Feed-out of Rear-Surface Perturbations to the Ablation Interface and Subsequent Growth


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The transference of perturbations from the inside of a DT-ice layer to the ablation surface (called “feed-out”) is a potential problem for high-gain, direct-drive inertial confinement fusion targets. This problem has been addressed theoretically with a model that is valid for wave number times the compressed-target thickness $kd_c < 1$. The work described is a series of planar experiments designed to study the feed-out of rear-surface perturbations to the ablation interface. We irradiate 20-µm-thick CH targets with 351-nm radiation from the OMEGA laser. The incident laser pulse shape is a 1-ns rise to a 2-ns constant intensity of $1 \times 10^{14}$ W/cm$^2$. The single-mode, rear-surface perturbations have wavelengths of 60, 30, and 20 µm with an initial amplitude of 1 µm. The range for $kd_c$ for these experiments is from 0.5 to 1.5. The theoretical model is compared to both the 2-D hydrodynamic simulation and the experimental data. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority.

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Feed-out of the rear-surface perturbation has been measured for $0.6 < k d_{\text{compressed}} < 1.8$

- The experiment was configured to measure the feed-out of large-amplitude, rear-surface perturbations.

- Hydrodynamic simulations agree with the feed-out of a rear-surface perturbation and Rayleigh–Taylor growth on CH targets.

- Target $\Delta \rho$’s calculated from the theoretical model of R. Betti\textsuperscript{1} et al. agree with the experimentally measured optical depth.

Outline

Feed-out of rear-surface perturbations to the ablation interface and subsequent growth

- Experimental configuration
- Hydrodynamic simulations and experimental data
- Theoretical model and experimental data
The OMEGA laser system illuminated the target at $2.0 \times 10^{14} \text{ W/cm}^2$ with a beam nonuniformity of 2.4%.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot size at 90% IO</td>
<td>700 μm</td>
</tr>
<tr>
<td>Number of beams</td>
<td>6</td>
</tr>
<tr>
<td>Phase plates</td>
<td>super-Gaussian</td>
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<tr>
<td>Phase-plate order</td>
<td>4.5\left[e^{-\left(\frac{r}{r_0}\right)^{4.5}}\right]</td>
</tr>
<tr>
<td>Polarization</td>
<td>DPRs in 6 beams</td>
</tr>
<tr>
<td>Smoothing</td>
<td>2-D SSD</td>
</tr>
<tr>
<td>SSD bandwidth</td>
<td>0.2 THz</td>
</tr>
<tr>
<td>Drive nonuniformity</td>
<td>6.4% – 0.1 ns; 2.4% – 1 ns</td>
</tr>
</tbody>
</table>
Feed-out of the rear-surface perturbation was measured for three wavelengths.

- Perturbation wavelengths used were:
  - 60 µm with a 0.5 µm amplitude
  - 30 µm with a 0.5 µm amplitude
  - 20 µm with a 0.5 µm amplitude

- Target foils were constructed from 20-µm-thick CH.

- Targets with 60-µm wavelength perturbations had a front-surface amplitude = 10% of rear-surface amplitude (0.05 µm).
Hydrodynamic simulations of feed-out agree with the experimental data.
If the rear surface is rippled, the rippled rarefaction wave will imprint a perturbation on the ablation front (feed-out).
When the rippled rarefaction wave reaches the ablation front, it imprints a velocity perturbation and the ablation front develops a ripple that starts growing linearly in time.

\[ t = t_{rb} = \text{rarefaction-wave break-out time} \]

\[ \Delta t = \frac{A_r}{C_s} \]

\[ v = g \Delta t \]

\[ g(t_{rb}) = \frac{5}{2} \frac{P}{\rho d} \]

This theory is only valid for \( k d_c < 1 \).
The acceleration as calculated by a planar-foil model agrees with the results from *ORCHID* simulations.
Calculated $\rho R$ from Betti’s long-wavelength model agrees with experimentally measured optical depth.

- $\rho R$ is scaled by x-ray mfp and framing camera MTF.
Summary/Conclusions

Feed-out of the rear-surface perturbation has been measured for $0.6 < k d_{\text{compressed}} < 1.8$

- The experiment was configured to measure the feed-out of large-amplitude, rear-surface perturbations.
- Hydrodynamic simulations agree with the feed-out of a rear-surface perturbation and Rayleigh–Taylor growth on CH targets.
- Target $\Delta \rho r$’s calculated from the theoretical model of R. Betti\textsuperscript{1} et al. agree with the experimentally measured optical depth.