A Consolidated Picture of the Stagnated Fuel in Cryogenic Direct-Drive Implosions on OMEGA

High adiabat ($\alpha > 3.5$)
Long wavelength modes

Low adiabat ($\alpha < 3.5$)
Long wavelength modes and short-scale mix

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March 8-9, 2016
Lawrence Livermore National Labs CA
Inferred hot spot pressure is lower than simulated for low-adiabat implosions ($\alpha < 3.5$)

- Absolute pressures decrease with increasing calculated convergence or decreasing calculated adiabat
  - Hot spot radius is larger than simulated for low adiabat implosions (Marshall)
  - Significant $T_{\text{ion}}$ variations are measured for all implosions (Knauer)
  - Experimental neutron rate is truncated relative to simulation for all implosions
- A number of hypotheses have been proposed
  - long wavelength asymmetries [laser beam imbalances] - high and low adiabat
  - Too much mass in the hot spot prior to deceleration [short scale mix due to imprint/jets; relaxation at inner boundary due to secondary shocks, EOS errors] – high and low adiabat
  - Incoming shell density is too low (ineffective piston) [imprint growth at ablation front] – low adiabat
- Measurements addressing each hypothesis are in progress
Hotspot pressure is the primary metric of OMEGA direct-drive cryogenic target performance

- Hotspot pressure is derived from observations

\[
\text{Yield} = \int_{\Delta t_{\text{burn}}} dt \int_{V_{hs}} n_D n_T <\sigma v> dV
\]

\[
\text{Yield} \sim n_D n_T T^2 \left( \int_{V_{hs}} \frac{<\sigma v>}{T^2} dV \right) \Delta t_{\text{burn}}
\]

- Measured yield
- \( p_{hs}^2 \)
- Depends on measured \( T_i \) and \( V_{hs} \)
- Measured burnwidth

- The highest pressure to date is \( P_{hs} = 56 \pm 7 \) Gbar to be compared to the simulated value of 80 Gbar. \( C_r < 17 \) and \( \alpha > 3.5 \) proceed close to 1-D.

- DD requires \( P_{hs} > 120 \) Gbar; \( C_r > 22; \alpha = 1.5-3 \)
Multidimensional effects are believed to be primarily responsible for pressure degradation in high adiabat implosions

- Beam-to-beam variations – $T_{\text{ion}}$ variations, burn truncation
- Target offset – $T_{\text{ion}}$ variations
- Isolated defects, stalk/glue etc. – burn truncation, excess emission from hotspot

Neutron averaged V≈100km/s
Measurements show earlier peak burn and burn truncation.
Additional performance degradation in low-adiabat implosions is from short-scale mix

- 1D effects (speculative)
  - Is the density of the incoming shell low (shock mistiming, preheat?)
  - Is there more mass in the hotspot from 1D effects? (excess emission from hotspot)

- Multidimensional effects
  - Beam-to-beam variations – $T_{\text{ion}}$ variations, burn truncation
  - Target offset – $T_{\text{ion}}$ variations
  - Isolated defects, stalk/glue etc. – burn truncation, excess emission from hotspot
  - Laser imprint – ineffective piston, more mass in the hotspot – excess emission from hotspot
Hypotheses/Understanding

Additional performance degradation for low-adiabat implosions is caused by short-scale mix at the ablation front

- Observables that give clues on degradation mechanisms: evidence of mix in low-α implosions

**Cryo backlighting**

**α = 2.5**

- SCI-XRFC: 3.45 ns
- Spect3D no mix: 3.35 ns
- Spect3D 0.1% C: 3.35 ns
- Spect3D 0.2% C: 3.35 ns

**α = 4, no evidence of mix**

**X-ray core emission**

 normalized emission $y^{0.57}$

- Experiment
- Simulation
- Mix

Adiabat

SCI-XRFC: spherical crystal imager x-ray framing camera