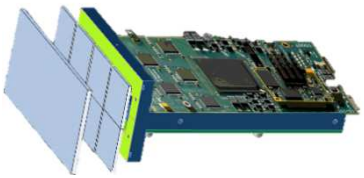
→ **a possible scenario:**

**MPCCD**



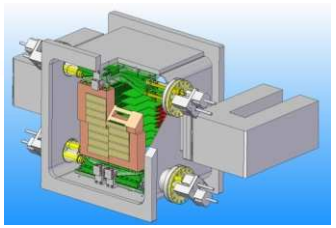
use in-vacuum

**Jungfrau**



large area
out of vacuum

**AGIPD**



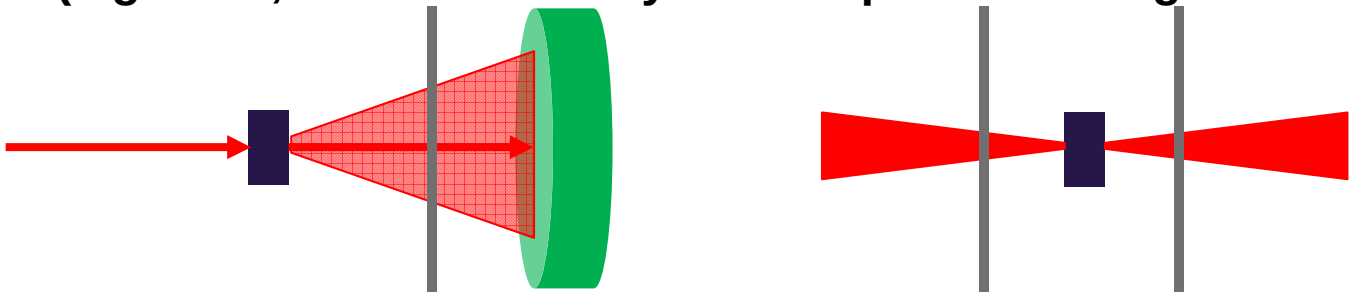
future extension

→ **in addition:** epix, large area scient. CCDs

# Damage issues – windows



**Several requests for experiments outside vacuum or in special environments (e.g. DAC, vacuum for very low temperatures: high B fields)**



⇒ **need to solve the issue of interaction with intense x-ray beam**

⇒ **Limits for min. beam size and/or max. pulse energy**

1. For experiments at repetition rates of 10 Hz (or less): absorbed dose needs to stay clearly below the dose enabling damage

   ➔ **Simulations (V. Lyamayev): 100 µJ for ∅ ~ 2 µm (for diamond & 20 keV)**

2. For experiments aiming at multiple pulses within (10 Hz) pulse train: absorbed energy needs to stay clearly below the energy required for melting or structural phase transitions

   ➔ **Simulations (V. Lyamayev) : on-going**

**In case of HE/UHI laser beam add. risks due to sample debris fragments**

# Early experiment program



**Available**

- X-ray beam (8 – 12 keV) – limited flexibility/parameters
- PP-OL
- X-ray transport/diagnostics (incl. x-ray-OL cross-correlation measurement)
- High magnetic fields and DAC setup

**Not available**

- Large laser systems (HE-OL & UHI-OL) still under installation/commissioning

**First experiments**

- X-ray-matter interactions
  - ➔ **Probed by x-ray (self-)scattering, x-ray emission, OL techniques**
- fs-mJ // 100 mJ-ps OL excitation
  - ➔ **Probed by x-ray scattering**
- Solids in high magnetic fields & at high P-T (DAC)
  - ➔ **Probed by x-ray scattering**

