January 2002 Progress Report on the Laboratory for Laser Energetics
Inertial Confinement Fusion Program Activities

Ignition Model: An accurate analytic model describing the deceleration phase and marginal ignition of cryogenic shells has been developed. The model is used to determine the growth rates of the deceleration-phase Rayleigh–Taylor (RT) instability and the energy requirements for marginal ignition. The main results are concerned with the role of mass ablation from the shell's inner surface into the hot spot. The effects of ablation are twofold. On one hand, mass ablation significantly reduces the growth of the deceleration RT instability, and on the other, it recycles the heat losses back into the hot spot, dramatically changing the hot-spot energetics. Indeed, most of the hot-spot mass is made up of plasma ablated off the shell, and the hot-spot pressure (i.e, energy per unit volume) is independent of the heat losses.

The ablation model approximately reproduces (see equations below) the marginal ignition scaling law derived by the Livermore group by fitting the results of *LASNEX** simulations of capsules having gain equal to unity.

$$E_K^{\text{model}} > 59\ (\text{kJ})\ \alpha_{\text{if}}^{2.4}\left(\frac{3\times10^7}{V_{\text{imp}}}\right)^{5.0}\left(\frac{P_{\text{shell}}}{100\ \text{Mb}}\right)^{-0.39} \quad \text{Ablation model ignition scaling}$$

$$E_K^{\text{LLNL}} > 51\ (\text{kJ})\ \alpha_{\text{if}}^{1.9}\left(\frac{3\times10^7}{V_{\text{imp}}}\right)^{5.9}\left(\frac{P_{\text{shell}}}{100\ \text{Mb}}\right)^{-0.77} \quad \textit{LASNEX}\ \text{ignition scaling}$$

In these equations, E_K, α_{if}, V_{imp}, and P_{shell} are the shell kinetic energy required for ignition, the shell in-flight adiabat, implosion velocity, and pressure at peak kinetic energy, respectively. The ablation model is also used to determine the growth rates of the deceleration-phase RT as shown in Fig. 1.

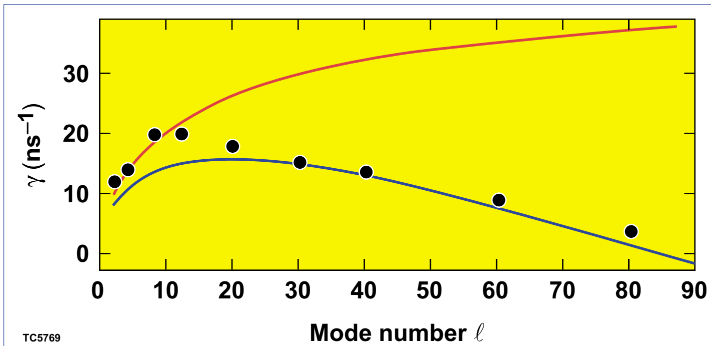

Figure 1. RT growth rate (γ) versus mode number for the deceleration RT of a direct-drive NIF-like capsule as predicted by the ablative RT theory (blue curve), classical theory without ablation (red curve), and 2-D numerical simulations (dots).

Two-dimensional simulations (Fig. 2) also show that the stabilizing effect of mass ablation is enhanced by alpha-particle heating, leading to an RT growth reduction well into the nonlinear regime.

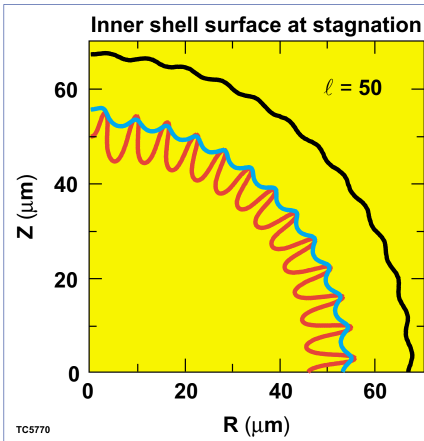

Figure 2. Inner shell surface at stagnation of a direct-drive NIF-like capsule with a preimposed $\ell = 50$ inner-surface perturbation. The 2-D simulations are carried out without both thermal conduction and alpha heating (red), with thermal conduction and without alpha heating (blue), and with both thermal conduction and alpha heating (black).

OMEGA Operations Summary: A total of 143 target shots were produced by OMEGA during January 2002. The shots were distributed as follows: 52 target shots for LLE (for several campaigns including integrated spherical, SSP, cryogenic capsules, power balance, and long-scale-length plasma experiments); 37 for the NLUF (including experiments by the General Atomics team for fast-ignitor capsule development, the University of Michigan collaboration on laboratory astrophysics, and the Polymath Sciences laser–plasma interaction physics experiments); 44 for LLNL experiments (including hot hohlraum, cocktail, x-ray Thomson scattering, x-ray conversion, radiation hydrodynamics, ignition diagnostics development, and equation-of-state campaigns); and 10 target shots for collaborative SNL/LLNL experiments on ablator burnthrough and shock propagation.

*M. C. Herrmann, M. Tabak, and J. D. Lindl, "A Generalized Scaling Law for the Ignition Energy of Inertial Confinement Fusion Capsules," Nucl. Fusion **41**, 99–111 (2001).

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