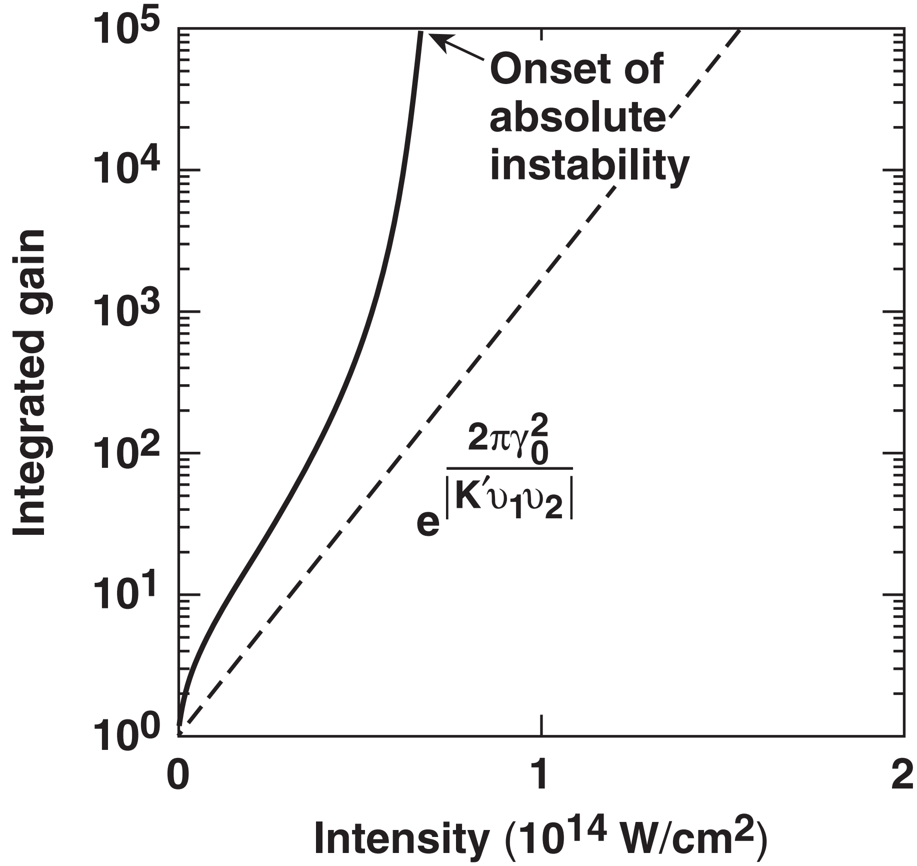
Convective Versus Absolute Two-Plasmon Decay in Inhomogenous Plasmas



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Summary

Accurate calculation of convective gain and absolute thresholds for TPD is greatly simplified in Fourier space

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- TPD is limited to a narrow range of densities. For such profiles, the eighth-order differential equation describing TPD becomes second- order in k-space.
- For small $k_{\perp}/k_0$, the convective spatial gain is roughly an order of magnitude larger than the Rosenbluth formula, and the absolute instability threshold is low.
- For larger $k_{\perp}/k_0$ the Rosenbluth formula is a better fit to the gain, and the absolute threshold is larger.

