Comparison of the 2-D DRACO Cross-Beam Energy Transfer (CBET) Simulations with OMEGA and NIF Experiments

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43rd Annual Anomalous Absorption Conference
Stevenson, WA
7–12 July 2013
Summary

**DRACO** provides self-consistent cross-beam energy transfer (CBET) simulations that agree with experiments.

- CBET increases scattered light through stimulated Brillouin scattering (SBS) of outgoing rays that removes energy from incoming high-energy rays.
- Nonlocal electron thermal transport model has been added to **DRACO**.
- The 2-D hydrodynamics code **DRACO** employs feedback control to maintain energy balance with CBET.
- CBET improves agreement of hydrocodes with experiment.
Collaborators


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CBET* occurs nearly uniformly over the entire target for OMEGA direct drive

- OMEGA direct drive offers a high amount of symmetry, which is reflected in the CBET gain power density (W/cm³)
- The CBET effect can be successfully mitigated by reducing the beam diameter**

\[ \Delta E_{\text{CBET}} (\times 10^{14} \text{ W/cm}^3) \]

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

\[ z (\mu\text{m}) \]

CBET modeling in the 2-D hydrodynamics code *DRACO* employs an angular spectrum representation (ASR) approach with feedback control

- ASR captures the relevant intensity and direction information from all the beams that propagate through any cell

- Feedback through a PID-controller (proportional-integral-differential) loop provides vital control over CBET energy balance
  - left uncontrolled, CBET equations do not conserve energy; e.g., they lack energy depletion
  - feedback minimizes energy imbalance through a controlled PID-loop by temporarily adjusting the ASR until the adjustment reaches zero

- The ASR from the previous time step is used to increase convergence by providing an estimate of the current time step’s ASR
The polar-drive (PD) illumination scheme drives a target using the NIF x-ray-drive ports.
A 40-beam subset of the 60-beam OMEGA laser emulates the NIF x-ray-drive configuration.
OMEGA PD shot 64099 simulations predict the increased scattered light around the poles of the chamber

- OMEGA shot 64099 employed a set of calorimeters around the chamber to measure the theta dependence of scattered light

- A DRACO simulation of shot 64099 reproduces the measured data with CBET; flux limiters of 6% and 10% bracket the data

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**Scattered-light diagnostic**

- **Scattered light (J/sr)**
  - 100
  - 300
  - 500
  - 700
  - 900
  - 1100
  - 1300
- **Exterior surface**

- **Scattered light fluence (J/sr)**
  - 0
  - 200
  - 400
  - 600
  - 800
  - 1000
  - 1200
  - 1400

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**Graph**

- CBET 6% flux limiter
- CBET 10% flux limiter
- No CBET 6% flux limiter
- s64099 scattered cals

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**Legend**

- **Scattered-light diagnostic**
- **Exterior surface**

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**Polar angle (°)**

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
The NIF N130129 PD shot was used to commission neutron diagnostics

- N130129 is a 50-kJ, 1540-μm-diam target - Peak $I = 5.4 \times 10^{14}$ w/cm$^2$
- Beams were refocused and repointed to improve implosion symmetry
- The GXD-3 framing camera shows a distinctive square shape

The blue curves are the fits to the peak emission. Images are 1500 μm × 1500 μm.
The Schurtz-Nicolaï-Busquet (SNB) non-local model solves for the thermal flux using multi-group diffusion*

- The model is based on the linear steady state transport equations with appropriate diffusion mean-free-paths.
- The source at each point is defined as the multi-group Spitzer flux:

\[ U_g = \frac{1}{24} \int \frac{E_g/kT}{E_{g-1}/kT} \beta^4 e^{-\beta} d\beta Q_{sh} \]

- This is used in conjunction with the group parameter \( H_g \), which is the solution of the differential equation:

\[
\left( \frac{1}{\lambda_g(\bar{r})} - \frac{\lambda_g(\bar{r})}{3} \nabla \right) H_g(\bar{r}) = -\nabla \cdot \bar{U}_g(\bar{r})
\]

\( H_g(\bar{r}) \) to solve for the thermal flux:

\[
\nabla \cdot \bar{Q}_t(\bar{r}) = -\sum_g \frac{H_g(\bar{r})}{\lambda_g(\bar{r})}
\]

The model does not transport electrons but rather diffuses the Spitzer flux.

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Simulations of NIF N130129 (exploding pusher) show better agreement when the non local model is employed.

DRACO results have been processed with Spect3D™

*Prism Computational Sciences, Inc., Madison, WI 53711.
CBET reduces the equatorial drive in N130129 non-local simulations which is not visible in experimental data.

Shell trajectories are consistent among all three.

A timing difference of ~100 ps exists between simulations.
Higher-intensity NIF glass exploding-pusher target shot demonstrates the need of the CBET model

- N130225 is a 130-kJ, 1523-μm-diam target - Peak $I = 1.6 \times 10^{15}$

**NIF shot 130225**

- **DRACO**
  - No CBET: $r = 427 \, \mu m$
  - CBET: $r = 426 \, \mu m$

**Angle (°)**

- **Fraction-radial deviation (with fit)**
  - Fit
  - Experiment

- The simulation without CBET over drives the target equator
**Summary/Conclusions**

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