Limits on the Level of Fast-Electron Preheat in Direct-Drive–Ignition Designs

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Result of retuning, straight-line transport

Gain

Energy into DT-ice layer (% laser energy)

Before retuning
Retuning the pickets
Retuning the rise time

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Summary

Fast-electron preheat in excess of 0.2% of the laser energy reduces the 1-D gain by 30%

- Optimized high-gain ignition targets are sensitive to preheat
- Fast electrons will increase preheat and reduce gain
- The gain reduction is dependent on the fast-electron-transport model
- Preheat effects from the fast electrons can be slightly reduced by reoptimizing the ignition targets
Collaborators

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Optimal target implosions\(^*\) have low preheat, which leads to high energy gains on the National Ignition Facility (NIF) laser.

\[ E = 1.5 \text{ MJ} \]

Picket power and timing, and the rise time of the drive portion of the pulse, control the preheat in the DT ice.

The fast electrons in *LILAC* are transported using either a straight-line method or a diffusion model

- The energy distribution of 40- to 50-keV electrons spans the two transport regimes; the two models bracket the uncertainty in the transport model

- In the straight-line model, the electrons are created with a 90° half-angle divergence, directed into the target,* and lose energy according to the stopping power derived by C. K. Li and R. D. Petrasso** and A. A. Solodov†

- In the diffusion model, flux limiting is replaced by a streaming description of the long mean-free-path electrons‡

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*B. Yaakobi et al., Phys. Plasmas 20, 092706 (2013).*

**C. K. Li and R. D. Petrasso, Phys. Rev. E 70, 067401 (2004).*

†A. A. Solodov and R. Betti, Phys. Plasmas 15, 042707 (2008).*

‡J. Delettrez and E. B. Goldman, Laboratory for Laser Energetics, University of Rochester, Rochester, NY, LLE Report No. 36 (1976).*
In both models, the fast-electron source tracks the conditions at the quarter-critical surface during the pulse

- The energy source scales as $F_{\text{fast}} S(\eta)$, where $F_{\text{fast}}$ is a free parameter and $\eta = I_{14} \times L (\text{mm}) / [233 \times T(\text{keV})]$ is the threshold parameter*

- The electrons are created at the quarter-critical surface with the temperature $T_h = 8.0 \times I_{14} - 22.0$ (keV), a fit to OMEGA experiments

- Using this source function replicates well the measured temporal hard x-ray emission**

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Ice-layer preheat from fast electrons must be kept below 0.1% to 0.18% of the laser energy to maintain 30% of the 1-D gain.

The higher preheat limit in the diffusion model is caused by differences in the spatial energy deposition by the fast electrons.
The optimizing code \textit{TELIOS*} was used to reduce the effects of fast-electron preheat

- \textit{TELIOS} uses the downhill simplex method (Nelder–Mead method) to optimize the gain from \textit{LILAC} runs by varying target and pulse parameters

- Two adjustments were carried out to compensate the preheat from fast electrons by reducing the preheat from shocks
  - picket timing and power
  - rise time of the main pulse

- The drive portion of the pulse is kept constant

*\textit{T. J. B. Collins et al., Phys. Plasmas} 19, 056308 (2012).*
Gain improvements by optimizing the picket power and timing were about 30% for both models.

Both retuning methods yield comparable gain improvement, reducing the shock preheat by the same amount.
Fast-electron preheat in excess of 0.2% of the laser energy reduces the 1-D gain by 30%.

- Optimized high-gain ignition targets are sensitive to preheat.
- Fast electrons will increase preheat and reduce gain.
- The gain reduction is dependent on the fast electron transport model.
- Preheat effects from the fast electrons can be slightly reduced by reoptimizing the ignition targets.
- Fast-electron preheat can also be reduced by using multilayer ablators*

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*M. Lafon et al, JO4.00011, this conference; D. H. Edgell et al, PO4.00002, this conference.*