Measurements of Shock Heating Using Al Absorption Spectroscopy in Planar Targets





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The Effect of Plasma-Formation Rate on Laser Imprinting

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In direct-drive inertial confinement fusion (ICF), target perturbations imprinted by laser nonuniformities can seed instabilities that ultimately can degrade the target's performance. Since laser absorption and hydrodynamic instability occur in separate regions, the intervening plasma can smooth laser nonuniformities and "decouple" them from the instability. Imprinting occurs up to the *decoupling time*, defined as the time to form a plasma of length (d_c), sufficient to smooth nonuniformities with wave number (k), where $kd_c \sim 2$. The imprinting level therefore depends on perturbation wavelength and on the plasma formation rate, which, in turn, depends on the laser pulse shape. In addition, the imprint level depends on the temporal behavior of beam-smoothing techniques (which also depend on spatial frequency). By comparing measured imprint levels for cases with and without temporal beam smoothing, the decoupling times have been determined and are found to be in good agreement with simulations. The experiments were performed on the OMEGA laser using planar targets irradiated with UV beams having various pulse shapes and various beam-smoothing techniques. Laser imprinting was measured using x-ray radiography on targets with pre-imposed, singlemode spatial modulations that provided calibration of the imprint levels produced by the laser conditions studied. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460.

Summary

Experiments have demonstrated that shock heating can increase target stability

- Shock heating can decompress the target and increase the ablation velocity. *Ablative stabilization* reduces the effect of the R–T instability.
- Absorption spectroscopy is used to measure <u>both</u> shock heating and heat-front penetration.
- Square pulses produce shock heating to ~25 eV and behave close to 1-D predictions.
- Ramp pulses produce shock heating to <15 eV and exhibit early burnthrough due to the R–T instability.
- Stability analysis demonstrates a correlation between shock heating (ablative stabilization) and increased target stability.

X-ray absorption spectroscopy is used to study shock heating produced by square and ramp pulses



Al absorption spectroscopy shows progressive heating by shocks and the heat front



1-D simulations accurately predict heating by the shock and heat-front produced by a square pulse



Targets driven by ramped pulses produce no Al absorption lines, even when heated to >500 eV

Ramp pulse Al 5 μ m deep Al 5 µm deep 1.65 1.60 K-ed X-ray energy (keV) K-edge 1.60 Energy (keV) 1.55 1.55 He-like emission 1.50 1.50 1.45 1.45 1.40 0.0 0.5 1.0 1.5 3 0 2 1 Time (ns) Time (ns)

• Burnthrough is also observed for the 10- μ m-deep case.

For the ramp pulse, burnthrough is predicted only for the 5-µm case



Both pulses displace targets by similar amounts, but the ablation velocities are very different

E-folds of growth are proportional to distance traveled.



An RT mix layer around the 1-D ablation depths explains the burnthrough results



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