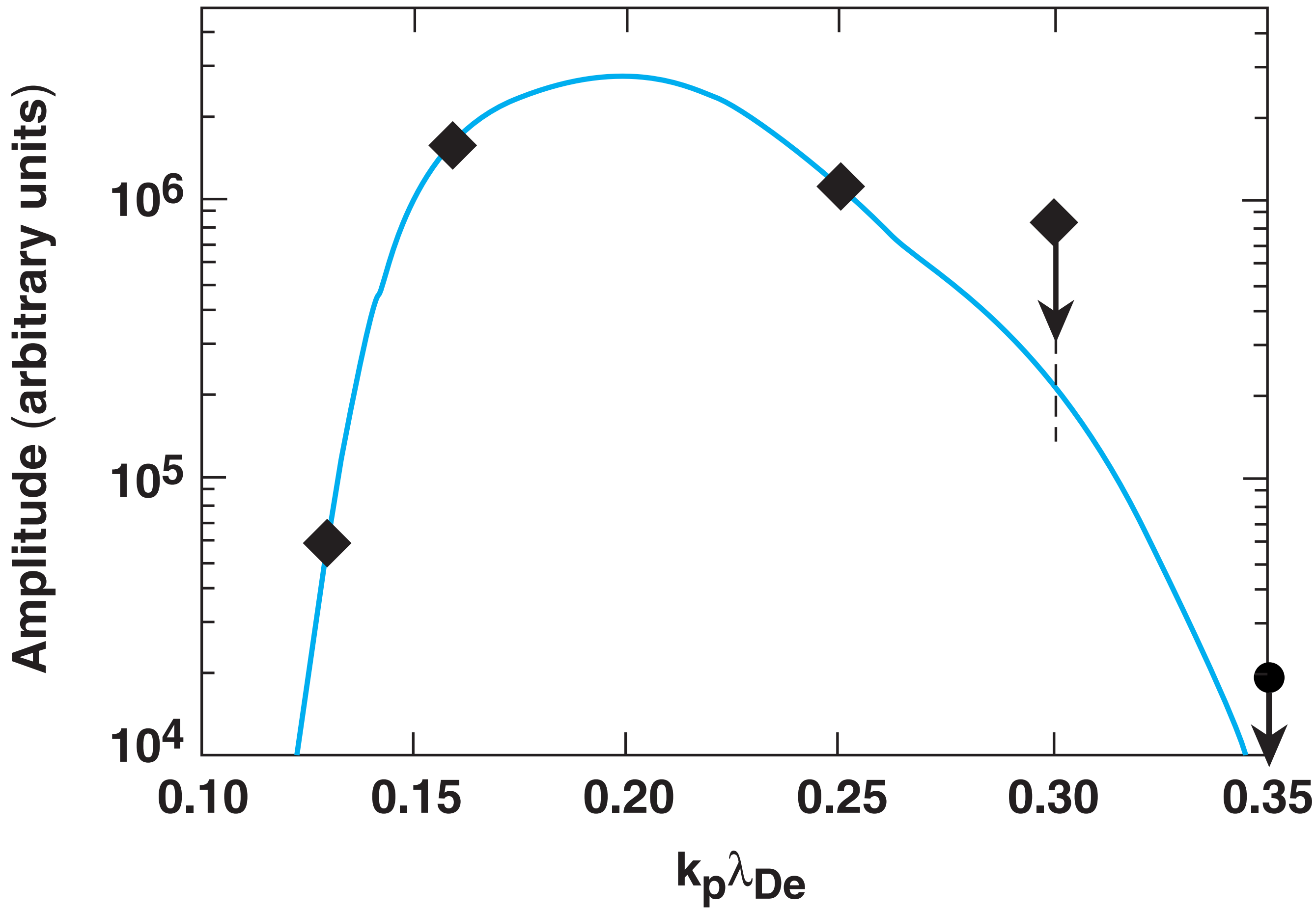
Outline

- Convective and absolute TPD in theory and experiment
- Advantages of the Fourier space approach
- Illustrative results
- Summary and conclusions

Both convective and absolute forms of the two-plasmon-decay (TPD) instability are expected to play a role in laser-fusion experiments

- Convective instability: Plasma waves arising from noise enter the interaction region, are amplified, and propagate out at an enhanced level.
  - Spatial growth $\rightarrow \infty$: absolute instability
- Absolute instability: Waves in the interaction region are amplified faster than they can propagate out; temporal growth continues until limited by nonlinear effects.
- Absolute instability predominates at small plasmon wave vectors; small group velocity, large phase velocity.
- Convective instability predominates at large wave vectors; large group velocity, smaller phase velocity (traps electrons more effectively).

The current TPD experiments allow for a rough estimate of the plasma-wave spectrum



The absolute instability would be just above threshold for $k_p\lambda_{De} < 0.13$.

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The equations describing TPD are difficult to treat in configuration space

- Using the velocity potential defined by $\mathbf{v} \equiv \nabla\psi$, the equations governing TPD can be written

$$\frac{\partial\psi}{\partial t} = \frac{e\phi}{m} - \frac{3\upsilon_e^2 n_1}{n_0} - \mathbf{v}_0 \bullet \nabla\psi\,; \quad \frac{\partial n_1}{\partial t} + \nabla \bullet \left(n_0 \nabla\psi\right) + \mathbf{v}_0 \bullet \nabla n_1 = 0; \quad \nabla^2\phi = 4\pi e n_1.$$

- These lead to an eighth-order ODE. Simplifications are of questionable validity near the plasma wave turning points.

