Analyses of Long-Scale-Length Plasma Experiments with Different Ablator Materials on the OMEGA EP Laser System

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Mitigating the two-plasmon-decay (TPD) instability in long-scale-length plasmas has been investigated with different ablators on OMEGA EP

- OMEGA EP is used to study laser–plasma-interaction (LPI) processes in NIF-scale plasmas
- NIF-scale-length plasmas ($L_n \sim 300$ to $400 \ \mu$m) of CH, saran, and aluminum have been created with various beam energies available on OMEGA EP
- Fast-electron generation from TPD instability are reduced by a factor of 3 to 10 for saran and aluminum plasmas, compared to the CH case at the same intensity
- Two-dimensional DRACO simulations suggest that saran may be a better ablator for the direct-drive–ignition design since it balances TPD mitigation and hydro-drive efficiency

Summary
Collaborators


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Direct-drive NIF designs require accurate assessments of LPI processes in long-scale-length plasmas
Hot electrons from TPD have been measured in long-scale-length \((L_n \sim 400 \mu m)\) plasma experiments with plastic-CH targets*

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Mitigating the TPD instability is important for reducing the possibility of compression reduction by hot electrons

• The TPD-threshold parameter* is defined as,

\[ \eta = \frac{I_q \times 10^{14} \text{ W/cm}^2 \times L_n \text{ (\mu m)}}{230 \times T_e \text{ (keV)}} \]

• Long-scale-length plasmas \((L_n > 400 \mu \text{m})\) are inevitable in direct-drive–ignition implosions on the NIF

• The TPD threshold parameter could be decreased by reducing \(I_q\), increasing \(T_e\), and decreasing \(L_n\)

• Ablator materials with \(\langle Z \rangle\) larger than the typical plastic-CH \((\langle Z \rangle \sim 3 \text{ to } 3.5)\) may have advantages of suppressing TPD-instability as a result of
  – more absorption so that less intensity reaches quarter-critical regime
  – hot-electron temperature at the quarter-critical regime
  – scale-length can be reduced

*A. Simon et al., Phys. Fluids 26, 3107 (1983).*
Experiments on OMEGA EP use large (1-mm) DPP’s to create long-scale-length plasmas with Mo-CH-ablator “sandwich” targets.

OMEGA EP shot 9647-saran (9.1 kJ)

Laser intensity ($\times 10^{14}$ W/cm²)

Time (ns)

5 to 30 μm Al, saran, or CH

Four OMEGA EP beams (23°)

30 μm Mo

20 μm CH

TC10030
DRACO simulations show lower laser intensities at $n_c/4$ for Saran and Al in contrast to CH.
DRACO simulations show different density-scale-length $L_n$ at $n_c/4$ for Saran and Al in comparison with CH.
The temperature at $n_c/4$ is higher for Saran and Al when compared to the CH case.
Finally, the TPD-threshold parameters ($\eta$) are smaller for saran and Al when compared to the CH case.
Experimental results have shown a factor of 3 to 10 reduction in TPD-induced hot-electron signals for saran ($\langle Z \rangle = 8$) and aluminum ($Z = 13$) compared to the CH-ablator case.

![Graphs showing hard x-ray signal and calculated TPD parameter vs. incident laser intensity for CH, Saran, and Al.](TC10031)
The hydro-drive efficiency must be considered when fighting/mitigating TPD instability in long-scale-length plasmas

- Although mid-/high-Z ablators can suppress the hot-electron generation from TPD instability, they may not be efficient for hydro drive because thermal conduction in plasmas is scaled with $1/Z$

- Radiation loss and radiative preheat are among the concerns when high-$\langle Z \rangle$ ablators are considered for direct-drive–ignition designs

- A balance between TPD-instability mitigation and maintaining an acceptable hydro-efficiency must be made
Optimal mid-Z (= 3 to 8) ablators can not only mitigate TPD instability, but also give acceptable hydro-efficiency.

Early time of drive: saran ablator gives only ~10% lower drive pressure.
DRACO simulations show that saran may be a better ablator for both mitigating TPD instability and maintaining acceptable hydro-efficiency.

The small shock-front position difference (~2 μm) indicates the acceptable drive efficiency of a saran ablator.
Summary/Conclusions

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