Laser-Direct-Drive Energy Coupling at $4 \times 10^{14}$ W/cm$^2$ to $1.2 \times 10^{15}$ W/cm$^2$ from Spherical Solid-Plastic Implosions at the National Ignition Facility

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Summary

Energy-coupling models are validated in the laser intensity range of $4 \times 10^{14}$ W/cm² to $1.2 \times 10^{15}$ W/cm² with PDD experiments of spherical solid-plastic targets on the NIF.

- The measurements provide experimental shock trajectories and shock collapse time.
- Agreement is obtained with the trajectories from 2-D DRACO radiation-hydrodynamics simulations using CBET* and nonlocal heat-transport models for three laser intensities.
  - The inferred experimental shock velocity is $4 \pm 3\%$ lower than the simulated velocity for $8 \times 10^{14}$ W/cm².

Future experiments will improve the measurement accuracy and field different laser pulse shapes. Similar experiments on OMEGA will test the scaling arguments of PDD implosions from OMEGA to the NIF.**

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PDD: polar direct drive
NIF: National Ignition Facility
CBET: cross-beam energy transfer
** C. Stoeckl et al., UO04.00002, this conference.
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Motivation

Previous NIF PDD energy-coupling experiments used shell-trajectory measurements inferred from coronal plasma emission and x-ray radiography.

NIF PDD implosion (0.65 MJ, $1.2 \times 10^{15}$ W/cm²)

Measured gated x-ray images ($dx = 30 \mu m$, $dt = 100$ ps)

Shell trajectory

Backlit image: Indicates match in modeled and measured $\nu_{imp}$ within 1%.

Self-emission: Indicates a 9% overprediction of $\nu_{imp}$ attributed to laser imprint and subsequent Rayleigh–Taylor growth.


$E_{min}$: minimum fuel energy required for ignition

$\nu_{imp}$: implosion velocity
Energy-coupling experiments relevant to LDD ignition-target designs are being conducted on the NIF using a spherical, solid-plastic target*

Solid spheres offer the advantage of quantifying energy coupling without the challenges from hydrodynamic instabilities of thin-shell implosions.

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One hundred eighty-four NIF laser beams irradiated the target in a PDD geometry with different laser pulse shapes.

The shock trajectory was recorded during and after the main drive over a ~7-ns time window for a peak intensity of $8 \times 10^{14}$ W/cm$^2$. 

$E_{\text{drive}} = 610$ kJ
$E_{\text{drive}} = 474$ kJ
$E_{\text{drive}} = 347$ kJ

$\langle E \rangle = 474$ kJ
$\langle E_{\text{back}} \rangle = 54$ kJ

Shock-trajectory measurements
The trajectory was recorded using a pinhole array imager on an x-ray framing camera with \(\sim 100\)-ps temporal and \(\sim 30\)-\(\mu\)m spatial resolution.
Two-dimensional DRACO simulations using CBET and nonlocal heat-transport models* accurately predict the energy coupling diagnosed with shock-trajectory measurements.

The simulations were post-processed with Spect3D** and take the instrument response function into account.

* R. Bahukutumbi et al., UO04.00001, this conference.
A slightly reduced experimental shock velocity is inferred for $8 \times 10^{14}$ W/cm$^2$ compared to simulations.

Future experiments will improve the measurement accuracy and field different pulse shapes.
Energy-coupling models are validated in the laser intensity range of $4 \times 10^{14}$ W/cm$^2$ to $1.2 \times 10^{15}$ W/cm$^2$ with PDD experiments of spherical solid-plastic targets on the NIF.

- The measurements provide experimental shock trajectories and shock collapse time.
- Agreement is obtained with the trajectories from 2-D DRACO radiation-hydrodynamics simulations using CBET* and nonlocal heat-transport models for three laser intensities:
  - The inferred experimental shock velocity is $4\pm3\%$ lower than the simulated velocity for $8 \times 10^{14}$ W/cm$^2$.

Future experiments will improve the measurement accuracy and field different laser pulse shapes. Similar experiments on OMEGA will test the scaling arguments of PDD implosions from OMEGA to the NIF.**

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Summary/Conclusions

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** C. Stoeckl et al., UO04.00002, this conference.
The arrival time of the shock in the center of the sphere was measured at $4 \times 10^{14} \text{ W/cm}^2$ from the x-ray flash created by the shock collapse.

The x-ray flash time from both diagnostics is in agreement, providing an average value of $13.61 \pm 0.05 \text{ ns}$, which will be compared to radiation-hydrodynamic simulations.