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Implosion of Indirectly Driven Reentrant-Cone Shell Target

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We have examined the implosion of an indirectly driven reentrant-cone shell target to clarify the issues attendant on compressing fuel for a fast ignition target. The target design is the hydrodynamic equivalent of a NIF cryoignition target scaled to be driven by Omega. Implosions were imaged with backlight x radiographs and modeled with LASNEX. The simulations were generally in good agreement with the experiments with respect to the shell diameter, density, and symmetry, but did not show the stagnation central absorption maximum. The existence of material between the original cone and the shell is sensitive to gold M-band radiation, which penetrates the shell and ablates gold from the cone. The simulated radiographs using recently measured M-band fractions showed absorption between the cone and shell similar to the experiment. This gold ablation might be a problem in a cryoignition target.

FIG. 1. (a) A NIF scale cryogenic ignition target consisting of a 2 mm in diameter. Be shell surrounding a DT ice layer, into which a hyperboloidal cone is inserted. (b) Cross section of shell in (a) scaled down for Omega experiments.
were taken from a flux vs time as the first set. From the image sets profiles set uses 6% at the peak, but the same overall incident the 6%–9% range at the peak [10]. The second simulation M time of the experiments. Recent measurements of the 

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band fraction in hohlraums driven similarly are in form of the mass (\(m/m_0\)). The model x-ray optical depth vs position across the apparent center (3.3 ns, FWHM size (70 \(\mu m\)), and maximum x-ray optical depth (2) agree with the model (3.4 ns, 65 \(\mu m\), and 2, respectively), the gross structure of the collapsing shell (horseshoe crablike) looks very much as predicted, and we assembled about the expected fraction of the mass \(m/m_0 = 28 \pm 4\%\) — calculated from the lineouts, ignoring the cone and assuming spherical symmetry to the collapsing mass). But there are differences: the experimental profiles lack the shallow hollow in the center and increasing optical depth at early times that ought to be observable (Fig. 4) and an associated decreasing FWHM during shell collapse (Fig. 5). More noticeably, the apparent cone shadow extends close to the shell in a manner inconsistent with the lower \(M\)-band fraction simulations. We believe these effects are connected. Most of that shadow is merely dense vapor [Fig. 6(b)]. The very opaque region (solid gold) is marked off by the white line in Fig. 6(b); the rest of the shadow transmits a few to 10\% of the backlight (~1 g/cm\(^3\) of Au). The model x-ray drive included the nonthermal \(M\)-line radiation from the gold hohlraum, with peak fractions of 4\% and 6\% as described earlier [Figs. 3(b) and 3(c)]. In the simulations these high energy x rays penetrate the capsule and heat
the tip of the cone, causing ablated gold plasma to extend past the center of the collapsing shell as seen in the experiment [Fig. 6(a)]. Later, as the capsule collapses, plastic plasma blown off the inside of the shell by shock waves impinges on the gold plasma with a pressure gradient that tries to push the gold plasma back toward the cone tip, but the Au vapor is dense enough that the boundary is Rayleigh-Taylor unstable some of the time, so some mixing is expected. This instability, however, is not captured by our simulations because it was not feasible to provide sufficient resolution in the region of these full implosion simulations. Therefore, in the simulations the gold plasma is pushed back with the result that no gold opacity remains in the capsule core region after \(3.0 \times 10^{-3}\) s. In reality, we expect the interface to be quite perturbed with the result that some gold plasma would not be pushed back toward the cone and out of the core but would instead be mixed with the plastic plasma in the interface region resulting in the core opacity seen in the experiment. Consider Fig. 4(b), roughly peak convergence. There is an optical depth deficit in the simulations, with respect to the experiments, of about 0.3 over the central 30 \(\mu\)m. Using a gold opacity of about 327 cm\(^2\)/g at 6.7 keV (the simulation indicates that the core is heated to \(400\) eV, which strongly bleaches the C absorption there, but has little effect on the Au), we find this deficit corresponds to about 4 ng of gold, amounting to about 1% of the mass density over the 30 \(\mu\)m diameter. The gold in the larger cavity could also explain the unexpectedly high early time absorption seen in Fig. 4(a). The observed central optical depth could be due to C in the central volume caused by turbulent mixing, but that requires an unusually high central density (\(25\) g/cm\(^3\)) at early time—about the same as observed at maximum compression. The 4 ng of gold estimated above is roughly 0.04 wt.% of the collapsed mass and therefore must be considered as a potential problem for ignition. At ignition scale, 0.1 wt.% of gold is sufficient to double the required ignition energy. Clearly, the amount of gold plasma ablated is sensitive to the amount of penetrating \(M\)-band radiation, but it seems difficult to eliminate this nonthermal, hard x-ray source since all the alternative hohlraum materials and mixtures (“cocktail hohlraums”) have fluorescent lines in the range 1–4 keV. At ignition scale, the shielding against those lines is much better; a NIF scale shell would have a doped ablator wall.
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