Experimental Scalings for the Two-Plasmon-Decay Instability

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Overlapped intensity ($10^{14}$ W/cm$^2$)

Fractional fast-electron preheat (preheat energy/laser energy)

Systematic error bar

H: 250 $\mu$m $\phi$
L: 500 $\mu$m $\phi$
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Summary

The hot electrons from the TPD instability scale predominantly with intensity and density scale length.

- The hot-electron production from the TPD instability shows a strong exponential scaling with total (overlapped) intensity in both planar and spherical experiments.

- The TPD instability appears to saturate above $10^{15}$ W/cm$^2$ for planar experiments with NIF-relevant scale length, at $\sim$0.1% fractional preheat.

- Beam smoothing techniques affect the hot-electron production only moderately, polarization wedges decrease (by a factor of 2) the hard-x-ray signal, 1-THz SSD increases the signal by 20%.

- The density scale length at quarter-critical density has a strong effect on the TPD instability, both in magnitude and scaling with intensity.
Hot electrons can significantly reduce the target gain

- The effect of an 80-keV hot-electron tail was simulated using the fast-electron package in LILAC.
- About 4% of the energy absorbed into fast electrons couples into the DT-ice fuel layer.

![Diagram showing the effect of hot electrons on DT fuel and DT-ice layer.]

Fractional energy into fast electrons (%)

![Graph showing the relationship between fractional energy in DT-ice layer and gain.]

Fractional energy in DT-ice layer (%)
Four hard x-ray detectors using single-edge-type filters are used to measure the hot-electron temperature.
Improvements in the single-beam nonuniformity by SSD or PS affect the hard x-ray emission for spherical targets.

- CH shell, 950-\textmu m diam., 1-ns square, varying single-beam intensity

\[
\text{Signal} = 0.013 \times \exp\left(\frac{I_{14}}{1.2}\right)
\]

Absorbed energy (% of energy)
In spherical geometry, the overlapped intensity on target depends on the target diameter.
The TPD instability scales with overlapped intensity in spherical implosion experiments

- Data taken on 60-beam OMEGA shots with CH shells varying from 900-μm to 1100-μm diameter

Diameter (μm)

Signal (arbitrary units)

Temperature $T_{hot}$

$3\omega/2$

~ exp ($I_{14}/1.2$)

X rays > 50 keV

Overlapped intensity ($10^{14}$ W/cm²)
Planar-foil experiments use three sets of delayed beams, six of which are interaction beams.
For current OMEGA implosions the temporal evolution of the hard x rays reflects the increasing density scale length.

- Current OMEGA implosion experiments
- Multibeam, long-scale-length interaction experiments
The hard-x-ray detectors (scintillator-PMT) are cross-calibrated with $K_\alpha$ emission from special targets.

- Comparison of signals and some analysis allow HXRD’s to be absolutely calibrated for pure-CH or D$_2$ targets.

![Diagram showing the interaction of electrons and x-rays with the target materials.](image-url)
In planar experiments TPD scales with overlapped intensity and saturates above $10^{15}$ W/cm².

- Planar CH targets, 100 μm thick, multiple-overlapping beams

![Graph showing the relationship between overlapped intensity and fractional fast-electron preheat.](image)
The hard-x-ray signal is strongly affected by the density scale length.

- CH shell, 950-μm diameter, 1 ns square, varying overcoat

Signal (arbitrary units) ~ \( \exp \left( \frac{I_{14}}{1.2} \right) \)
Simulations show that the density scale length is shorter for the high-Z targets.

- $T_e \sim 2.5$ keV at $0.25 \, n_c$

![Graph showing $n_e/n_c$ vs. Distance (μm) for different materials: Au, Cu, CH.](image-url)

- Materials: Au, Cu, CH
Long-scale-length planar and spherical experiments show different intensity scalings

\[ \sim \exp \left( \frac{I_{14}}{1.2} \right) \]

\[ \sim \exp \left( \frac{I_{14}}{0.7} \right) \]
Summary/Conclusions

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• The hot-electron production from the TPD instability shows a strong exponential scaling with total (overlapped) intensity in both planar and spherical experiments.

• The TPD instability appears to saturate above $10^{15}$ W/cm$^2$ for planar experiments with NIF-relevant scale length, at ~0.1% fractional preheat.

• Beam smoothing techniques affect the hot-electron production only moderately, polarization wedges decrease (by a factor of 2) the hard-x-ray signal, 1-THz SSD increases the signal by 20%.

• The density scale length at quarter-critical density has a strong effect on the TPD instability, both in magnitude and scaling with intensity.