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Status of Fast Ignition ICF Research at LLNL

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The fast ignition approach to inertial confinement fusion (ICF) offers the prospect for achieving the high target gains (fusion yield out over laser energy in) necessary for an attractive inertial fusion energy system. In the fast ignition scheme a two step approach is used to reach the conditions in density and temperature required to initiate fusion and burn: firstly, a cryogenic deuterium-tritium-filled fuel capsule is compressed via a quasi-isochoric implosion to form a high density core (ρ>300 g/cm^3); secondly, a small region of the core (~40 microns) is heated rapidly to ignition temperature (12 keV) with a relativistic energy electron beam generated by an ultrashort-pulse, ultrahigh power laser. In this talk we report on progress at LLNL on the design and experimental validation of an indirectly-driven re-entrant-cone fast ignition target. The indirect-drive irradiation scheme is compatible with the 1.8 MJ National Ignition Facility (NIF) at LLNL. We describe integrated hohlraum and capsule designs that optimize the peak density, areal density, and spatial uniformity of the compressed fuel around the cone tip. Major challenges of these simulations include preventing ablation of the high-Z cone wall and consequent contamination of the ignition hot spot, minimizing the fuel to cone tip separation distance, and maintaining cone tip integrity in the extreme environment of the imploding capsule. The ultrashort-pulse laser-plasma interaction and fast electron generation is simulated with a three-dimensional explicit particle-in-cell (PIC) code. The subsequent transport of the electrons through the imploding plasma and their heating of the dense core is modeled with a hybrid-PIC electron transport code, ZUMA, coupled to the radiation-hydrodynamics ICF code, HYDRA. This integrated modeling approach enables the self-consistent treatment of the hohlraum radiation drive, capsule implosion, fast electron generation and transport, core heating, and burn in a fast ignition implosion. A parallel experimental program aims to provide experimental validation of the key physics underpinning the fast ignition design. We describe the status of experiments in three principal areas: short-pulse laser experiments performed on the TITAN Petawatt-class laser at LLNL designed to study the physics of relativistic laser-plasma interaction and fast electron generation at laser intensities of 10^{20}-10^{21} W/cm^2; integrated experiments at the OMEGA laser facility at LLE to study core heating in sub-scale fast ignition targets with simultaneous compression and heating; and finally, implosion experiments on the NIF to study isochoric compression of a fast ignition target at the full hydrodynamic scale required for high gain ignition.

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