New perspectives for research of matter at extreme conditions : the high-energy density instrument at the European XFEL.

K. Appel[1], M. Nakatsutsumi[1], A. Pelka[2], G. Priebe[1], I. Thorpe[1], Th. Tschentscher[1]
[1]*European XFEL, Albert-Einstein-Ring 19, 22761 Hamburg, GERMANY*
[2]*Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, GERMANY*

ABSTRACT.

Free-electron lasers (FELs) produce extremely intense, coherent and ultrashort pulses of light. Due to these properties, FELs can be used to investigate electronic and structural properties of short lived systems at very high spatial and temporal resolution and thus open up completely new scientific applications. From 2017 onwards, the European **X**-ray **F**ree **E**lectron **L**aser (XFEL) in Hamburg, Germany will provide hard and soft X-ray FEL radiation [1]. This facility will be operated as a user facility providing access to a wide user community.
The High-Energy Density science instrument (HED) is one of the six baseline instruments at the European XFEL. It is dedicated to the study of dense and highly driven matter. For such excitation either the FEL, various types of optical lasers (OLs) or pulsed magnetic fields will be available. Located on the SASE2 FEL undulator, hard X-rays with energies between 5 and 25 keV, a photon flux of about 10^{12} photons/pulse at 12 keV photon energy, a pulse duration of 2 - 100 fs and a repetition rate of up to 4.5 MHz will be available for experiments.
The HED instrument is currently in its technical design phase [2]. First user experiments are foreseen for 2017. The X-ray beam transport at HED is based on the use of mirrors, compound refractive Be lenses and crystal monochromators. X-ray beam sizes on the sample will range from few μm to 200 μm. The relative energy resolutions can be chosen to be $\sim 10^{-3}$, 10^{-4} or 10^{-6}. A hard X-ray split-and-delay unit will provide a sequence of two X-ray pulses to excite and probe a sample with delays between the pulses of up to 23 - 2 ps in the energy range of 5 – 20 keV, respectively [3].
Three OL systems are planned at the HED instrument for driving samples into extreme states. A high-repetition rate system, matching the X-ray delivery pattern, can provide up to 100 mJ pulse energies. A 10 Hz 100 TW-class ultrahigh-intensity OL does reach focused intensities beyond 10^{19} W/cm^2, allowing the study of relativistic laser-matter interactions. For the studies of planetary matter, a 10 Hz 100 J class high-energy OL will be available. It is furthermore planned to provide magnetic fields with up to ~50 T for magnetic scattering experiments. The two high energy OLs and the pulsed magnet setup will be provided by the HIBEF user consortium [4]. The X-ray split-and-delay unit will be build by the University Münster (BMBF-05K10PM2 and -05K13PM1).
In this contribution, we discuss prototype hard-condensed matter experiments in the field of planetary research. These include optical laser induced quasi-isentropic (ramped) compression and shock compression experiments and diamond anvil cell experiments.

REFERENCES

[1] M. Altarelli, R. Brinkmann *et al.*, “The European XFEL Technical Design Report” doi:10.3204/DESY_06-097 (2007).
[2] M. Nakatsutsumi, K. Appel *et al.*, “Technical design report : Scientific instrument High Energy Density Physics (HED)” XFEL:EU TR-2014-001, doi : 10.3204/XFEL.EU/TR-2014-001 (2014).
[3] S. Roling, L. Samoylova *et al.* “Design of an x-ray split and delay unit for the European XFEL,” Proceedings of SPIE8504, 850407 (2012).
[4] http://www.hzdr.de/db/Cms?pOid=35325&pNid=3214.