Rarefaction Flows and Mitigation of Imprint in Direct-Drive Implosions

I. V. Igumenshchev,[1] A. L. Velikovich,[2] V. N. Goncharov,[1] R. Betti,[1] E. M. Campbell,[1] J. P. Knauer,[1] S. P. Regan,[1] A. J. Schmitt,[2] R. C. Shah,[1] and A. Shvydky[1]

[1]Laboratory for Laser Energetics, University of Rochester
[2]Plasma Physics Division, Naval Research Laboratory

A 3-D hydrodynamic simulation using the code *ASTER*[1] helped to identify a new mechanism that is responsible for mitigating imprint with a scale length corresponding to Legendre modes down to $\ell \simeq 30$ in direct-drive OMEGA implosions[2] driven by laser pulses with a picket(s). This mechanism involves rarefaction flows developed by unsupported shocks. Rarefaction flows can result in a decay of imprint modulations in implosion shells during their early evolution, consequently improving the stability of these shells with respect to the acceleration Rayleigh–Taylor (RT)[3] growth at a later time.

Figure 1 illustrates the development of imprint modulations in implosion shells compressed by supported and unsupported shocks, which are produced by continuous and picket laser pulses, respectively. The green areas at the ablation front indicate the locations of modulations originating from laser nonuniformities in the beginning of the pulses. These modulations can feed through to the shell (to the left) in the case of a supported shock [Fig. 1(a)] and cannot feed through in the case of a unsupported shock, which develops a post-shock rarefaction flow [Fig. 1(b)]. As a result, imprint is mitigated only in the latter case, in which modulations are localized near the ablation front and moved away (to the right) with the ablating mass.

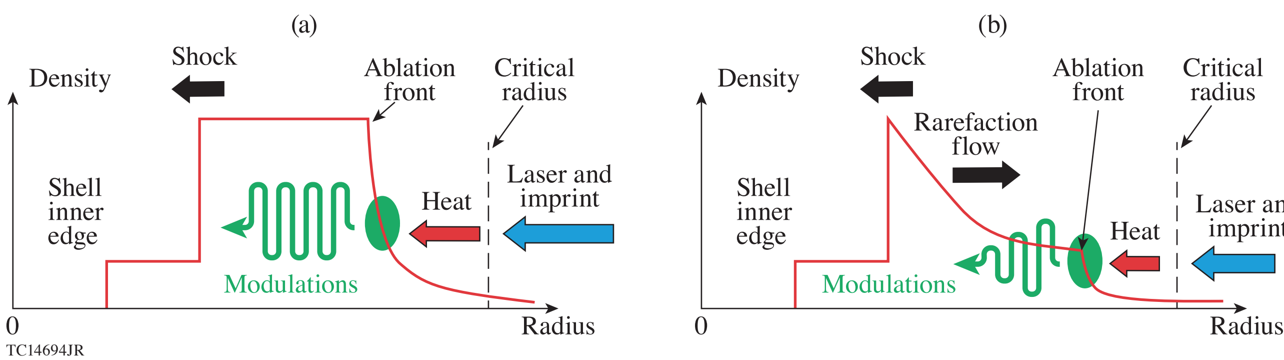

Figure 1
(a) Imprint modulations (the green area) localized at the ablation front can feed through to an implosion shell compressed by a supported shock but (b) cannot feed through in a shell compressed by an unsupported shock.

Three-dimensional *ASTER* simulations were used to demonstrate the new mechanism and employed two OMEGA cryogenic implosion designs having laser pulses with and without a picket. Simulations show that imprint is not mitigated in the no-picket design; therefore, large seeds for RT growth during the target acceleration phase are provided, resulting in a "broken shell" just prior to the target deceleration phase [see Fig. 2(a)]. This implosion shows poor performance, producing only 13% of neutron yield and 37% of neutron-averaged areal mass predicted in 1-D (symmetric) simulations. Contrary to this, simulations of the single-picket design, which develops an after-shock rarefaction flow, show apparent mitigation of the dangerous imprint modes $\ell \sim 100$ to 200. This implosion is characterized by relatively small-amplitude perturbations in the shell with dominant modes $\ell \sim$ 30 to 60 [see Fig. 2(b)] and produces 46% of neutron yield and 81% of neutron-averaged areal mass of those in 1-D simulations.

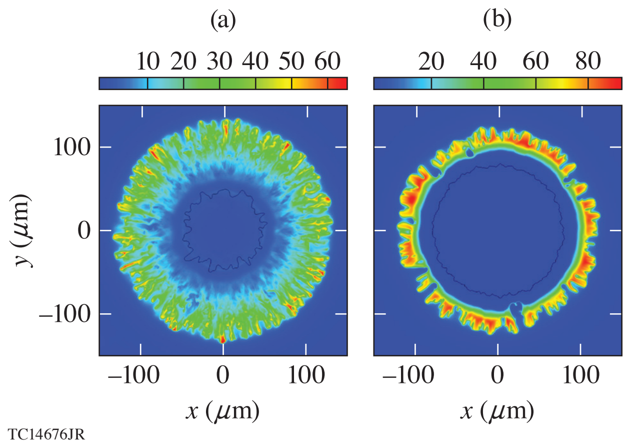

Figure 2
Meridional cross sections of the distribution of density (in g/cm^3) from 3-D simulations of the designs using the (a) no-picket and (b) single-picket laser pulses. The images are shown at times corresponding to moments prior to deceleration of the implosion shells.

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1. I. V. Igumenshchev *et al*., Phys. Plasmas **23**, 052702 (2016).

2. T. R. Boehly *et al*., Opt. Commun. **133**, 495 (1997).

3. Lord Rayleigh, Proc. London Math Soc. **XIV**, 170 (1883); G. Taylor, Proc. R. Soc. London Ser. A **201**, 192 (1950).