Title: New regimes of high energy density (HED) experimental science on the Omega and NIF laser facilities

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Highlights from research done on high energy density (HED) laser facilities such as NIF, Omega, and Omega EP will be presented. Examples from experiments in unique regimes of (1) high pressure, high density materials science; and (2) high Reynolds number, HED hydrodynamics will be discussed.

1. Materials science

High pressure and density deuterium was studied on NIF and observed to undergo an abrupt insulator to metal transition near 200 GPa pressure using a shaped radiation drive. [Celliers 2018] The formation of diamond from doubly shocked CH polymer was observed in experiments on Omega EP, with the carbon forming nanograins of diamond, leaving the hydrogen free to flow as a fluid. [Marshall 2022] Water has been studied at 100s of GPa pressures at Omega [Millot 2019], where H_2O can transition to the superionic phase of matter with the oxygen locked in a lattice, and the hydrogen remaining free to flow as a fluid. Another intriguing result is the Omega experiment demonstrating demixing of a homogeneously mixed He-H gas sample at high pressure and density, where He comes out of solution (demixes) as droplets, leaving H in the gaseous state. [Brygoo 2021] Experimental observations of open structures in magnesium at terapascal pressures were made on NIF in the peculiar electride phase of matter. [Gorman 2022]. Sodium was also observed in the electride phase at high pressure and density at Omega EP. [Polsin 2022]. Experiments were carried out on NIF to map out the high pressure melt curve of Fe up to peak pressures of 1000 GPa, relevant to super-Earth core conditions. [Kraus 2022]. And connections were made to rocky exoplanet interiors by studying iron oxide (FeO) ramp compressed to 700 GPa. [Coppari 2021]. A selection of examples from the HED science described above will be given.

2. Hydrodynamics

Hydrodynamic instability experiments are being developed and carried out on the National Ignition Facility (NIF) laser at LLNL through the NIF Discovery Science (basic science) program and the high energy density science (HEDS) program. The motivations are many, including supernova explosion dynamics [[Kifonidis 2003, Müller 1991]; supernova remnant evolution [Fraschetti 2010, Kuranz 2018]; planetary formation dynamics [Ida 2018, Sasaki 2007, Hoogenboom 2006]; and asteroid impact and breakup dynamics [Korycansky 2000]. Examples include single-mode and multimode classical (non-stabilized) Rayleigh-Taylor (RT) experiments in planar geometry [Nagel 2017, Shimoni 2022]; classical RT in single-mode cylindrically convergent geometry [Sauppe 2020, Palaniyappan 2020]; RT mixing into the hot spot at high compression in inertial confinement fusion (ICF) capsule implosions [Smalyuk 2020a, Smalyuk 2020b;[Ma 2013, Bachmann 2020]; ablation front RT experiments in direct drive [Casner 2018]; in indirect drive [Casey 2014]; and in the nonlinear RT bubble merger regime [Martinez 2015]. Radiative shock stabilized RT instability experiments have been developed [Kuranz 2018]; as well as material strength stabilized RT experiments at high pressures and strain rates in solid-state ductile metals [Krygier 2019]. Examples will be given, connections to astrophysical and planetary science settings made; and future directions will be discussed.

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