Multidimensional Study of High-Adiabat OMEGA Cryogenic Implosions

Bang time, 2.55 ns

Offset = 10.5 μm
σ_{ice} = 0.65 μm
5.3% power imbalance
8-μm mispointing
5-ps mistiming

Port geometry only
Laser-beam imbalances, ice roughness, target offset

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Simulations indicate that high-adiabat cryogenic implosion performance on OMEGA is dominated by target offset and ice roughness

- Cryogenic targets were imploded with a minimum shell adiabat of $\alpha \sim 7$, with smoothing by spectral dispersion (SSD) on and off, and with moderate- and high-intensity pulses
- 2-D simulations indicate that the primary loss of yield is a result of a reduction in the hot-spot volume caused by ice roughness and target offset
- High-adiabat experiments and simulations confirm that the shell remains integral despite laser imprint
Collaborators

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Cryogenic targets were imploded on a high adiabat to prevent shell breakup as a result of imprint and to explore a “1-D” regime*

- The predicted minimum adiabat is ~7, much higher than that of designs that scale to ignition
- These implosions use a single ~10-TW picket for low-mode growth with a convergence ratio (CR) of 13 and an in-flight aspect ratio (IFAR) of 15
- A comparison with high-intensity shots \( I \sim 10^{15} \text{ TW cm}^{-2} \) shows minor indications of intensity-dependent effects, such as ~10% increase in hot-spot size and ~6% reduction in \( \rho R \)

\*R. Betti et al., PO5.00008, this conference.
Imprint as a result of single-beam nonuniformities is expected to have a small effect on target performance

- Turning off SSD in warm-target implosions reduces the bang time and lengthens the burn*
- Shots based on the same pulse were performed with and without SSD
- Small changes in the pulse energy and spot size account for the majority of the 55-ps difference in bang times
- The burn duration [full width at half maximum (FWHM)] in both experiment and simulation is nearly identical when SSD is turned off

Drive nonuniformities have a modest impact on target yield in 2-D simulations

- A 5-ps beam mistiming, 8-μm mispointing, and 5.3% power imbalance were estimated experimentally.
- When these are simulated, the yield is degraded 8% relative to a “clean” simulation.
- The yield is degraded 12% when the power from modes with $m \neq 0$ is added in quadrature to the $m = 0$ modes to account, in part, for 3-D mode growth.
- High-adiabat, low-convergence implosions are expected to have little sensitivity to drive perturbations.

The power imbalance must be increased to over 20% to reproduce the experimental yield.
Ice roughness has a small impact on target performance for $\alpha \sim 7$ implosions

- Despite the large $\ell = 2$, the hot-spot volume is largely unchanged, leading to almost no reduction in yield
- The yield reduction relative to clean is 6%
Target offset is predicted to be the leading cause of target-performance degradation

• A simulation with target offset has a 12% degradation of yield relative to a “clean” simulation, approximately the same as all laser imbalances put together, with 10% power imbalance
• Simulations including beam mistiming, mispointing, and 5.3% power imbalance, with measured ice roughness and target offset, show a reduction in yield of 17% from the clean yield
• Even when the power imbalance is doubled to 10%, the yield degradation is just 26%
Burn widths are well reproduced by simulation

- Long-wavelength perturbations lead to a small amount of burn truncation
- 2-D ion temperatures are closer to experimental values

![Graph comparing simulated and experimental burn widths](image1)

![Graph comparing simulated and experimental hot-spot ion temperatures](image2)

Data are shown for high intensity (80802), low intensity (80807), and low intensity without SSD (80811)
DRACO simulations show hot-spot sizes comparable to those determined by integrated x-ray images

- The gated monochromatic x-ray imager (GMXI) was used to observe 4.5- to 6-keV x rays
- The hot-spot size is affected by the amount of mass ablated into the hot spot disruption
- The simulated hot-spot shape is more oblate than the GMXI image
High-adiabat implosions are being used to identify physical processes that must be better modeled or added to simulation

- Simulations reproduce expected trends but over-predict target yield
- 1-D modeling of the cryogenic implosion using the preheat inferred from the plastic-target implosions indicates an $\sim 10\%$* reduction of areal density and a 5% reduction of yield
- The power imbalance must be increased by $4 \times$ over the measured level to account for the observed yield degradation
- Other sources of performance degradation include
  - 3-D effects, notably asymmetric hot-spot fluid flow**
  - perturbations caused by the target mounting stalk, including possible ice-surface perturbations†
  - shell disruption caused by surface target debris
  - uncertainties in physics modeling
- Simulations will be performed modeling the first two of these, and efforts are underway to improve target characterization to the submicron level

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* J. A. Delettrez et al., UO9.00015; A. R. Christopherson et al., NO5.00007, this conference.
** K. S. Anderson et al., NO5.00011, this conference.
† D. Cao et al., TO5.00012, this conference.
Summary/Conclusions

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CBET has a modest effect on the spectrum of drive nonuniformities

- In CBET, an ion-acoustic wave couples incoming and outgoing laser beams, removing energy from incoming rays, and reducing the overall laser drive by as much as 40%
- CBET occurs nearly uniformly around the target
- CBET increases the deposition-weighted radius, resulting in a larger smoothing volume for drive perturbations