Mitigation of Cross-Beam Energy Transfer in Direct-Drive Implosions on OMEGA

OMEGA cryogenic ignition hydro-equivalent design
\[ \rho R = 300 \text{ mg/cm}^2, \ V_{\text{imp}} = 3.7 \times 10^7 \text{ cm/s} \]

\[ m = 48 \mu g, \quad \alpha = 1.7 \]

\[ m = 65 \mu g, \quad \alpha = 3.2 \]

Current stability threshold

Hydro-equivalent curve

Zooming (CH)

CBET curve

No CBET

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Reducing cross-beam energy transfer (CBET) on OMEGA will allow for more stable ignition-relevant implosions.

- CBET can be mitigated by reducing the diameter of the laser beams.
- Mitigating CBET increases the ablation pressure, allowing for thicker shelled targets and higher adiabats.
- Two approaches are being investigated on OMEGA to reduce the laser beams:
  - smaller laser spots—reduced beam-to-beam overlap
  - two-state zooming—increased single-beam imprint

Experiments to validate these schemes are underway.
Collaborators


University of Rochester
Laboratory for Laser Energetics
CBET reduces the energy coupled to the fusion capsule

CBET is spatially limited near $M \sim 1$

Energy is transferred between beams by ion-acoustic waves

CBET reduces the most hydrodynamically efficient portion of the incident laser beams.
CBET modeling is required to match the experimental observables (scattered light, implosion velocity, and bang time)*

CBET reduces the ablation pressure by \( \sim 45\% \).

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Experiments have demonstrated that CBET can be mitigated by reducing the radius of laser beams.

Reducing the radius of the beams will allow the thickness of the shell and the adiabat to be increased in a hydro-equivalent design but the reduced overlap uniformity may increase the imprint.


*V. N. Goncharov, GI3.00001, this conference (invited).
Simulations suggest that reducing the beam diameters by 20% ($R_b/R_t = 0.8$) will have minimal impact on the hot-spot symmetry.

Reducing the beam diameters by more than 20% significantly degrades the target performance.

Reducing the diameter of the laser beams beyond 20% after a sufficient conduction zone is generated ("zooming") is predicted to maintain good low-mode uniformity.

\[ \frac{R_b}{R_t} = 0.7 \]

\[ \sigma \approx 17 \, \mu m \]

\[ \frac{R_b}{R_t} = 1.0 \]

\[ \sigma < 3 \, \mu m \]

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\[ \sigma \approx 12 \mu m \]

Zooming from \( \frac{R_b}{R_t} = 1.0 \) to 0.7

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\[
\frac{R_b}{R_t} = 1.0 \\
\frac{R_b}{R_t} = 0.7
\]

Zooming from \( R_b/R_t = 1.0 \) to 0.7

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\[ r \text{ (\si{\mu m})} \]

\[ \sigma \approx 17 \mu m \]

\[ \sigma \approx 12 \mu m \]

\[ \sigma \approx 3.5 \mu m \]

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\[ \text{Power (} \times 10^{12} \text{ W)} \]

\[ \text{Time (} \text{ns)} \]

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\[ \rho (\text{g/cm}^3) \]

\[ 360 \]

\[ 240 \]

\[ 120 \]

\[ 0 \]

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Reducing the diameter of the laser beams beyond 20% after a sufficient conduction zone is generated ("zooming") is predicted to maintain good low-mode uniformity.
Zooming can be implemented on OMEGA using a radially varying phase plate and a dynamic near field.

Implementing zooming on OMEGA will provide a more-robust implosion to hydrodynamic instabilities.

Both CBET mitigation strategies on OMEGA will allow the mass of the shell and the adiabat to be increased while maintaining ignition-relevant conditions.

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