- Simple generic three-wave convective instability theory gives the spatial gain formula $G = \exp\left(\frac{2\pi\gamma_0^2}{\left|K'\upsilon_1\upsilon_2\right|}\right)$. Constant parameters, and the exponential function of intensity must break down at the absolute threshold ($G \to \infty$ for finite intensity).

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For a linear density profile, a more sophisticated treatment is feasible using Fourier transforms

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- TPD is confined to a narrow range of densities below quarter-critical, so a linear density profile should be a good approximation.

- For a linear density profile, Fourier transforming in space leads to two coupled first-order ODEs in k-space:

$$\frac{dW_+}{d\kappa} = h(\kappa)W_-, \quad \frac{dW_-}{d\kappa} = -h^*(\kappa)W_+ \quad \text{for density profile} \quad \frac{n_1}{n_0} = 1 + \frac{x}{L};$$

$$\text{coupling coefficient} \quad h(\kappa) = \frac{\alpha\left(\dfrac{k_y}{k_0}\right)\kappa e^{i\alpha\sqrt{\beta}\kappa(\kappa-2\Omega)}}{\sqrt{\left[\kappa^2 + \dfrac{1}{4} + \left(\dfrac{k_y}{k_0}\right)^2\right]^2 - \kappa^2}}.$$

- Previous studies have employed this k-space formulation to treat the absolute instability (Liu and Rosenbluth, 1976; Simon *et al*., 1983).

Both absolute and convective forms of TPD can be studied using the k-space approach

- Absolute modes are found by searching for temporally growing modes localized in k-space (Simon *et al*., 1983). It can be difficult to obtain accurate results near the threshold.

- The convective instability can be studied using real k and ω; the absolute threshold can be identified with divergent spatial gain.

- $\begin{pmatrix} W_+ \\ W_- \end{pmatrix}$ represents the plasma wave amplitudes at $\begin{pmatrix} k + k_0, \omega + \omega_0 \\ k - k_0, \omega - \omega_0 \end{pmatrix}$.

- Incoming waves at a large negative x are represented by $W_{\pm}(\kappa \rightarrow \pm\infty)$ and outgoing waves by $W_{\pm}(\kappa \rightarrow \mp\infty)$; numerical integration in k-space gives the gain factor.

At small values of k_y/k_0, spatial amplification is larger than predicted by the simple model and shows transition to absolute mode

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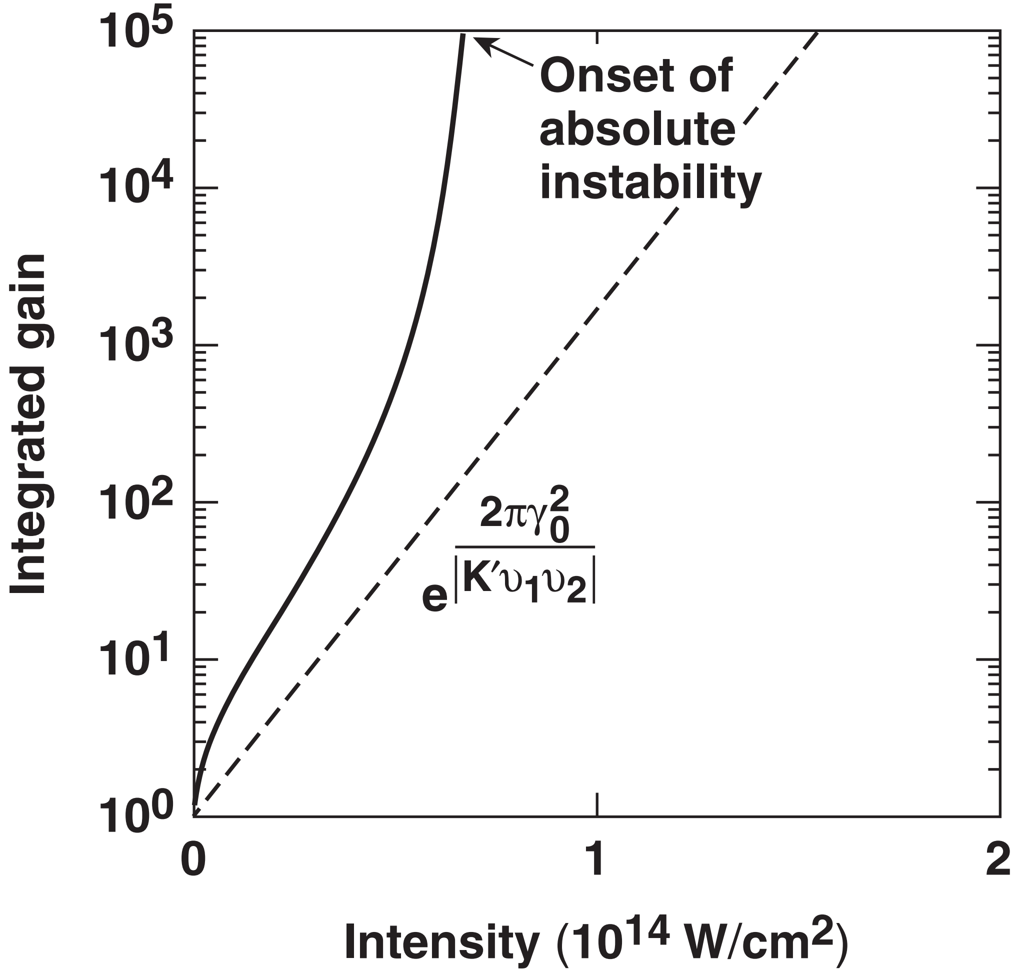

