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Time-resolved measurements at high pressures using diamond anvil cells

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Time-resolved and pump and probe experiments using pulsed-laser heating and the diamond anvil cell technique have recently shown that they can yield information on transport properties of matter [1] as well as they can create and probe warm dense matter [2]. Time-resolved temperature response of an iron sample has been measured in order to provide thermal conductivity constraints in the Earth's core, valuable information not directly accessible by static measurements. The pump and probe experiments utilized intense short laser pulses capable of driving noble gases at high pressures to temperatures where a transition to a metallic state occurred. Such short-lived states, however, call for fast X-ray probes, which are not available at the synchrotron sources.
The unprecedented brightness offered by the European XFEL at hard X-ray energies of up to 25 keV facilitates method-development utilizing diamond anvil cells (DAC). Using rapid compression and pulsed-laser heating combined with DAC technology it is possible to create extreme states of matter, which are short lived and therefore require ultrafast probes in form of short FEL X-ray pulses. The HED instrument [3] will feature a second interaction chamber with a setup fully optimized for research using diamond anvil cells [4]. Rapid compression reaching higher pressures and greater strain rates than in conventional DAC will be realised using a piezo-driven dynamic DAC (dDAC), potentially also combined with pulsed-laser heating. Pulsed-laser heating will be used to create warm dense matter in nanosecond timescales. The X-ray repetition rate of the European XFEL of up to 4.5 MHz will then be used to characterize these extreme states by means of scattering, imaging and/or spectroscopic methods.

[1] Konôpková, Z., McWilliams, R. S., Gómez-Pérez, N., & Goncharov, A. F. (2016). Direct measurement of thermal conductivity in solid iron at planetary core conditions. Nature, 534(7605), 99–101.

[2] McWilliams, R. S., Dalton, D. A., Konôpková, Z., Mahmood, M. F., & Goncharov, A. F. (2015). Opacity and conductivity measurements in noble gases at conditions of planetary and stellar interiors. Proceedings of the National Academy of Sciences, 112(26).

[3] Nakatsutsumi et al., Technical Design Report, Scientific Instrument High Energy Density Physics (HED), 2014

[4] HP. Liermann et al., Conceptual Design Report for Diamond Anvil Setup (DAC) at the HED instrument of the European XFEL, 2016

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