Influence of the solid-to-plasma transition on the laser energy deposition in targets and subsequent hydrodynamics for direct drive inertial confinement fusion

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Inertial Confinement Fusion (ICF) is a method of achieving nuclear fusion reactions by bringing a small mass of combustible material at high densities with the desired thermodynamic properties. To achieve this goal, high power laser beams are used to implode a spherical shell constituted of gaseous DT fuel surrounded by solid DT and a plastic ablator. The laser ionizes the ablator which is ablated and the target implodes due to the rocket effect. In radiation-hydrodynamics codes modeling this process, the plastic ablator is supposed opaque to the laser radiation, which is only the case when it is already in plasma state, where the laser field is reflected at the critical density. However, the mechanisms that lead to the transition from solid state to plasma state of the ablator are not modeled in the aforementioned codes, whereas they may have an important role in implosion symmetry, target compressibility, shock timing, and hydrodynamic instabilities.

This work focuses on the introduction of a solid-to-plasma transition model in a 3D radiation hydrodynamics code, in order to study such an influence on direct-drive implosions. It is based on a recent physical model developed in Ref. [1, 2] which describes the solid-to-plasma transition of polystyrene step by step (most of ICF ablators are composed of polystyrene). The hydrodynamic code is a numerical tool coupling the 3D laser propagation code IFRIIT [3] with the 3D Eulerian hydrodynamic code ASTER [4]. Simulations with a single beam have confirmed the validity of the implementation, and have provided information about the dynamics of the transition: the ablator undergoes the solid-to-plasma transition, i.e. transforms from transparent to reflective optical state, on a timescale of 50ps. Simulations are then applied to the 60 laser beams configuration of the OMEGA laser facility. Test simulations conducted on warm targetsshow a modification in the spherical harmonics mode distribution of the target areal density (ρR), where the volume heating during the solid to plasma transition is then to smooth the predominant OMEGA modes. They also shows a slightly modification of shock velocity in the target, probably due to the preheating of the inner ablator. We will also present results for cryogenic cases at different adiabats and consider other applications such as modeling of foams for the Dynamic Shell design or the Spherical Strong Shock experiments conducted on the NIF.

References

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