A Numerical Model for Hot-Electron Generation in Direct-Drive Implosions

J. F. Myatt
University of Rochester
Laboratory for Laser Energetics

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The new hot-electron package in $LPSE^*$ enables hot-electron production caused by two-plasmon decay (TPD) to be computed in spherical implosions.

- The recent “alternate ablator” campaign on OMEGA has been simulated with the laser–plasma instability (LPI) code $LPSE$

- The temporal behavior and strength of the hot-electron signatures are predicted to differ between the three ablator materials (CH, Be, and CHSi-Si-Be)
  - $LPSE$ predicts the lowest hot-electron fraction in the Be-Si-CHSi target
  - Be and CH are predicted to be similar

- The goal of this campaign was to demonstrate hot-electron reduction in multilayer targets

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*Laser-plasma simulation environment ($LPSE$)
Collaborators


University of Rochester
Laboratory for Laser Energetics

D. F. DuBois and D. A. Russell
Lodestar Research Corporation

H. X. Vu
University of California, San Diego
LPSE is designed to perform large-scale simulations of laser–plasma interactions, where the three-dimensional geometry is essential

- LPSE computes TPD in the $n_c/4$ region of the corona
  - it is designed to compute the effect of multibeam instability*
- Laser irradiation can be very complex [standard OMEGA, OMEGA EP, and National Ignition Facility (NIF) beam geometries are built in]
- It uses an established model of TPD-driven electrostatic plasma turbulence**
  - hot electron production is computed using a novel hybrid-particle algorithm that integrates $10^7$ to $10^8$ particles taking advantage of hardware (GPU) acceleration
  - it is similar to the quasilinear model***

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**LPSE quantifies hot-electron production (energetics and spectral properties) relevant to inertial confinement fusion (ICF) experiments at the Omega Laser Facility and on the NIF**

- Other diagnostic signatures of TPD in OMEGA experiments can be computed
  - Thomson scattering
  - hard x rays
  - half-harmonic emission

- Predictions have been made for FY15 NIF experiments by A. A. Solodov**

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**Thomson scattering from TPD waves [comparison with LPSE (blue lines)]**

![Thomson scattering graphs](image-url)


**T. M. Rosenberg et al., this conference.**
Three spherical implosions experiments were simulated with LILAC to obtain the hydrodynamic variables as a function of time (CBET,* but no TPD)

- The coronal temperature is predicted to increase in the Be-Si-CHSi target
- the TPD threshold increases according to the simple $IL/T$ scaling

*Cross-beam energy transfer
The Si layer reduces the density scale length at the \( n_c/4 \) surface.
Based on *LILAC* predicted scale lengths, temperatures, and intensities, the Be-Si-CHSi target is expected to excite the least TPD

- The “strength” of TPD should depend on the quantity $\frac{IL_n}{T_e}$
- Linear threshold parameter for a single beam $\eta = \frac{I_{14} L_{n, \mu m}^*}{230 T_{e, keV}}$
- $IL/T_e$ varies little during the main pulse because temperature increases compensate for the scale length

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*SiCH-Si-Be*  
*CH*  
*--- Be*

Si present at $n_c/4$  

$T_e$ (keV) and $\eta$  

$\eta = 1.0$

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Each target is simulated by LPSE to quantify the hot-electron production

- The simulations take advantage of the separation between hydro and LPI time scales
- The duration of the implosion is broken up into several runs chosen to sample the main pulse (markers)
- The hydrodynamic variables are “frozen” over the duration of the LPSE simulation
The 3-D simulation volume is determined by the density scale length at the chosen time.

- This is a local analysis in the neighborhood of a point \( \hat{r} = (r, \theta, \phi) \) on the quarter-critical surface.
- Each run is made to 20 ps.
For each simulated time, six different locations near the $n_c/4$ surface were computed [using a distributed polarization rotator (DPR) model]

- The location determines the laser beam geometry
For all cases (tangentially focused SG5) TPD hot electrons are preferentially generated at the hex centers*

- This is broadly consistent with Seka’s observations*

The absolute time-dependent hot-electron power has been computed for each ablator type.

- CH and Be targets produce similar hot-electron fluxes.

Hot-electron power is strongly reduced in the CHSi-Si-Be design when Si is present at the $n_c/4$ surface.
The Langmuir wave (LW) intensity shows differences between Be and CH that are not seen in hot electrons

- The reasons are caused by differences in the acoustic damping rate
- This effect might be observable with Thomson scattering**

\[ \text{LW intensity (arbitrary units)} \]

\[ \text{Incident laser intensity (} \times 10^{14} \text{ W/cm}^2 \) \]

\[ \text{Time (ns)} \]

\[ \text{Si present at } n_c/4 \]

\[ \text{Be} \]

\[ \text{CH} \]

\[ \text{SiCH-Si-Be} \]

\[ ^* \text{J. F. Myatt et al., Phys. Plasmas 20, 052705 (2013).} \]

\[ ^** \text{R. K. Follett et al., this conference.} \]
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*LPSE* stands for Laser-plasma simulation environment.