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Study of short-wavelength perturbation growth on a NIF double-shell ignition target design

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Achieving ignition with the National Ignition Facility is a major goal of the US-ICF program. To maximize the prospects of accomplishing this objective an improved non-cryogenic double-shell target was recently proposed as a complement to the cryogenic baseline design [Amendt *et al*, Phys. Plasmas **9**, 2221 (2002)]. Notwithstanding the advantage of non-cryogenic preparation, double shells pose a major challenge in controlling instabilities seeded by unavoidable interface perturbations. During implosion, these perturbations become unstable as they are subjected to impulsive (Richtmyer-Meshkov) and time-dependent (Rayleigh-Taylor) accelerations. The inner surface of the inner shell is unstable at deceleration onset leading to mix of the dense high-Z pusher and the DT gas with the consequent cooling of the fuel and possible quenching of ignition. Furthermore, irregularities in the outer surface of the pusher are unstable during most of the implosion phase. If uncontrolled, the growth of these perturbations may feed-through to the inner surface, further contributing to dangerous fuel-pusher mix. In order to understand and therefore control these instabilities, we have undertaken an ambitious program of simulating short-wavelength perturbations (Legendre mode numbers up to a few thousand) on the surfaces of the pusher. To study the non-linear RT evolution for such a large range in modes we use the parallel 3-D rad-hydro code HYDRA. Our approach consists of introducing perturbations (from measured surrogate spectra) on all surfaces of the capsule and systematically studying the effects on ignition. Our results have indicated that the growth of perturbations on the inner surface of the pusher give rise to a mix-width well below the minimum radius with only a slight degradation in yield. However, we have encountered a new pathway for RT instability of the pusher's outer surface perturbations that may lead to shell disruption (well-before peak compression). L-band radiation (>8 keV) from the laser-irradiated high-Z hohlraum wall passes through the outer shell and ablates the outer surface of the high-Z inner shell, promoting a large outward expansion (to nearly twice its original radius), which is subsequently recompressed by the converging outer shell. During recompression, low density material (foam) pushes onto high density (inner shell) material, giving rise to the classic conditions for RT instability. We show that this phenomenon can be controlled by tamping of the inner shell with a low-Z material. However, the instability is not entirely suppressed and we find that the pusher/tamper interface becomes turbulent at late time with high Reynolds number. The mix-width that develops follows closely Young's bubble-spike late time behaviour. Our simulations are unable to resolve the smallest scales that evolve during the turbulent flow, but we are confident that the larger scales are well modelled. To avoid the onset of turbulence, and therefore gain more confidence on the simulations, we have introduced a new design with a manufactured density gradient scale length in combination with a high-Z supporting foam. The benefits of reducing the Atwood number during implosion have been assessed through DNS that show little growth of perturbations and near 1D performance.

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