Effects of ablation and mode coupling on the deeply nonlinear stages of the Rayleigh-Taylor instability

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High-quality radiography was obtained of the nonlinear Rayleigh-Taylor instability (RTI) at the National Ignition Facility (NIF) to explore the role of ablation

- Previous experiments* used this platform to reach nonlinear stage of ablative RTI, but experienced unexpected behavior at late times, potentially due to perforation or other unpredicted phenomena**

- An initial experiment was recently performed to explain these discrepancies while simultaneously examining the role of ablation by doubling the target thickness, thus significantly reducing acceleration

- High-quality radiographic images were captured along three axes, the analysis of which is underway and will help resolve the discrepancies between theory, simulations, and experiments.

A second experiment is scheduled for 2022 and will explore the absolute effects of ablation velocity using Be targets.

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Collaborators

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The ablative Rayleigh-Taylor instability is expected to reach a self-similar behavior in its nonlinear stage

- Constant bubble velocity expected beyond so-called saturation limit**

- Predicted self-similar behavior in this nonlinear stage:

\[ h_b = \alpha_b g t^2 \]

- \( h_b \): Bubble height
- \( g \): Acceleration
- \( t \): Time
- \( \alpha_b \): Mixing parameter

Previous experiment captured face-on images

Post-processed radiographs*

Bubbles in white
Spikes in black

$300 \, \mu m \, CH$

$g \approx 5.4 \, \mu m/\text{ns}^2$

Drive 30 ns
440 kJ

Previous experiment captured face-on images, but saw no growth beyond saturation

Saturation Limit

Modes stagnated upon reaching saturation

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Previous experiment captured face-on images, but saw no growth beyond saturation, leading to bubble height stagnation instead of self-similarity.

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**Saturation Limit**

No self-similar behavior observed

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Saturation Limit**

Modes stagnated upon reaching saturation

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Theoretically predicted behavior†

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Previous experiment captured face-on images, but saw no growth beyond saturation, leading to bubble height stagnation instead of self-similarity ‡

Why do these modes stagnate, and why is this not seen in classical RTI experiments?

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‡ L. Ceurvorst, et al. To be submitted to Nature Communications.
New experiment designed to examine these discrepancies by doubling target thickness

- Increase target thickness to 600 µm
  - Prevents perforation
  - Reduces acceleration
  - Increases role of ablation
- Increase drive duration to 44 ns
  - Allows similar distance-traveled to be observed
- Add gated side-on radiography
  - Monitor for perforation
  - Observe any bowing effects
Thicker targets are diagnosed by three lines of radiography.

- Zn (8.8 keV) XRFC
- V (5.2 keV) DISC
- Sc (4.3 keV) XRFC

$600 \, \mu m \, CH$

$g \approx 2.9 \, \mu m/\text{ns}^2$
Thicker targets are diagnosed by three lines of radiography, each guarded with line-of-sight shields.
The same imprint beam as the previous experiment was used to create the initial surface perturbations 300 ps before main drive.
Target was driven for 44 ns to displace it to similar distances as before, allowing the results to be directly compared.
High-quality face-on radiographs were obtained

N211020-002

N211021-001

20 ns

27 ns

31 ns

35 ns

35 ns

38 ns

41 ns

44 ns
Analysis has begun
Analysis has begun, and early results suggest stagnation still exists.

Stagnation continues despite increased thickness!
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Side-on images were obtained for late times.