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Experimental Evidence of Kinetic Effects in Indirect-Drive Inertial Confinement Fusion Hohlraums

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High-Z hohlraums are used to convert intense laser pulses or charged particle beams into soft x rays at a radiation temperature of hundreds of eV in indirect-drive inertial confinement fusion (ICF). Successful indirect drive ignition requires highly symmetric implosion of a deuterium and tritium-filled capsule driven by these x rays. In order to minimize the motion of the laser deposition region and reduce the low-mode-number implosion asymmetries, low-Z gas filled hohlraums are used. However, the lack of control over the time dependence of the cross-beam energy transfer (CBET) within the gas filled hohlraums has led to a program to develop alternative near-vacuum hohlraums (NVHs)or vacuum hohlraums as a means of mitigating this issue. In vacuum hohlraums (or NVHs), the high-Zplasma expands from the hohlraum wall and collides with the blowoff from the capsule (or the low-density fill-gas). Such a 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. The formation and evolution of this inter-penetration region have been proposed as a cause for the symmetry discrepancy between NVH experiments and simulations, and lack of detailed interpenetration modeling in the code causes a density spike at the interface, which blocks inner-beam propagation. Furthermore, strong electromagnetic field structures associated with the Au wall-gas diffusion layer have been observed in the hohlraum using proton radiography. These kinetic effects, will have significant impact on the energy transport and other intrinsic plasma properties.

In this talk, We will 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 at the Shenguang-III prototype laser facility. Solid plastic capsules were coated with carbon-deuterium layers; as the implosion neutron yield is quenched, DD fusion yield from the corona plasma provides a direct measure of the kinetic effects inside the hohlraum. An anomalous large energy spread of the DD neutron signal (~282keV) and anomalous scaling of the neutron yield with the thickness of the carbon-deuterium layers cannot be explained by the hydrodynamic mechanisms. Instead, these results can be attributed to kinetic shocks that arise in the hohlraum-wall–ablator interpenetration region, which result in efficient acceleration of the deuterons (~28.8J, 0.45% of the total input laser energy). These studies provide novel insight into the interactions and dynamics of a vacuum hohlraum and nearvacuum hohlraum.

References

[1] L. Q. Shan,H. B. Cai(*),W. S. Zhang,Q. Tang,F. Zhang,Z. F. Song,B. Bi,F. J. Ge,J. B. Chen,D. X. Liu,W. W. Wang,Z. H. Yang,W. Qi,C. Tian,Z. Q. Yuan,B. Zhang,L. Yang,J. L. Jiao,B. Cui,W. M. Zhou,L. F. Cao,C. T. Zhou,Y. Q. Gu(*),B. H. Zhang,S. P. Zhu,and X. T. He, Experimental Evidence of Kinetic Effects in Indirect-Drive Inertial Confinement Fusion Hohlraums, PHYSICAL REVIEW ETTERS,120,195001(2018)

Figure 1 (a) The density profile of Au and CD plasma from PIC simulations, (b) phase space plots vx~x of the Au-D ions, (c) electric field Exand electrostatic potentialΦx profile, and (d) energy spectrums of the CD ions within the precursor region.

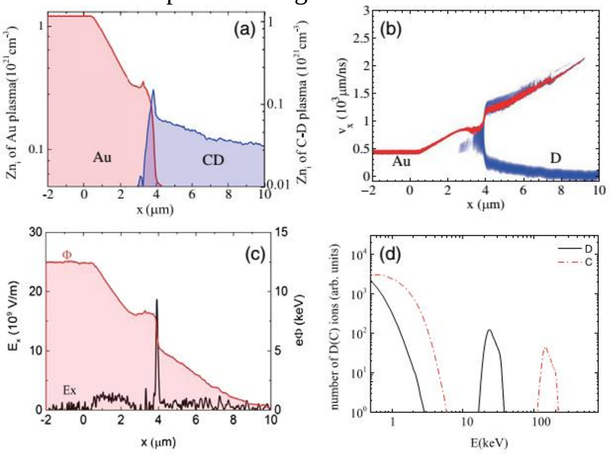

Figure 2 (a) The density distribution of CD plasma (red solid line), electron temperature (black dashed line), and ion temperature (magenta dash-dotted line) distribution of CD plasma at 866 ps from RDMG-1D spherical model. (b) Typical proton imaging data of the collision of the Au bubble with low-density CD plasma at the time 3 ns after the end of the long pulse laser.