# Next steps & Conclusion


**Time to 1st x-ray beam is little more than 2 years**

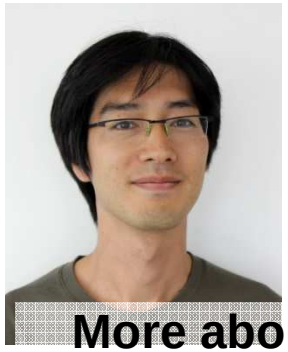
- Rooms and infrastructure will be completed 2016
- X-ray delivery systems will be available 2016
- First x-rays during 1st half 2017
- Early user experiments to start in fall 2017
- Optical lasers systems will become available during 2017
  - → **PP-OL: ~summer 2017**
  - → **HE-OL: ~end 2017**
  - → **UHI-OL: 2018**

⇒**HED instrument will be available in time for first x-rays**

⇒**First experiments probably using x-rays only and PP-OL**

# The HED team *plus*




Motoaki Nakatsutsumi


Karen Appel


Ian Thorpe


Gerd Priebe (OL)

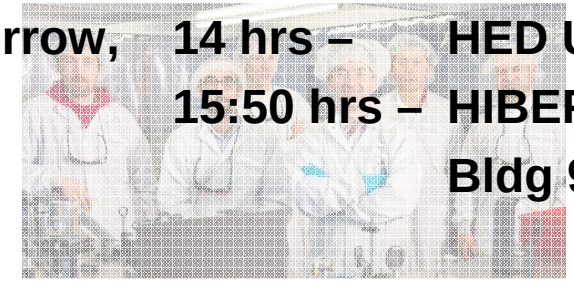

Alexander Pelka (HZDR)

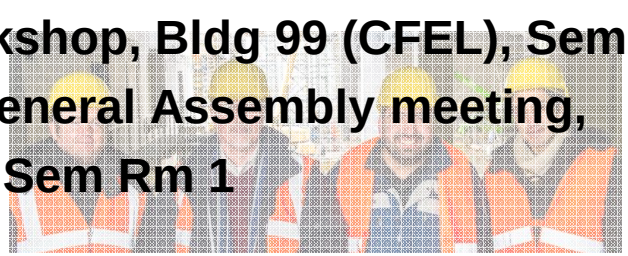

Andreas Schmidt

**More about the HED instrument during this meeting:**

**Tomorrow, 14 hrs – HED Users Workshop, Bldg 99 (CFEL), Sem Rm 1**

**15:50 hrs – HIBEF User & General Assembly meeting, Bldg 99 (CFEL), Sem Rm 1**


Laser group
Gerd Priebe, Guido Palmer & Max Lederer


CIE team
Antonios Lalechos, Osama, Viktor Lyamayev & Wolfgang Tscheu

**Friday, 14:30 hrs – Postersession, FLASH2 hall**

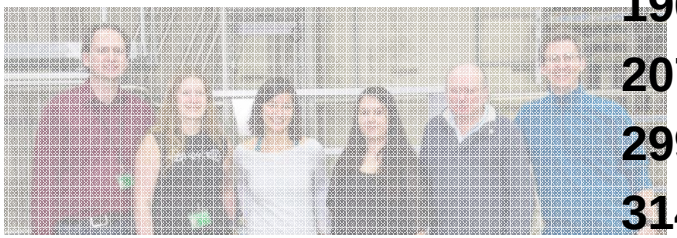
**196 – The HED instrument**

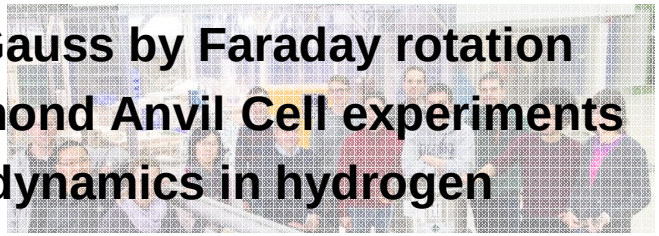
**207 – Observing MGauss by Faraday rotation**

**299 – Dynamic Diamond Anvil Cell experiments**

**314 – Equilibration dynamics in hydrogen**

**… and probably more**


Sample environment group
Joachim Schulz, Carsten Deiter, James Moore


XROBT group
Harald Sinn, Fan Yang, Martin Dommach