Adiabat Shaping by Relaxation in Plastic and Cryogenic Shells for Experiments on the OMEGA Laser

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Mode amplitude (µm) at laser shutoff

Mode number

Flat
Relaxation

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2-D simulations have confirmed that adiabat shaping by relaxation suppresses RT growth

• Relaxation (RX) implosion experiments have been designed on OMEGA for both cryogenic and CH-plastic-shell targets.

• Simulations show lower RT growth rates and smaller overall growth with RX as compared to “flat” adiabat designs of similar 1-D performance.

• CH-shell implosions are planned for next month on OMEGA.
Cryogenic-capsule pulses are designed within limits of the current capabilities of OMEGA

- Total laser energy: 30 kJ
- 1-D, DT neutron yields $\sim 7 \times 10^{14}$
- 6-TW, 50-ps Gaussian prepulse (RX)
RX design leads to significantly higher ablation-front adiabats and ablation velocities

- Theoretical RT growth rates\(^1\) in DT ice:

\[ \gamma_{DT} = 0.94 \sqrt{\text{kg} - 2.7 \text{ kV}_a} \]

\(^1\) Betti et al. (1998); Takabe et al. (1985).
Single-mode 2-D simulations of imprint in DT cryo targets show reduced growth rates and lower perturbation mode amplitudes for RX designs.

$\delta l/l = 10^{-4}$

**Graphs:**
- Left: RT growth rate vs. Mode number, showing data points for Flat and Relaxation.
- Right: Mode number vs. Mode amplitude (µm) at laser shutoff, with data points for Flat and Relaxation.
CH capsule implosions are planned as proof-of-principle for the RX method

- Mitigating the RT instability in CH targets is more difficult than in cryogenic targets due to lower ablation velocities.

- The RX method has demonstrated in simulation a unique ability to significantly shape the adiabat and thereby lower RT growth rates in CH targets.

- Typical flat-adiabat designs exhibit RT cutoff at $\ell \gtrsim 1000$.

- RX designs could see RT cutoffs near $\ell \sim 600$. 
CH capsule pulses are designed within the current capabilities of OMEGA

- Total laser energy: 18 kJ
- 1-D, DD neutron yields $\sim 5 \times 10^{10}$
- 6-TW, 60-ps Gaussian prepulse (RX)
- Contrast ratio of 2 in RX main pulse
Relaxation adiabat shaping in CH is effective throughout the acceleration phase

- RX shaping is significantly higher than “natural” radiative shaping.

**Shock-breakout time**

- Ablation-front adiabat

**Near peak acceleration (R = 350 \( \mu m \))**

- Ablation-front adiabat

**Graphs:**
- Shock-breakout time
- Near peak acceleration

**Axes:**
- Adiabat
- Mass (\( \mu g \))

**Lines:**
- Flat
- RX
Ablation velocity for the shaped-adiabat design is significantly higher than for flat-adiabat design

- Plots are from shock-breakout time to end of pulse.
- RX curve shifted in time for better comparison.
- Theoretical RT growth rates\(^1\) in CH plastic:

\[
\gamma_{CH} \approx \sqrt{\frac{kg}{1+kL_m}} - 1.7 \text{ kV}_a
\]

\(1\) Betti \textit{et al.} (1998).
Single-mode 2-D simulations in CH targets show lower Rayleigh-Taylor growth rates for RX designs.

\[ \delta l/l = 10^{-3} \]

![Graphs showing RT growth rate and mode amplitude]
CH multimode simulations of 35-μm shells confirm the RX pulse shape is more stable

- Modes $\ell = 2$ to 300 simulated up to 130 ps after laser shutoff.

- Since cutoffs are much higher than $\ell = 300$, we expect this is a significant underestimate of RX stabilization.
Multimode simulations in CH targets show RX design exhibits better shell integrity

- Contours drawn at time = laser shutoff time + 130 ps.
- Density contours are drawn at 1/e points from max. density.

RX: $\sigma_{rms}(\text{outer}) = 1.73 \, \mu m$  $\sigma_{rms}(\text{inner}) = 0.23 \, \mu m$

Flat $\alpha = 3$: $\sigma_{rms}(\text{outer}) = 2.90 \, \mu m$  $\sigma_{rms}(\text{inner}) = 1.22 \, \mu m$
Two-prepulse, all-DT cryogenic design achieves peak ablation velocities of 15 $\mu$m/ns

Ablation velocity is comparable to indirect-drive designs!
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