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Plasma Physics Seminar

Physics & Astronomy Building (PAB) Room 4-330

Via Zoom: https://ucla.zoom.us/j/92785449357?pwd=SVBTSko3bTdEUW03dzQwNks1Q2lKZz09

Friday, June 9, 2023. 11:30 AM Lunch will be served

New regimes of materials science at ultrahigh pressures and densities*

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History: The field of high energy density (HED) materials science has been under development for nearly 50 years. The emergence of high energy, high power lasers and magnetic pinch facilities, together with sophisticated target design capabilities, has allowed physics samples to be loaded to pressures from 100 GPa (1 Mbar) to 10 TPa (100 Mbar). This work started in the 1980s and 1990s on facilities such as the Nova laser at LLNL and the Z facility at SNLA. Early work from the Nova laser used a ~6 ns ramped radiation Tr drive from a shielded hohlraum to drive the first laser based, strength Rayleigh-Taylor (RT) experiments to pressures of ~2 Mbar using a rippled Cu foil. [Kalantar, IJIE 23, 409 (1999)]. A variation on this was a 3-staged-shock, ~8 ns Tr drive on Nova using a shielded hohlraum to reach ~1 Mbar pressures in strength Rayleigh-Taylor experiments on aluminum. [Remington, MMTA 35A, 2587 (2004)] This work moved to the Omega laser when Nova was shut down in 1999. We switched to using a reservoir-gap-sample design, [Edwards, PRL 92, 075002 (2004)] motivated by the seminal Barnes experiment. [Barnes, JAP 45, 727 (1974)] This approach worked well and reduced the sensitivity on laser pulse shape in those early years. But with NIF came good pulse shaping, opening the door to experiments that could reach solid state conditions from 1 – 10s of Mbar pressures with drive durations that could last 60 ns or more, [Spaeth, FST 69, 25 (2016); Krygier, PRL 123, 205701 (2019)] and the science progress accelerated significantly.

Recent highlights: Examples from some recent highlights in the HEDS field include the following. High pressure and density deuterium was studied, and observed to undergo an abrupt insulator to metal transition at 2-3 Mbar pressures in experiments at the Z facility [Knudson, Science 348, 1455 (2015)] and on NIF laser [Celliers, Science 361, 677 (2018)] using a shaped Tr(t) radiation drive. Another intriguing example is the formation of diamond from doubly shocked CH polymer (plastic), with the carbon forming nanograins of solid diamond, leaving the hydrogen free to flow as a fluid. [Marshall, JAP 131, 085904 (2022)] Water (H2O) has been studied at 100s of GPa pressures, both at Z [Knudson, PRL 108, 091102 (2012] and at Omega [Millot, Nature 569, 251 (2019)]. Under these conditions, H2O can transition to the superionic phase of matter. This phase is both solid and liquid at the same time, with the oxygen locked into a bcc or fcc lattice, and the hydrogen remaining free to flow as a liquid. Another intriguing result is the Brygoo experiment demonstrating the demixing of a He-H homogeneously mixed dense gas sample at high pressure and density conditions. At sufficiently high (P,r), the He can come out of solution (demix) as He droplets, leaving H in the gaseous state. This process is thought to occur in Saturn, and helps to explain the enhanced heating of its interior and core. [Brygoo, Nature 593, 517 (2021)] Gorman et al. describe experimental observations of open structures in magnesium at terapascal pressures, where they observe the peculiar electride phase of matter. [Gorman, Nature Physics 18, 1307 (2022)]. Polsin et al. studied Na at Omega EP, and also inferred the electride phase of sodium at high-(P,r). [Polsin, Nat. Comm.13, 2534 (2022)]. Kraus et al carried out experiments on NIF to map out the high pressure melt curve of Fe up to peak pressures of 10 Mbar, relevant to super-Earth core conditions. [R.G. Kraus, Science375, 202 (2022)]. And finally, Coppari et al. make connections to planetary interiors by studying magnesium oxide (MgO) ramp compressed to 900 GPa. [Federica Coppari, Nature Geophyics 14, 121 (2021)]. A selection of examples from the HED science described above will be presented.