Measurements of shock timing and $\rho R$ evolution of D$^3$He implosions at OMEGA

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45th Annual Meeting of the Division of Plasma Physics
Albuquerque, NM
October 27-31, 2003
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Summary

Shock timing and $\rho R$ evolution of $D_3He$ implosions have been measured at OMEGA

- $D_3He$ burn history contains a shock component in addition to a compression history similar to that of DD neutrons.

- $T_i(t)$, shock time and shock-burn duration have been obtained and compared with 1-D calculations.

- Low-mode $\rho R$ asymmetries at shock time are amplified and mirrored at bang time, and correlated to laser drive asymmetry (for a large imposed $\ell = 1$).

- We are looking into $^3He$-seeded cryogenic $D_2$ implosions.
Related work

Related talks and posters at this conference:

- F.J. Marshall et al., CO2.005
- R. Epstein et al., CO2.008
- R. D Petrasso et al., CO2.009
- F. H. Séguin et al., CO2.011
- C. K. Li et al., CO2.012
- R. Rygg et al., CO2.013
- J. DeCiantis et al., CO2.015
- V. Yu. Glebov et al., UP1.007
- D. Wilson et al., B12.04

Recent related papers:

Outline

- Principle of measuring $\rho R$ evolution and $D^3\text{He}$ burn history
- Experiments
- Effects causing time dispersion in measured $D^3\text{He}$ burn history data
- Analysis method
- Results
- $^3\text{He}$-seeded cryogenic $D_2$ implosions
\( \rho R(t) \) can be inferred from \( D^3He \) proton spectrum and \( D^3He \) burn history

\[
D + ^3He \rightarrow ^4He + p \ (14.7 \text{ MeV})
\]
Three types of capsules were imploded

- Shock time
- Shock burn duration
- Nature of compression burn
- $T_i$ evolution
- Evolution of $\rho R$
- Evolution $\rho R$ asymmetries

60 laser beams
23 kJ energy
1 ns square laser pulse
1 THz, 2-D SSD+PS

20 µm CH
18 atm $D^3He$

24 µm CH
18 atm $D^3He$

27 µm CH
18 atm $D^3He$
D$_3$He proton spectra were simultaneously measured from different directions.
A proton temporal diagnostic (PTD) was implemented for measurements of $D^3$He burn history.
$^{3}\text{He}$ burn history and $^{3}\text{He}$ proton spectra were simultaneously measured.
PTD data must be corrected for time dispersion

Effects causing time dispersion:

- $\rho R$ evolution: Needs to be determined.
- Source and shell geometry: From Proton Core Imaging data and X-ray imaging data.
- Doppler broadening from $T_i(t)$: From measurements.
- PTD response: From Monte-Carlo simulations.
Using DD burn history, $\rho R(t)$ was initially determined from a fit to measured $D^3He$-proton spectrum.

A Lorentzian function was used as a $\rho R(t)$ function in the fitting procedure.
A convolution of D³He burn history and components causing time dispersion is fitted to measured PTD data.
Using unfolded $D^3He$ burn history, $\rho R(t)$ was finally determined from a fit to measured $D^3He$-proton spectrum.

A Lorentzian function was used as a $\rho R(t)$ function in the fitting procedure.
$D^3He$ burn history contains a shock component in addition to a compression history similar to that of DD neutrons.
By comparing measured $D^3He$ and DD bang times to 1-D calculations, effects of mix can be addressed.
Due to a broader burn profile, DD burn history is more sensitive to mix than D³He burn history.
Shock time and shock-burn duration have been obtained and compared to 1-D calculations.
Evolution of $T_i$ can be inferred from the ratio of $D^3He$ and DD burn histories.
Evolution of $T_i$ has been obtained and compared to 1-D calculations.
Evolution of $T_i$ has been obtained and compared to 1-D calculations.

![Graph showing proton and neutron rates over time, with 1-D calculations included.]
Evolution of $T_i$ has been obtained and compared to 1-D calculations.
How do $\rho R$ and $\rho R$ asymmetries evolve in time?

Nominally perfect implosion

![Plot showing the evolution of $\rho R$ and $\rho R$ asymmetries over time with different curves for TIM1 to TIM6 and PTD.](image_url)
Low-mode $\rho R$ asymmetry at shock time is amplified and mirrored at bang time.
Low-mode $\rho R$ asymmetry is primarily driven by capsule convergence

\[ \xi(t) = \frac{C_r(t) - 1}{C_r(t) - 1} \left( \frac{\langle \rho R(t) \rangle}{\langle \rho R \rangle_s} \right) \]

Convergence ratio $C_r(t)$ is defined as

\[ C_r(t) = \left( \frac{\langle \rho R(t) \rangle}{\langle \rho R \rangle_s} \right)^{1/2} \rho_0 R_0 \]

At shock time, $C_{r_s} \approx 5$
At bang time, $C_{r_b} \approx 10$
Is there a correlation between \( \rho R \) asymmetry and laser drive asymmetry (for a large imposed \( \ell = 1 \))?
$\rho R$ asymmetry is strongly correlated to laser drive asymmetry (for a large imposed $\ell = 1$)

$$\frac{\Delta \rho R(t, \Theta)}{\langle \rho R(t) \rangle} = k[Cr(t) - 1] \frac{\Delta I(\Theta)}{\langle I \rangle}$$

** F. H. Séguin et al., CO2.011
We are looking into $^3$He-seeded cryogenic $\text{D}_2$ implosions

α = 4 pulse

$3\text{-μm CH}$
$100\text{-μm D}_2$ ice
$^3$He seeded $\text{D}_2$ gas

Proton rate (1/s)

Time (ns)

$T_e$ (keV)

Shock-front position (μm)
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