Two-Plasmon Decay Driven by Multiple Incoherent Laser Beams

\[ \int |E(x, y, t)|^2 \, dy \biggm/ \int dy \text{ (arbitrary units)} \]

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Summary

Two-plasmon decay (TPD) driven by multiple incoherent beams in inhomogeneous plasma is investigated.

- Multiple coherent laser beams can share plasma waves in both large†-and small*-k regions.
- TPD driven by laser beams with finite temporal bandwidth and spatial incoherence give a higher absolute threshold.
- A more-realistic model including both distributed phase plates (DPP’s) and smoothing by spectral dispersion (SSD) is in development.

†C. Stoeckl et al., Phys. Rev. Lett. 90, 235002 (2003);
Collaborators

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The Zakharov model is a time-enveloped fluid moment model that describes the coupling between Langmuir and ion-acoustic fluctuations.

Extended Zakharov model equations†

\[
\nabla \cdot \left[ 2i\omega_0 \left( \partial_t + \mathbf{v}_e \cdot \right) + 3\nu_e^2 \nabla^2 - \omega_p^2 \left( \delta n + \delta N \right)/n_0 \right] E
\]

\[
= \left( e/4m_e \right) \nabla \cdot \left[ \nabla \sum_{m=1}^{N} (E_{0,m} \cdot E^*) - \sum_{m=1}^{N} E_{0,m} \nabla \cdot E^* \right] e^{-i(\omega_0 - 2\omega_p)e^t} + S_E
\]

Collisional plus Landau damping

Density gradient

Laser source

Noise source

Landau damping for ion-acoustic waves

Ponderomotive force

where the laser field \( E_L = \sum_{m}^{N} E_{0,m} (\mathbf{\hat{x}}, t) \exp(-i\omega_0 t) + c.c. \)

Multiple laser beams can share plasma waves in both large- and small-k regions

Energy spectrum of a Langmuir wave (LW) during the linear growth phase (early time, arbitrary units)

- Common wave at large $k$ (convectively saturated)*
- Common wave at small $k$ (corresponding to Simon’s absolutely unstable modes)†

$\mathbf{k}_{0,1}$ and $\mathbf{k}_{0,2}$

Landau cutoff (LC)

$\langle E^2 \rangle$

$k_x/k_0$

$k_y/k_0$

$10^{-4.7}$

$10^{-6.0}$

$10^{-7.4}$

$10^{-8.7}$

*R. W. Short et al., Bull. Am. Phys. Soc. 57, 300 (2012);
The investigation of TPD in incoherent laser beams is broken into three parts

• Temporal bandwidth is introduced in a way that is similar to SSD*
  – a large bandwidth ($\Delta \lambda \approx 10$ Å) is required to modify absolute growth

• Spatial incoherence is introduced using a DPP model**
  – the first investigations have looked at a single DPP speckle

• A model that includes both temporal and spatial bandwidth is under development

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The effect of temporal bandwidth on the absolute threshold for a single beam is investigated

- \( E(t) = E_0 \exp(i\delta \sin \omega_m t) \); similar to SSD*
  - here \( \delta \) and \( \omega_m \) are the modulation amplitude and frequency
  \[ \Delta \omega = 2\delta \omega_m; \quad \Delta \lambda / \lambda_0 = \Delta \omega / \omega_0 \]

**Absolute growth rate for different temporal bandwidth**

- \( T_{keV} = 2; \quad L_{\mu m} = 150; \) normal incidence
- Temporal bandwidth used here is one order larger than the growth rate

\( \Delta \lambda = 33.6 \text{ Å} \) increases the threshold intensity by \( \sim 30 \% \).

\[ * \text{S. Skupsky et al., J. Appl. Phys. 66, 3456 (1989).} \]
\[ ** \text{Simon et al., Phys. Fluids 26, 3107 (1983).} \]
Temporal bandwidth must be large to have an effect on the TPD saturation level

- Nonlinear calculations
  - Two laser beams polarized in the same plane (p-polarized) $I_{14} = 4$, $L_n = 150$ $\mu$m, $T_e = 2$ keV, $\theta = 27^\circ$ (Laser intensity is $1.2 \times$ above absolute threshold)

$$\int |E(x,y,t)|^2 \, dy / \int dy \text{ (arbitrary units)}$$

If the temporal bandwidth is large enough to suppress absolute modes, the saturation level is greatly reduced.
A DPP model* is in development to include spatial incoherence

- Comparisons are underway between DPP and single speckle

An example of 2-D DPP laser beam with f/4

Single speckle with f/4

Single Gaussian laser beam with different f number:

\[ f = \frac{\omega_a}{\lambda_0}; \quad T_{\text{keV}} = 2; \quad L_{\mu m} = 150 \]

So far it appears that the threshold is increased as the speckle f number (width) decreases.

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Summary/Conclusions

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