Two-Plasmon-Decay Instability in Plasmas
Irradiated by Incoherent Laser Beams

A. Maximov, J. Myatt, R. W. Short,
W. Seka, and C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

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Summary

The increase in the angular spread of the incoherent laser beams detunes the two-plasmon-decay (TPD) resonance and reduces the TPD growth

- TPD instability driven by incoherent laser beams has been studied with a non-paraxial model.
- The TPD driven by incoherent laser beams has a regime where the growth rate is proportional to overlapped laser-beam intensity, consistent with OMEGA experimental results.
- When the density scale length is large enough, the low-frequency density perturbations can reduce the TPD growth.
The growth rate of the TPD instability can be proportional to the average laser intensity

Equation for the instability growth rate $\gamma$:

\[
\frac{2(\gamma + \gamma_e)}{\omega p_0} = -\text{Im} \int \frac{d\mathbf{k}_0}{k_0 \Delta \theta} \left( \frac{1}{2i(\gamma + \gamma_e)\omega p_0} \langle |v_0|^2 \rangle F(\mathbf{k}_0, \mathbf{k}) \right)
\]

where $F(\mathbf{k}_0, \mathbf{k}) = \frac{(k_0^2 - 2k_0 \mathbf{k})^2}{4 [(\mathbf{k} - \mathbf{k})^2 k^2]} k_\perp^2$,

$\gamma_e$ – damping coefficient,

resonance width $\Delta \omega = 3k_\parallel k_0 \lambda_{De} |\sin \theta_c| \Delta \theta \omega p_0$

\[
\int d\mathbf{k}_0 \rightarrow \int d\theta: \text{to integrate over the resonant denominator in the integrand}
\]

Large angular width $\Delta \theta: (\gamma + \gamma_e) << \Delta \omega$

\[
\gamma + \gamma_e = \frac{\pi}{4} \frac{\langle |v_0|^2 \rangle F(\mathbf{k}_{0C}, \mathbf{k})}{\Delta \omega}
\]
The increase of the angular width of an incoherent laser beam leads to the decrease of TPD growth rate and an increase of the threshold.

\[
\frac{\gamma_e}{\omega p_0} = 10^{-3}
\]

\[
\Delta \omega = 0.1 \gamma_e
\]

\[
\Delta \omega = 8 \gamma_e
\]

\[
\Delta \omega = 30 \gamma_e
\]

\[
\frac{\gamma + \gamma_e}{\omega p_0} = \sqrt{\langle I \rangle / I_0} \quad \text{at} \quad \Delta \omega = 0
\]

Resonance width \( \Delta \omega / \omega p_0 = 3 k \cdot k_0 \cdot \lambda_{De}^2 \cdot |\sin \theta_c| \cdot \Delta \theta \)
The effect of density inhomogeneity on TPD are limited in OMEGA plasmas

- Different studies* have shown that for TPD in inhomogeneous plasmas the absolute growth rate

\[
\left(\frac{\gamma}{\omega p_0}\right)_{\text{inhom}} = \left(\frac{\gamma}{\omega p_0}\right)_{\text{hom}} - \Delta_{\text{inhom}}
\]

\[
\Delta_{\text{inhom}} \sim \frac{1}{k_0 L_N}
\]

- for OMEGA plasmas the density scale length near quarter-critical density

\[
L_N = 200 - 400 \, \mu m,
\]

and

\[
\Delta_{\text{inhom}} \sim 10^{-4}
\]

A new code has been developed to model the TPD instability driven by incoherent laser beams

- The code is based on fluid-type description.
- It runs in two spatial dimensions.
- Equations for plasma waves are enveloped around \( \omega_0/2 \).
- The solver for plasma waves is nonparaxial.
- The grid allows to resolve scales few times smaller than the laser wavelength.
- The code has been tested in a linear instability regime.

\[
\mathbf{k} = \mathbf{k}_\perp + \mathbf{k}_\parallel \\
\mathbf{k}_\perp \cdot \mathbf{E}_0 \parallel \\
\mathbf{k}_0 \mathbf{C} \mathbf{k}_\parallel \\
\mathbf{k}_0 - \mathbf{k}_\parallel
\]
For the parameters of OMEGA plasmas, the plasma inhomogeneity moderately decreases the absolute growth rate of TPD.

Simulation region

- $200 \lambda_0 \times 200 \lambda_0$
- $\Delta \theta = 0.15$
- $\Delta \omega > \gamma_e$
- $k_0 \lambda_{De} = 0.15$, $k_\perp = k_0$
- $\gamma_e/\omega p_0 = 10^{-3}$
The increase in the angular spread of the driving laser beam reduces the TPD growth.

\[
<\mathbf{I}> = 6 \times 10^{14} \text{ W/cm}^2
\]
Interaction of incoherent laser beams with plasmas produces low-frequency perturbations in electron density

\[ \langle I \rangle = 9 \times 10^{14} \text{ W/cm}^2, T_e = 2 \text{ keV}, n_e \approx n_c/4 \]
The low-frequency perturbations in the electron density can detune the TPD resonance and reduce the TPD growth.

\[ I = 9 \times 10^{14} \text{ W/cm}^2 \]
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