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Hydrodynamic Instabilities in High-Energy-Density Settings[1]

VLADIMIR SMALYUK, Lawrence Livermore Natl Lab

Our understanding of hydrodynamic instabilities, such as the Rayleigh-Taylor (RT), Richtmyer-Meshkov (RM), and Kelvin-Helmholtz (KH) instabilities, in high-energy-density (HED) settings over past two decades has progressed enormously. The range of conditions where hydrodynamic instabilities are experimentally observed now includes direct and indirect drive inertial confinement fusion (ICF) where surprises continue to emerge, linear and nonlinear regimes, classical interfaces vs. stabilized ablation fronts, tenuous ideal plasmas vs. high density Fermi degenerate plasmas, bulk fluid interpenetration vs. mixing down to the atomic level, in the presence of magnetic fields and/or intense radiation, and in solid state plastic flow at high pressures and strain rates. Regimes in ICF can involve extreme conditions of matter with temperatures up to kilovolts, densities of a thousand times solid densities, and time scales of nanoseconds. On the other hand, scaled conditions can be generated that map to exploding stars (supernovae) with length and time scales of millions of kilometers and hours to days or even years of instability evolution, planetary formation dynamics involving solid-state plastic flow which severely modifies the RT growth and continues to challenge reliable theoretical descriptions. This review will look broadly at progress in probing and understanding hydrodynamic instabilities in these very diverse HED settings, and then will examine a few cases in more depth to illustrate the detailed science involved. Experimental results on large-scale HED facilities such as the Omega, Nike, Gekko, and Shenguang lasers will be reviewed and the latest developments at the National Ignition Facility (NIF) and Z machine will be covered. Finally, current overarching questions and challenges will be summarized to motivate research directions for future.

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