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Study of the kinetic effects in indirect-drive inertial confinement fusion hohlraums

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Kinetic physics has the potential to impact the performance of indirect-drive inertial confinement fusion (ICF) experiments. In near vacuum hohlraums (or vacuum hohlraums), the high-Z plasma expands from the hohlraum wall and collides with the blow-off from the capsule (or the low-density fill-gas). Such collision produces conditions in which kinetic effects may dominate since the ion-ion mean free paths are larger than the size of the interaction region. In the present work, we present the first experimental evidence supported by simulations of kinetic effects launched in the interpenetration layer between the laser-driven hohlraum plasma bubbles and the corona plasma of the compressed pellet on the Shenguang laser facilities. Our study showed kinetic shocks arisen in the hohlraum wall/ablator interpenetration region, which result in efficient acceleration of the low-Z ions. When these high energy ions were deposited inside the capsule, it resulted in significant low-mode asymmetry of the implosion capsule since there are no high energy ions from the laser entrance holes.

On the other hand, in high gas-filled ICF hohlraum, diffusion-driven collisionless shock wave can be generated from an initially sharp high-Z and low-Z plasma interface with total pressure balance and constant temperature in the laser propagation channel inside the hohlraum. The mechanism for such an anomalous mix in the interpenetration layer at the high-Z and low-Z plasma interface and its effects on the laser plasma instabilities have been investigated by particle-in-cell simulations. This purely electrostatic shock wave propagates into the high-Z plasma and leads to mix of different species of ions which is significantly faster than classical mix in the presence of the large electric field. The mix layer width, measured as a separation distance affected by the shock, grows as the time. The effect of the anomalous mix on the linear growth rate of laser plasma instabilities is evaluated. The PIC simulation and theoretical evaluation indicate that the anomalous mix of the high-Z and low-Z ions can significantly reduce laser plasma instabilities by increasing Landau damping of the ion acoustic wave. This ion mixing model has been used to evaluate the stimulated Brillouin scattering in the LPI experiments on SG-III laser facility. It is found the SBS spectrum evaluated from LPI simulation code is much closer to the experiments. Furthermore, the time-averaged SBS reflectivity in experiments is about 8.5%, while that in simulation is 18% without ion mix model and 9.3% with ion mix model. As a result, this kinetic ion mix process should be included in LPI process.

References

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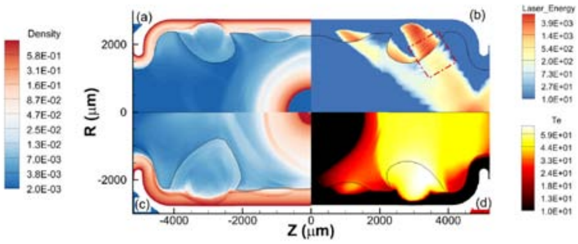

Figure 1. Radiation hydrodynamic simulations by LARED-integration for a typical cylindrical Au hohlraum for ICF. Here, the hohlraum has a diameter of 5.4mm and a length of 10mm. The hohlraum is filled with helium at a density of 0.96g/cc. The hohlraum were driven with 10-ns-shaped laser pulses with a total energy of 1.4MJ. (a) (c) The simulated spatial distributions of the normalized electron density ne (g/cm^3) at time (a) t=6ns and (c) t=8ns, (b) the laser deposition and (d) the electron temperature (MK) inside the hohlraum.