Studying effects of drive asymmetry on burn asymmetry with proton emission imaging

Fredrick H. Séguin et al., M.I.T.

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Summary:

Low-mode asymmetry in the 3-D burn distribution directly reflects drive asymmetry

- Burn asymmetry amplitude is proportional to drive asymmetry
- Burn images, proton spectra, and x-ray images can provide a self-consistent picture of asymmetric capsule structure at burn time
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46th APS DPP Meeting, 2004
Three orthogonal proton imaging cameras are used at OMEGA.
Information about the spatial distribution of burn is extracted from penumbral images in two ways*

1-D reconstruction:

2-D reconstruction:

Penumbral image

* Séguin et al., RSI 75, 3520 (2004)
Spatial resolution in 2-D reconstructions is limited by noise filtering.

The noise filtering used here results in a Gaussian point-response function parameterized by a radius $r_p$:

$$e^{-\left(\frac{r}{r_p}\right)^2}$$

$$r_p \approx 15 \mu m \left(\frac{r_s}{30 \mu m}\right)^{4/5} \left(\frac{Y_s}{10^9}\right)^{-1/5}$$
The 2-D point-response function broadens the true structure.

Constrained in shape:

1-D reconstruction:
- Usually close to Gaussian

Unconstrained:

2-D reconstruction:
- (resolution > 15 µm)
A modified 2-D algorithm produces more accurate estimates of source sizes by constraining the source to belong to a family of functions:

- Circular, with Gaussian radial profile
- Elliptical, with Gaussian radial profiles
- 2 ellipses, with Gaussian radial profiles
The cameras were used to study burn asymmetry resulting from imposed laser drive asymmetry at OMEGA.
Prolate drive

OMEGA
Shots 35172,3
Three different axially-symmetric laser drive schemes have been compared.
Different drive asymmetries generate different burn asymmetries

Polar view

- Prolate: shots 35172, 35173
- Symmetric: shot 36020
- Oblate: shot 35174

Equator view

- Prolate: shots 35172, 35173
- Symmetric: shot 36020
- Oblate: shot 35174
Constrained reconstructions result in better estimates of actual sizes

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<th>Prolate</th>
<th>Symmetric</th>
<th>Oblate</th>
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-200 -100 0 100 200 µm
Burn asymmetry $\equiv \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}} + L_{\text{min}}}$
Increasing drive asymmetry $\rightarrow$ increasing burn asymmetry $\rightarrow$ decreasing yield

- Burn asymmetry
- $\langle \delta I \rangle / \langle I \rangle$
- Prolate
- Oblate
- Symmetric

- $D^3$He yield
- $\langle \delta I \rangle / \langle I \rangle$
- Prolate
- Oblate
- Symmetric
Burn image structure is roughly consistent with x-ray-image-implied fuel-shell interface

Large emission peak shows hot shell material near axis

See Reuben Epstein et al., H01.013, x-ray image simulation

xrfc at peak burn ( ~ 4 – 5 keV )
shot 35173

D$^3$He burn
shots 35172,3
Proton spectra provide additional information and strong constraints on capsule structure.
A self-consistent interpretation of structure involves two emission sources and cool material around the waist.
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