$L_\mu = 400$

$T_{keV} = 2.0$

$k_y/k_0 = 0.1$

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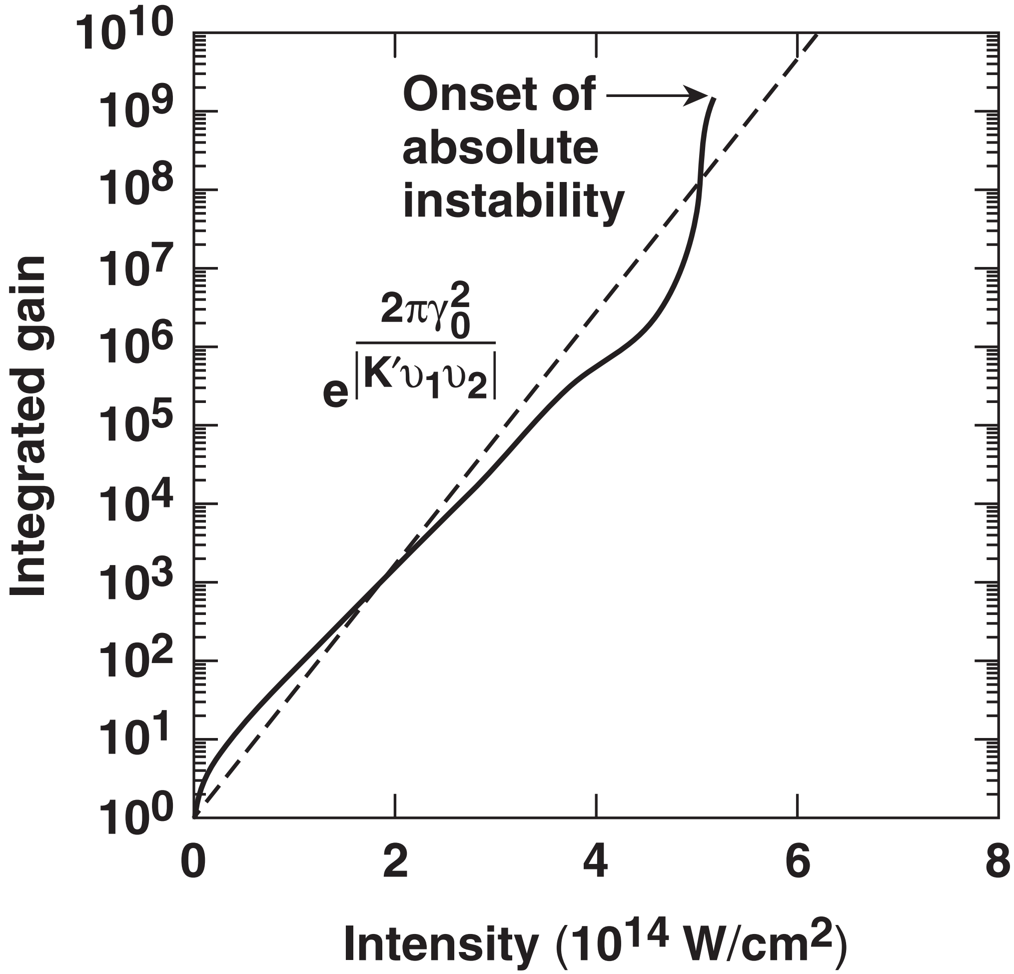
At larger values of k_y/k_0, spatial amplification is closer to the simple model; absolute threshold is higher



