Study of cross-beam energy transfer in solid ball laser-target coupling experiments in polar direct drive at the NIF, in a regime relevant to shock ignition.

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ABSTRACT.

When the interaction parameter $I\lambda^2_L$ crosses the threshold of ∼ 10^{14} $W\mu m^2/cm^2$, the laser plasma interaction becomes prone to numerous couplings between electromagnetic and plasma waves [1]. Most of these additional processes have nonlinear behaviors and are in general nefarious to the implosion in Inertial Confinement Fusion. It is notably the case of the Cross-Beam Energy Transfer (CBET). CBET is a process that arises when two or more propagating laser beams intersect in a plasma and resonantly couple through Ion Acoustic Waves. CBET can lead to a net transfer of beam energy and affects both the symmetry of the implosion and the laser-target coupling [2].

In this work we focus on the 3D modeling of direct drive experiments in PDD geometry [3] carried out at the NIF. These experiments aimed to study the efficiency of the laser energy coupling to a spherical target with beam intensities close to the shock ignition regime. A couple of shots were performed with peak intensities of 3.0E10^{15} W/cm^2 and 1.0E10^{15} W/cm^2 with a 5-ns-long shaped pulse [4]. These shots are studied numerically with and without CBET to investigate its influence on compression and coupling efficiency using the IFRIIT (3D laser-plasma interaction) + ASTER (3D radiation hydrodynamics) [5] coupled code.

We observe that with CBET, there is a large loss of total energy absorbed for both shots. The energy absorption decreases from 85% energy absorption without CBET to 40-60% absorption (and drops at 30% during spike) with CBET. These energy losses occur mainly around the equatorial plane, where the overlap between the beams is much more efficient for inducing CBET effects. This results in an inhomogeneous compression that is much stronger at the poles, leading to the creation of a pancake-shaped shock, and to several ns delays regarding the convergence time. We also present comparisons of these results to radiography data.

The effect of hot electrons (HEs) is known to influence greatly the dynamics of shocks. However, this was not accounted for in the current modeling. In these experiments, HEs were diagnosed with the FFLEX instrument and about 5% of the laser energy is deposited into hot electrons with T_h = 56keV in the high intensity shot. These electrons may contribute strongly to the shock propagation during the spike, which motivates the implementation of a Monte Carlo HE package in IFRIIT to further this study. We also consider the possibility to generate polar shocks, reducing the beam overlap, as a way to mitigate the coupling losses due to CBET during the spike.

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