ρR-asymmetry time evolution following low-mode drive asymmetry at OMEGA

Fredrick H. Séguin et al.
Massachusetts Institute of Technology
Plasma Science and Fusion Center

45th APS DPP Meeting, 2003
$\rho R$-asymmetry time evolution following low-mode drive asymmetry at OMEGA

Fredrick H. Séguin et al.
Massachusetts Institute of Technology
Plasma Science and Fusion Center

45th APS DPP Meeting, 2003
Summary

For asymmetric laser drive $I(\theta)$ dominated by mode numbers $\leq 3$, applied to room-temperature capsules with thick CH shells at OMEGA,

- $\delta I(\theta)$ produces $\delta \rho R(\theta)$ with the same shape;

- $\delta \rho R(\theta)$ maintains that shape throughout the implosion — different modes grow at the same rate; no phase inversions

- Amplitudes depend primarily on the radial convergence ratio $C_r$:
  \[
  \frac{\delta \rho R(\theta)}{\langle \rho R \rangle} \approx 0.4 \left( C_r - 1 \right) \frac{\delta I(\theta)}{\langle I \rangle}
  \]
Collaborators

University of Rochester
Laboratory for Laser Energetics

M.I.T.
Plasma Science
and Fusion Center

J.R. Rygg
J.A. Frenje
C.K. Li
R.D. Petrasso*

J.A. Delettrez
V.Yu. Glebov
V. Goncharov
R.L. Keck
J. Knauer
F.J. Marshall
P.W. McKenty
D.D. Meyerhofer
T.C. Sangster
V. Smalyuk
J.M. Soures

Lawrence Livermore
National Laboratory

S. Hatchett

*Visiting Senior Scientist, LLE

Fredrick H. Séguin et al.
Massachusetts Institute of Technology
Plasma Science and Fusion Center

45th APS DPP Meeting, 2003
Previous work with proton spectra indicated correlations between low-mode $I(\theta, \phi)$ and $\rho R(\theta, \phi)$ at OMEGA

- $\delta \rho R(\theta, \phi)$ growth due to spherical convergence effects should lead at bang time to*
  
  $$\frac{\langle \delta \rho R \rangle_{rms}}{\langle \rho R \rangle} = K(C_r - 1) \frac{\langle \delta I \rangle_{rms}}{\langle I \rangle}$$

  and that data for both room-temperature and cryo D$_2$ capsules are roughly consistent with this growth if

  $$K \sim \frac{1}{2}$$

* C.K. Li et al., submitted to PRL
New experiments have been performed with controlled drive asymmetries

60-Beam OMEGA laser:
Pulse shape: 1-ns square
Beam smoothing: 2D-SSD + PS
On-target energy: ~23 kJ

Asymmetry is dominated by \( P_1, P_2, P_3 \)

\[
\frac{A_\ell}{A_0}
\]

\[
\frac{I(\theta)}{\langle I \rangle}
\]

150-\( \mu \)m offset
\( \rho R \) was studied at two different times

\[ t = 0 \quad \text{1 ns} \quad \sim 1.7 \text{ ns} \quad \sim 2.1 \text{ ns} \]

- **"Shock Flash"**
  - \( \rho R \sim 15 \text{ mg/cm}^2 \)
  - \( C_r \sim 3.5 \)

- **Compression burn**
  - \( \rho R \sim 70 \text{ mg/cm}^2 \)
  - \( C_r \sim 8 \)

- D-\(^{3}\)He Burn
  - \( \rho R \sim \text{15 mg/cm}^2 \)
  - \( C_r \sim 3.5 \)

- D-\(^{3}\)He Burn
  - \( \rho R \sim \text{70 mg/cm}^2 \)
  - \( C_r \sim 8 \)

- D-\(^{3}\)He
  - (18 atm)
  - \( \sim 465 \mu\text{m} \)

- \( 26 \mu\text{m CH} \)

- \( Y \text{ield} / \text{MeV} \)

- \( \text{Proton Energy (MeV)} \)
J.A. Frenje – FL2.004
PTD and $\rho R$ evolution

V.Yu. Glebov – UP1-007
PTD

R.D. Petrasso – CO2.013
Dynamics of the shock convergence

~ 1.7 ns
~ 2.1 ns

D-$^3$He Burn
“Shock Flash”  Compression burn

time
\( \rho R \) was studied at different angles (typically 6)

Shot 31784:
offset = 0 \( \mu \)m

\[ \theta = 79^\circ \]

\[ \theta = 0^\circ \]

\[ \theta = 180^\circ \]
When the capsule was offset, spectra (and \( \rho R \)) were different at different \( \theta \)

Shot 31787: offset = 50 \( \mu m \)

\( \theta = 79^\circ \)

\( \theta = 180^\circ \)

\( \theta = 0^\circ \)
Fitting with \[ \rho R(\theta) = \sum_{\ell} A_{\ell} P_{\ell}(\cos \theta) \] gives us mode amplitudes.
\[ \langle \rho R \rangle \text{ at shock time is independent of offset, while } \langle \rho R \rangle \text{ at bang time decreases with offset} \]
\[
\frac{\langle \delta \rho R \rangle}{\langle \rho R \rangle} \neq K \frac{\langle \delta I \rangle}{\langle I \rangle}
\]
The previously-proposed scaling

\[
\frac{1}{(C_r-1)} \frac{\langle \delta \rho R \rangle_{\text{rms}}}{\langle \rho R \rangle} = K (C_r - 1) \frac{\langle \delta I \rangle_{\text{rms}}}{\langle I \rangle}
\]

works at different times with \( K \approx 0.4 \)
The angular dependence of $I(\theta)$ is carried through to $\rho R$ at shock time and at bang time.

\[ \frac{1}{0.4 \ (C_r - 1)} \frac{\delta \rho R(\theta)}{\langle \rho R \rangle} \]

at bang time

\[ \frac{1}{0.4 \ (C_r - 1)} \frac{\delta \rho R(\theta)}{\langle \rho R \rangle} \]

at shock time
The angular dependence of $I(\theta)$ is carried through to $\rho R$ at shock time and at bang time.

\[
\frac{\delta I(\theta)}{\langle I \rangle} = \frac{1}{0.4 \ (C_r-1)} \frac{\delta \rho R(\theta)}{\langle \rho R \rangle}
\]

at bang time

\[
\frac{1}{0.4 \ (C_r-1)} \frac{\delta \rho R(\theta)}{\langle \rho R \rangle}
\]

at shock time
Individual mode amplitudes scale as predicted

\[ \frac{A_\ell}{A_0} \quad \text{for} \quad I(\theta) \]

\[ \frac{1}{0.4 (C_r - 1)} \frac{A_\ell}{A_0} \quad \text{for} \quad \rho R(\theta) \]

![Graph showing mode number vs. amplitude ratio and correlation with \( I(\theta) \) and \( \rho R(\theta) \).]
Summary

For asymmetric laser drive $I(\theta)$ dominated by mode numbers $\leq 3$, applied to room-temperature capsules with thick CH shells at OMEGA,

- $\delta I(\theta)$ produces $\delta \rho R(\theta)$ with the same shape;

- $\delta \rho R(\theta)$ maintains that shape throughout the implosion — different modes grow at the same rate; no phase inversions

- Amplitudes depend primarily on the radial convergence ratio $C_r$: 

$$\frac{\delta \rho R(\theta)}{\langle \rho R \rangle} \approx 0.4 \left( C_r - 1 \right) \frac{\delta I(\theta)}{\langle I \rangle}$$