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Enhanced Stability of National Ignition Facility (NIF) Ignition Capsule Designs

Recent NIF ignition capsule designs have significantly less growth of short-wavelength hydrodynamic instabilities than previous designs, according to simulations. The graded doped beryllium capsule design, described in the *December 2003 Bimonthly Update*, has been adopted as our new point design due to its remarkable stability. In addition, we also have a graded doped plastic design and reoptimized uniformly doped designs; all are significantly more stable than previous designs (see Fig. 1).

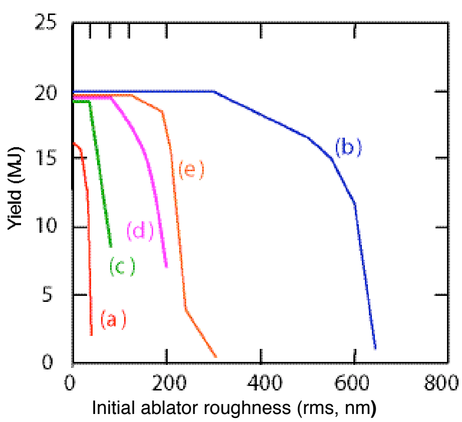

Fig. 1. Sensitivity of several recent ignition capsule designs to ablator surface roughness. These simulations include modes above 12, and assume the same power spectrum for the perturbations, which for high modes is the "NIF standard" used by target fabrication to evaluate power spectra. The capsules are all "scale 1," requiring about 1.5 MJ of laser energy absorbed in a 300-eV hohlraum. The curves are: (a) plastic capsule prior to 2003; (b) graded doped beryllium; (c) recent reoptimization, uniformly doped plastic capsule; (d) graded doped CH; and (e) recent reoptimization, uniformly doped beryllium.

The stability of these capsules relaxes specifications for surface roughness for targets by almost an order of magnitude over earlier specifications. Furthermore, the enhanced hydrodynamic stability opens the possibility of in-situ filling of the capsule with DT fuels using a small tube, a significant simplification in the capsule filling and fielding process. A preliminary estimate of the relaxed tube requirement, based on linear analysis, is shown in Fig. 2. More detailed hydrodynamic simulations of a capsule with fill tubes, to assess nonlinear jetting, are in progress.

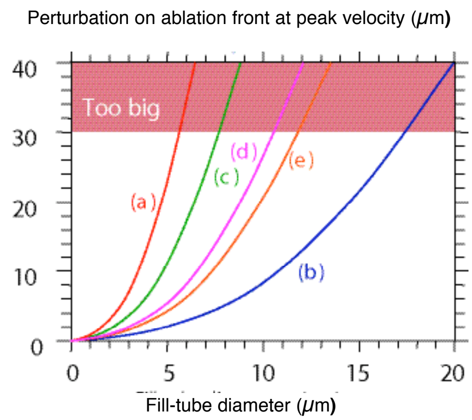

Fig. 2. Estimated implication of the enhanced stability for the requirement on the diameter of a capsule fill tube. For the capsules shown in Fig. 1, with the same legend, linear analysis was used to estimate how large a perturbation results from a tube attached to the capsule. This suggests that the specification can be relaxed from 5-μm diameter to about 17 μm. Any tube diameter in this range would probably allow for an in-situ fill scenario, but the larger tubes would make it significantly less demanding to fabricate.

The graded doped capsule has been designated as a new point design and we are performing a detailed analysis of its sensitivities and performance. Integrated 3D calculations have produced excellent symmetry, as shown in Fig. 3. This simulation put in 1.6 MJ of absorbed laser light and yielded 11.8 MJ, compared to 16 MJ for a perfect 1D implosion. This simulation assumed a central DT gas density of 0.5 mg/cc, since forming a good ice layer may require operating at a higher central gas density. This reduced its yield relative to the results in Fig. 1.

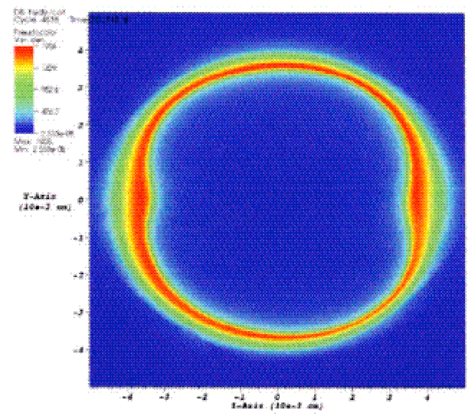

Fig. 3. Imploded configuration in a 3D integrated calculation of the graded-doped beryllium design in a gold hohlraum. The small 3D asymmetry results from the pattern of the beams in the NIF configuration.

We have used simulations of the capsule implosion only, in 2D, to quantify the sensitivity to combined uncertainties. These simulations include deviations in almost every input parameter, including 20 1D variations (e.g., capsule dimensions, shock timing) and most 3D effects (e.g., surface roughness on all interfaces, and low-mode asphericities). The assumed value for each uncertainty was chosen randomly from a normal distribution with width equal to the specification for that uncertainty. Nominal uncertainties only reduce the yield by about 10%, and a multiplier of more than two can be put on the whole set of uncertainties before the yield is reduced by 50%. The tolerable multiplier depends on the central gas density: with 0.5 mg/cc and nominal ^{3}He, a multiplier of 2.3 gives 50% yield, while with 0.3 mg/cc and no ^{3}He, the multiplier can be as big as 3.3.

Based on the remarkable stability of these new designs, future work in target fabrication will focus on developing graded doped Be and CH capsules, and DT capsule filling through micron-scale fill tubes.

For comments about content of the ***Bimonthly Update***, contact Bruce A. Hammel (925) 422-3299.
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