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The Matter in Extreme Conditions (MEC) instrument at LCLS[1]

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The last five years have seen the commissioning of and first user experiments on both the Free Electron Laser in Hamburg (FLASH) and the Linac Coherent Light Source (LCLS) in Stanford, and more are slated to come online in the next couple of years . The high photon frequency (i.e. larger than the plasma frequency of solid density), short pulse length (i.e. 10s to 100s of femtoseconds) and large photon number per pulse (i.e. 1012 photons per pulse) make it an ideal source to create and study states of matter at high energy density, a long-standing scientific challenge. Indeed, while matter in extreme conditions, which for the purpose of this talk we define as states under pressure up to hundreds of GPa and with temperatures ranging between 1eV and 1000eV, has been studied through dynamic shock compression and there has been significant progress made over many decades. However, large uncertainties still exist in the atomic structure and crystallographic structure, existence of high pressure phases, scattering factors, and equation of state of matter in extreme conditions. The Matter in Extreme Condition (MEC) instrument at LCLS is designed to overcome the unique experimental challenges that the study of matter in extreme conditions bring. It combines a suite of diagnostics and high power and energy optical lasers, which are standard fare in this research field, with the unmatched LCLS X-ray beam, to create an instrument that will be at the forefront of, and have a major impact on MEC science, in particular in the field of high pressure, warm dense matter, high energy density, and ultra-high intensity laser-matter interaction studies. The LCLS beam allows for unique investigation in all these extreme states using diagnostic methods such as X-ray Thomson Scattering, X-ray emission spectroscopy, X-ray diffraction, X-ray absorption spectroscopy, X-ray phase-contrast imaging, and pumping specific absorption lines to study (dense) plasma kinetics. Augmented with optical diagnostics, such as Velocity Interferometry for Any Reflector (VISAR) and Fourier Domain Interferometry (FDI), the instrument provides information of surface velocity, shock conditions and pressure that is reached. MEC instrument equips two relatively high power and high energy optical laser systems to produce extreme conditions. The long pulse beam at 527 nm from the frequency-doubled Nd-YAG MEC laser system is operated in a power-limited mode (~1.5 GW) within a flat-top or temporally-shaped 2-200ns pulse to produce high pressure through shock compression. A standard Ti:Sapphire laser system delivers 1J with a repetition rate of 5 Hz. In this presentation, we will show on overview of the MEC instrument and its capabilities, and show some selected results from past experiments.

[1]This research was carried out on the MEC Instrument at the Linac Coherent Light Source (LCLS), a division of SLAC National Accelerator Laboratory and an Office of Science user facility operated by Stanford University for the U.S. Department of Energy.