Planar Two-Plasmon–Decay Experiments at Polar-Direct-Drive Ignition-Relevant Scale Lengths at the National Ignition Facility

M. J. Rosenberg
University of Rochester
Laboratory for Laser Energetics

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Summary

A platform has been developed at the National Ignition Facility (NIF) to study two-plasmon–decay (TPD) hot-electron production at polar-direct-drive (PDD) ignition-relevant conditions.

- Planar-geometry experiments were performed on the NIF with predicted scale lengths of $\sim 0.5$ mm and $T_e > 3$ keV.
- Experimental evidence of TPD ($\omega/2$ emission and $T_{\text{hot}} \sim 40$ keV) was observed.
- The beam angle of incidence did not have a strong effect on the TPD.
Collaborators

A. A. Solodov, W. Seka, R. Epstein, J. F. Myatt, S. P. Regan,
M. Hohenberger, and T. J. B. Collins

University of Rochester
Laboratory for Laser Energetics

J. E. Ralph, D. P. Turnbull, J. D. Moody, and M. A. Barrios

Lawrence Livermore National Laboratory
PDD* is an alternative approach to achieving ignition on the NIF

NIF beams configured for indirect drive
(arranged around the poles)

Motivation

*S. Skupsky et al., Phys. Plasmas 11, 2763 (2004);
PDD ignition designs predict long density scale lengths and high electron temperatures under which TPD may occur.

2-D simulated plasma conditions for igniting PDD design

Currently, these coronal plasma conditions can only be created in NIF planar experiments.
Planar target TPD experiments on the NIF were designed using DRACO

The empirical TPD threshold is greatly exceeded $[\eta = I_{14}L_n,\mu m/(230T_{e,keV}) \sim 4]$ in this experimental design.
Two planar experiments were performed on the NIF to study the beam angle-of-incidence dependence of TPD.

Pole
Shot N150520: 23° and 30° beams (32 beams total)

Equator
Shot N150521: 45° and 50° beams (60 beams total)

Each experiment uses a laser drive with the longest allowable flat top while avoiding laser damage.
Principal measurements include the spectroscopy of a microdot layer, Mo K$_{\alpha}$ fluorescence, hard x-ray bremsstrahlung, and $\omega/2$ emission.
The electron temperature ($T_e$) is inferred from the isoelectronic ratio* of the Mn/Co K-shell emission lines.

DRACO predicts that the microdot is at the $n_c/4$ surface at $t = 2.0$ to 2.5 ns.

The measured Co/Mn He$\alpha$ line ratio indicates $T_e = 3.8 \pm 0.6$ keV at $n_C/4$

Future experiments will explore the effect of the microdot on plasma conditions.
ω/2 emission indicates TPD is driven during the flat top of the laser pulse

The ω/2 signal is weak because the viewing angle is far from optimal.
$\omega/2$ emission indicates TPD is driven during the flat top of the laser pulse.

The $\omega/2$ signal is weak because the viewing angle is far from optimal.
TPD-generated hot electrons were observed via hard x-rays and $K_\alpha$ fluorescence.

The beam angle of incidence did not have a strong effect on TPD hot-electron production for the first $\sim 5.5$ ns.
The hard x-ray and $\omega/2$ signals have similar temporal histories

Pole
Shot N150520: 23° and 30° beams

Equator
Shot N150521: 45° and 50° beams

The hard x-ray and $\omega/2$ signals have similar temporal histories.

- **Pole**
  - Shot N150520: 23° and 30° beams
  - 23° and 30° beams

- **Equator**
  - Shot N150521: 45° and 50° beams
  - 45° and 50° beams

The hard x-ray and $\omega/2$ signals have similar temporal histories.

$\omega/2$ (normalized)
Laser pulse
Hard x rays (~50 keV)
Time-integrated hard x-ray spectra indicate $T_{\text{hot}} = 40 \pm 5$ keV for both experiments.

Measured time-integrated hard x-ray spectrum (N150521 data integrated over the duration of the N150520 laser pulse)

$T_{\text{hot}} \sim 40$ keV is consistent with TPD.
A platform has been developed at the National Ignition Facility (NIF) to study two-plasmon–decay (TPD) hot-electron production at polar-direct-drive (PDD) ignition-relevant conditions

- Planar-geometry experiments were performed on the NIF with predicted scale lengths of \(~0.5\) mm and \(T_e > 3\) keV
- Experimental evidence of TPD (\(\omega/2\) emission and \(T_{hot} \sim 40\) keV) was observed
- The beam angle of incidence did not have a strong effect on the TPD

These experiments will be used to assess laser–plasma simulation environment (LPSE) simulations* and test the theory that larger angles of incidence have a lower TPD threshold (more hot electrons).**

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* J. F. Myatt et al., presented at the 44th Annual Anomalous Absorption Conference, Estes Park, CO, 8–13 June 2014.

Future work will explore the use of higher-Z ablators to mitigate TPD in the $\eta > 1$ regime.

The Si ablator reduces hot electrons in NIF PDD implosions.

Table: Reduction of hot electrons ($f_{hot}$) with different laser powers and temperatures.

<table>
<thead>
<tr>
<th>Temperature (keV)</th>
<th>CH laser power $8 \times 10^{14}$ W/cm²</th>
<th>Si laser power $12 \times 10^{14}$ W/cm²</th>
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<tr>
<td>30</td>
<td>Must be below 0.0</td>
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</tr>
<tr>
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</tr>
<tr>
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