Modeling Two-Plasmon–Decay Experiments at Direct-Drive Ignition-Relevant Plasma Conditions at the National Ignition Facility

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Shot N150520

Hot-electron conversion efficiency

Conversion efficiency (%)

Time (ns)

Laser power (×8 TW)

$T_{\text{hot}} = 40 \text{ keV}$

$T_{\text{hot}} = 50 \text{ keV}$

57th Annual Meeting of the American Physical Society
Division of Plasma Physics
Savannah, GA
16–20 November 2015
Summary

A new planar-target experimental platform was developed to investigate the impact of two-plasmon decay (TPD) in direct-drive (DD)–ignition designs.

- Planar experiments at the National Ignition Facility (NIF) studied the beam angle-of-incidence dependence of TPD.
- A laser-energy conversion efficiency of ~1% into hot electrons with $T_e = 40$ keV to 50 keV was found.
- The beam angle of incidence did not have a strong effect on TPD.
Collaborators

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¹M. J. Rosenberg et al., NO5.00006, this conference.
²R. Epstein et al., NO5.00008, this conference.
Planar NIF experiments explore TPD in more extreme conditions than OMEGA and current NIF polar-direct-drive experiments

Coronal conditions predicted by DRACO radiation–hydrodynamic simulations

<table>
<thead>
<tr>
<th>Parameters at $n_c/4$ surface</th>
<th>OMEGA*</th>
<th>Current NIF DD**</th>
<th>Ignition NIF DD***</th>
<th>Planar NIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_L$ (W/cm$^2$)</td>
<td>$&lt;4 \times 10^{14}$</td>
<td>$4.5 \times 10^{14}$</td>
<td>$8 \text{ to } 10 \times 10^{14}$</td>
<td>$6 \text{ to } 9 \times 10^{14}$</td>
</tr>
<tr>
<td>$L_n$ ($\mu$m)</td>
<td>$&lt;350 \mu$m</td>
<td>$350 \mu$m</td>
<td>$600 \mu$m</td>
<td>$550 \text{ to } 600 \mu$m</td>
</tr>
<tr>
<td>$T_e$ (keV)</td>
<td>$&lt;2.5$ keV</td>
<td>$3.5$ keV</td>
<td>$5$ keV</td>
<td>$3.2$ keV</td>
</tr>
</tbody>
</table>

Two planar experiments were fielded on the NIF to study the beam angle-of-incidence dependence of TPD.

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

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

Post-shot DRACO simulated conditions at $n_c / 4$

The empirical TPD threshold is exceeded in this experimental design: $\eta = I_{14} L_{n14} / (230 T_{e, keV}) \sim 4$ to 5.
Laser-energy-to-hot-electron conversion efficiency and x-ray spectra were computed using Monte Carlo EGSnrc* simulations

- EGSnrc models the hot-electron transport, hard x-ray emission, and Mo $K_\alpha$ fluorescence
- Plasma profiles are taken from DRACO simulations
- Hot electrons are injected
  - at $n_c/4$ surface ($r < 500 \mu m$)
  - isotropic in the forward $2\pi$ solid angle
  - temperature $T_{\text{hot}} = 40$ to $50$ keV from the hard x-ray spectra

*I. Kawrakow et al., NRC, Ottawa, Canada, NRCC Report PIRS-701 (May 2011).
Measured and simulated time-integrated hard x-ray spectra compare well

Time-integrated hard x-ray spectra indicate $T_{\text{hot}} = 40$ to 50 keV, consistent with TPD.
Absolute hard x ray and Mo K\(\alpha\) emission levels indicate the laser-energy-to-hot-electron conversion efficiency is \(\sim\)1% in both shots.

- The overall conversion efficiency is 0.5% to 1.0\% \((T_{\text{hot}} = 40\ \text{to}\ 50\ \text{keV})\) in shot N150520 and 0.7% to 1.3% in shot N150521 (during the first 5 ns).

**Shot N150520: 23° and 30° beams**

- From hard x rays
- From Mo K\(\alpha\)

**Shot N150521: 45° and 50° beams**

- From hard x rays
- From Mo K\(\alpha\)

\(T_{\text{hot}} = 40\ \text{keV}\) and \(T_{\text{hot}} = 50\ \text{keV}\).

Not DD relevant.
The 3-D laser-plasma simulation code LPSE* models TPD in the experiments

*J. F. Myatt et al., NO5.00002, this conference.
*LPSE* simulations confirm the onset of TPD when the threshold parameter $\eta \sim 1$

- *LPSE* shows a similar onset of TPD for the 45° and 50° shot
- *LPSE* overestimates the hot-electron production
- The mechanisms of TPD saturation such as pump depletion are being implemented in *LPSE*
Summary/Conclusions

A new planar-target experimental platform was developed to investigate the impact of two-plasmon decay (TPD) in direct-drive (DD)–ignition designs.

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- A laser-energy conversion efficiency of \( \sim 1\% \) into hot electrons with \( T_e = 40 \text{ keV to 50 keV} \) was found.
- The beam angle of incidence did not have a strong effect on TPD.