Direct-Drive Implosions on OMEGA with Optimized Illumination Uniformity

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Summary

Direct-drive illumination uniformity on OMEGA has been improved by using a new beam shape

• Several low $\ell$-mode sources of direct-drive illumination nonuniformity have been minimized:
  – beam pointing
  – beam-size variation
  – beam balance
  – target position

• A new distributed phase plate (DPP) design, yielding a different beam shape and size, has facilitated minimizing these contributors.

• With the new DPP design, the low $\ell$-mode illumination nonuniformities, averaged over time, have been reduced to $\sim 1\%$ rms.
The low $\ell$-mode contributors to illumination nonuniformities on OMEGA have been significantly reduced with new DPP’s

<table>
<thead>
<tr>
<th>Source</th>
<th>$\sigma_i$</th>
<th>$\ell$ mode</th>
<th>Previous DPP’s $n = 2.3$</th>
<th>New DPP’s $n = 3.7$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect beam</td>
<td>$\sigma_n$</td>
<td>10</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Beam imperfections</td>
<td>$\sigma_{\text{beam}}$</td>
<td>1–5, 10, 20</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Size variations</td>
<td>$\sigma_{\text{size}}$</td>
<td>1–6</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Pointing</td>
<td>$\sigma_{\text{pntg}}$</td>
<td>1–6</td>
<td>2.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Target position</td>
<td>$\sigma_{\text{pos}}$</td>
<td>1, 2</td>
<td>&lt; 1.0</td>
<td>&lt; 0.4</td>
</tr>
<tr>
<td>Beam balance</td>
<td>$\sigma_{\text{bal}}$</td>
<td>1, 2, 3</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{total}}$</td>
<td></td>
<td>3.3%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>
In the OMEGA 60-beam illumination geometry, there are beam shapes that optimize the uniformity.

- $n = 2.2$ and $3.6$ are preferred super-Gaussian orders.
- The $n = 3.6$ order is less sensitive to beam mispointing and beam-to-beam imbalance.

**SG3’s:**
- $n = 2.3$, $R_0 = 308 \, \mu m$
- $D_{95\%} = 930 \, \mu m$

**SG4’s:**
- $n = 3.7$, $R_0 = 380 \, \mu m$
- $D_{95\%} = 865 \, \mu m$
The new DPP design with a flatter profile is more optimum for direct-drive illumination on OMEGA.

Pointing surrogate images

Previous DPP
\(n = 2.3\)

New DPP
\(n = 3.7\)

ETP’s on OMEGA

Normalized intensity

Distance (\(\mu\)m)
Beam mispointing has been reduced to as low as 11-\(\mu\)m rms by active repointing.

<table>
<thead>
<tr>
<th>Before repointing</th>
<th>4-(\mu)m Au Pointing</th>
<th>After repointing</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-(\mu)m rms</td>
<td>Target Images</td>
<td>11-(\mu)m rms</td>
</tr>
</tbody>
</table>

Eight images per shot are used in analysis.
Nonuniformities resulting from beam mispointing have been significantly reduced.

Simulations of Gaussian mispointing distribution on OMEGA.

Nominal pointing

SG3 DPP’s

SG4 DPP’s

Best pointing with SG4 DPP’s
The beams of OMEGA have a larger area and a smaller beam-to-beam variation with SG4 DPP’s.

OMEGA beam area distributions with 1-THz SSD and PS

**With SG3 DPP’s**

- Average \( A = 0.30 \text{ mm}^2 \)
- \( \pm 7.0\% \)

**With SG4 DPP’s**

- Average \( A = 0.47 \text{ mm}^2 \)
- \( \pm 5.6\% \)
We have used the enhanced balance technique* to minimize on-target beam-to-beam differences.

Histograms of X-Ray-Determined Beam Peak Fluences

OMEGA shot 33571

\[ \sigma = 7.5\% \]

Standard balance

OMEGA shot 33579

\[ \sigma = 2.9\% \]

Enhanced balance

Minimizing the lowest $\ell$-mode nonuniformities with new DPP’s, enhanced beam balance, and beam repointing has resulted in more-symmetric implosions.

Framed x-ray images
15-atm-D$_2$-filled, 20-$\mu$m-thick CH-shell implosions

<table>
<thead>
<tr>
<th>TIM1</th>
<th>Standard balance and pointing</th>
<th>TIM2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak burn</td>
<td>+58 ps</td>
<td>Peak burn</td>
</tr>
<tr>
<td></td>
<td>+116 ps</td>
<td></td>
</tr>
</tbody>
</table>

100 $\mu$m

Enhanced balance and pointing
Summary/Conclusions

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