Multiple-Beam Effects on the Fast-Electron Generation due to the Two-Plasmon-Decay Instability

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

Fractional preheat level (preheat energy/laser energy)

$P_f \sim \exp \left( \frac{I_{14}}{2.63} \right)$

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Contributors


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The two-plasmon-decay (TPD) instability appears to saturate around \(10^{15}\) \(W/cm^2\) under NIF direct-drive ICF conditions.

- Multibeam experiments showed the importance of total (overlapped) intensity for TPD-generated fast electrons.
- Both spherical implosions on OMEGA and planar target experiments with NIF-relevant scale lengths show similar scalings.
- Target preheat by fast electrons due to TPD instability appears to saturate around \(10^{15}\) \(W/cm^2\).
- Fractional energy preheat level of \(~ 0.1\%\) for illumination conditions relevant to direct-drive ICF is inferred.
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.
The $3\omega/2$ signature of the two-plasmon-decay instability is produced by Thomson scattering.
Four hard x-ray detectors using single-edge-type filters are used to measure the hot-electron temperature.
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

\[ T_{\text{hot}} \sim \exp \left( \frac{I_{14}}{1.19} \right) \]

\[ X \text{ rays} > 50 \text{ keV} \]
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 (> 50-keV) signal depends only on the overlapped intensity and saturates above $10^{15}$ W/cm$^2$. 

The graph shows NIF scale planar experiments with the signal in arbitrary units plotted against the overlapped intensity in $10^{14}$ W/cm$^2$. The relationship is given by $\sim \exp(I_{14}/1.19)$. The data points are color-coded by the number of beams: blue for 2 beams, red for 3 beams, and black for 6 beams.
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:

- Ti (4 µm) absorbs x rays generated in the corona and passes energetic electrons.
- CH
- K$_{\alpha}$
- V (40 µm) (K$_{\alpha}$ electron pumped)
- HXR
- e$^-$
- HXRD’s
Using two different materials allows to separate the effects of radiation and hot electrons.
The fractional preheat level caused by energetic electrons due to TPD appears to saturate above $10^{15} \text{ W/cm}^2$.

\[ P_f \sim \exp\left(\frac{I_{14}}{2.63}\right) \]

Diagram: Plot of \( P_f \) vs. overlapped intensity for 100-\(\mu\)m-thick CH slabs.
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