Collisional Effects on Hot-Electron Generation in the Two-Plasmon–Decay Instability in Inertial Confinement Fusion

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**Summary**

Electron–ion collisions can reduce hot-electron generation in two-plasmon–decay (TPD) instability*

- Particle-in-cell (PIC) simulations reveal a staged-acceleration mechanism for hot-electron generation in TPD*

- PIC and fluid simulations found that this reduction is partially caused by collisional suppression of the nonlinear TPD modes away from the quarter-critical surface
  - these modes form the first stage of hot-electron acceleration

Collaborators

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TPD hot-electron generation has been studied with PIC simulations with parameters relevant to OMEGA experiments.

- Hot electrons generated in TPD can preheat a target in inertial confinement fusion (ICF).
- PIC simulation is a useful tool to study TPD hot-electron generation.
- Numerical collisions in OSIRIS* are lower than physical collisions:
  - for $n = 0.25 \, n_c$ and $T_e = 3 \, \text{keV}$, $T_i = 1.5 \, \text{keV}$,
    
    $\nu_{ei}^{\text{numerical}} \approx 0.1 \nu_{ei}^{\text{physical}}$

- The effects of physical collisions are studied by turning on/off the collisional package in OSIRIS.

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The electron–ion collision package from OSIRIS is benchmarked by measuring the plasma-wave damping rates

- Simulation parameters
  \[ n_e = 0.25 \, n_c \quad \text{CH plasma} \]
  \[ T_e = 3 \, \text{keV} \quad 100 \, \text{particles/cell} \]

- The energy of a plasma wave should evolve like
  \[ \varepsilon_x = a e^{-\nu_{ei} t} \sin^2 (\omega_p t) + c \]

Fitted results: \[ \nu_{ei}^{\text{package}} = 2.94 \times 10^{-4} \quad \omega_0 = 98\% \nu_{ei} \]
The high-$k$ modes of electron plasma waves away from the quarter-critical surface are important for the first stage of acceleration*

- New modes away from the quarter-critical surface appear in the nonlinear stage and form the first stage of electron acceleration
- Hot electrons are stage accelerated from left to right
- It is important to know the nature and phase velocities of the high-$k$ modes

Fluid* simulations show that the high-k modes are TPD modes under ion-density fluctuations**

\[ \frac{\partial \psi}{\partial t} = \phi - 3v_e^2 \frac{n_p}{n_0} - v_0 \cdot \nabla \psi \]
\[ \frac{\partial n_p}{\partial t} = -\nabla \cdot (n_0 \nabla \psi) - v_0 \cdot \nabla n_p \]
\[ \nabla^2 \phi = n_p \]

- *LTS* is a fluid code solving the full linear PDE's of TPD
- Static background ion-density fluctuations taken from OSIRIS can be added to LTS
  \[ n_0 \rightarrow n_0 + \delta n \]
- The high-k modes have significant growth in LTS only when ion-density fluctuations are introduced

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Collisions can reduce the strength of the high-$k$ modes.

The TPD modes in the low density region can develop wherever the growth rate is higher than the local e-i collision rate.
The longitudinal electrostatic field energy and hot-electron generation are reduced by collisions.

- Collisions reduce the efficacy of the staged-acceleration mechanism
  - increase the phase velocity of the first-stage plasma wave
  - reduce the amplitude of all plasma waves
**Summary/Conclusions**

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