Laser-Plasma Interaction Near the Quarter-Critical Density in Direct-Drive Inertial Confinement Fusion

Langmuir wave intensity, pol = 45°, saturation stage

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Linear theory of TPD
- - - Linear theory of SRS

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Summary

The interplay between different instabilities was studied near the quarter-critical density for National Ignition Facility (NIF)-relevant parameters

- A series of two-dimensional simulations has been performed with the particle-in-cell (PIC) code OSIRIS*
- Spectral analysis of the fields confirms the signatures of two-plasmon decay (TPD) and stimulated Raman scattering (SRS)
- SRS determines the broad feature in the frequency spectra, consistent with the NIF experimental results**
- The fast-electron generation in the simulations including both TPD and SRS is significantly lower than in TPD-only simulations

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** W. Seka et al., UO9.00003, this conference.
Recent experiments on the NIF [planar laser–plasma interaction (LPI) platform*] motivate a study of LPI near quarter-critical density at large density scale lengths and high $T_e$

- Three types of simulations in 2-D have been performed with varying polarizations
- Parameters
  - incident laser intensity $I = 8 \times 10^{14} \text{ W/cm}^2$ (plane wave)
  - density range from 0.20 to 0.27 $n_c$ (with density scale length $L_n = 300 \ \mu\text{m}$)
  - temperatures $T_e = 4 \text{ keV}, T_i = 2 \text{ keV}$
  - simulation box size: $112 \times 20 \ \mu\text{m}$ (laser propagates along the $x$ axis)

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*M. J. Rosenberg et al., NO5.00010, this conference.
Quasi-stationary nonlinear saturation is reached after a few picoseconds.

\[ \text{Energy} = \int \, d\vec{x} \frac{E_i^2}{8\pi} \]

In out-of-plane simulations, the field spectra are consistent with the signatures of SRS.

\[ E_{\text{field}} \]

\[ \text{Energy} \]

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

\[ \text{Incident pump and scattered SRS light} \]

\[ \text{SRS Langmuir wave (LW)} \]

\[ \text{2-D out-of-plane (SRS)} \]

\[ \text{Incident pump and scattered SRS light} \]

\[ E_L, \text{ saturation stage} \]

\[ k_y/k_0 \]

\[ k_x/k_0 \]

--- Linear theory of SRS

--- Total E
--- \( E_z \)
--- \( E_x \)
--- \( E_y \)
--- \( Y_{\text{SRS}}^{**} \)

With the laser polarization at 45° to the simulation plane, there is an interplay between TPD and SRS.

Growth rates of TPD* and SRS** are calculated for intensities of the projections of the laser field (0.5 $I_0$).

The range of densities over which the instabilities are active has been identified.
The frequency spectra in simulations are consistent with the SRS developing at densities below the quarter-critical density.

Scattered-light spectra from the planar NIF experiment*

The broad feature in the frequency spectra is caused by SRS.

*W. Seka et al., UO9.00003, this conference.
The Poynting flux analysis shows the density range where the instability develops for different polarization orientations.
The distribution of fast electrons generated by the instability depends strongly on the orientation of the incident laser field.

The flux of fast electrons \( (E > 45 \text{ keV}) \) in the direction of the incident laser propagation.

<table>
<thead>
<tr>
<th>The temperature (fitted between 50 and 150 keV)</th>
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</thead>
<tbody>
<tr>
<td>( T_e = 62 \text{ keV} ) In-plane</td>
</tr>
<tr>
<td>( T_e = 35 \text{ keV} ) Polarization 45°</td>
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<th>The flux of fast electrons (in percentage of incident laser)</th>
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<td>( E &gt; 50 \text{ keV} ) 100 keV ( &gt; E &gt; 50 \text{ keV} )</td>
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