$L_\mu = 400$
$T_{keV} = 2.0$
$k_y/k_0 = 0.1$

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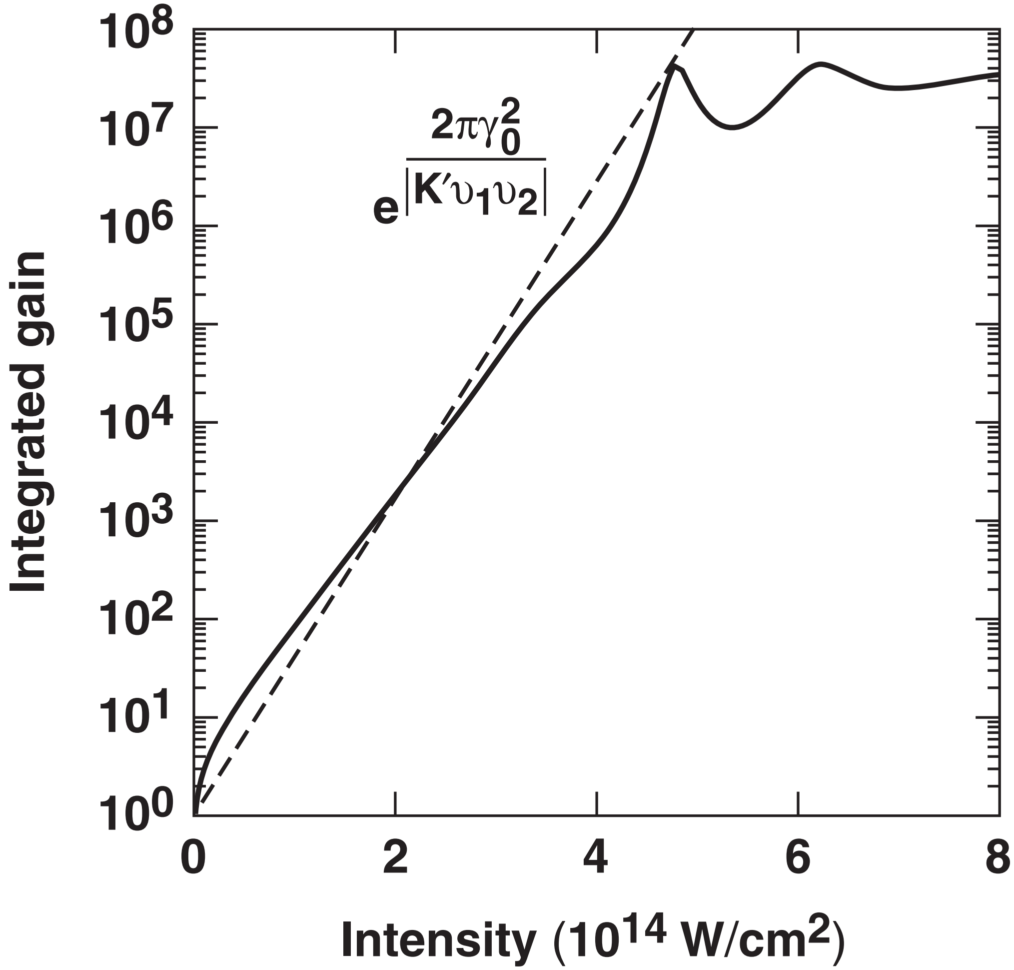
Off-resonance, instability remains convective, but gain may be large enough to make it effectively absolute



$L_\mu = 400$
$T_{keV} = 2.0$
$k_y/k_0 = 0.1$
Off-resonant ω

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