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Novel platform for high-pressure static and dynamic X-ray diffraction experiments

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Recent developments in experimental techniques have significantly enlarged the possibilities of high-pressure crystallography: with the development of double-stage Diamond Anvil Cells (DACs), the structure of matter can now be studied statically at pressures beyond 1 TPa [1]. Ultrafast probes such as X-ray diffraction or X-ray absorption at modern light sources enable to study snapshots of states at a time resolution down to 100 ps at the synchrotron [2] or down to the few fs at Free-Electron-Lasers [3]. Nowadays, these probes can be combined with fast drivers such as dynamically driven DACs, laser shocks or pulsed-laser heated DACs. While the first two drivers enable measurements of pressure-induced phase transformations at different strain rates, the latter allows to study the properties of matter at extreme PT conditions.

A high number of X-ray photons per pulse and short pulse lengths are vital to obtain structural information on time scales of fast phase transitions. European XFEL, in Schenefeld, Germany is the first FEL in the hard X-ray regime. It will produce about 10E12 photons/pulse in the energy range between 5 and 25 keV at maximum repetition rates of 4.5 MHz. Due to the availability of the high photon energies, it will be the first FEL enabling XRD studies in DACs.

The High-Energy-Density science instrument (HED) at European XFEL is a new platform for shock wave experiments as well as novel high pressure static and dynamically driven DAC experiments. This will give us opportunity to study matter at high pressures at various strain rates and time scales. Thanks to the high flux and novel fast large area detectors we will be able to collect diffraction data in sub-second scale. Fast data collection will help us to avoid chemical reactions with the samples (e.g. in laser heated double stage DAC) and reach higher pressures before failure of the diamonds (e.g. in piezo driven DAC). HED is currently in its set-up phase and will come online to user operation by mid-2018.

In this contribution, we present the current state-of-the-art techniques in high-pressure crystallography and present the planned capabilities of European XFEL with focus on new perspectives. Finally, we will show ideas for first experiments.

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