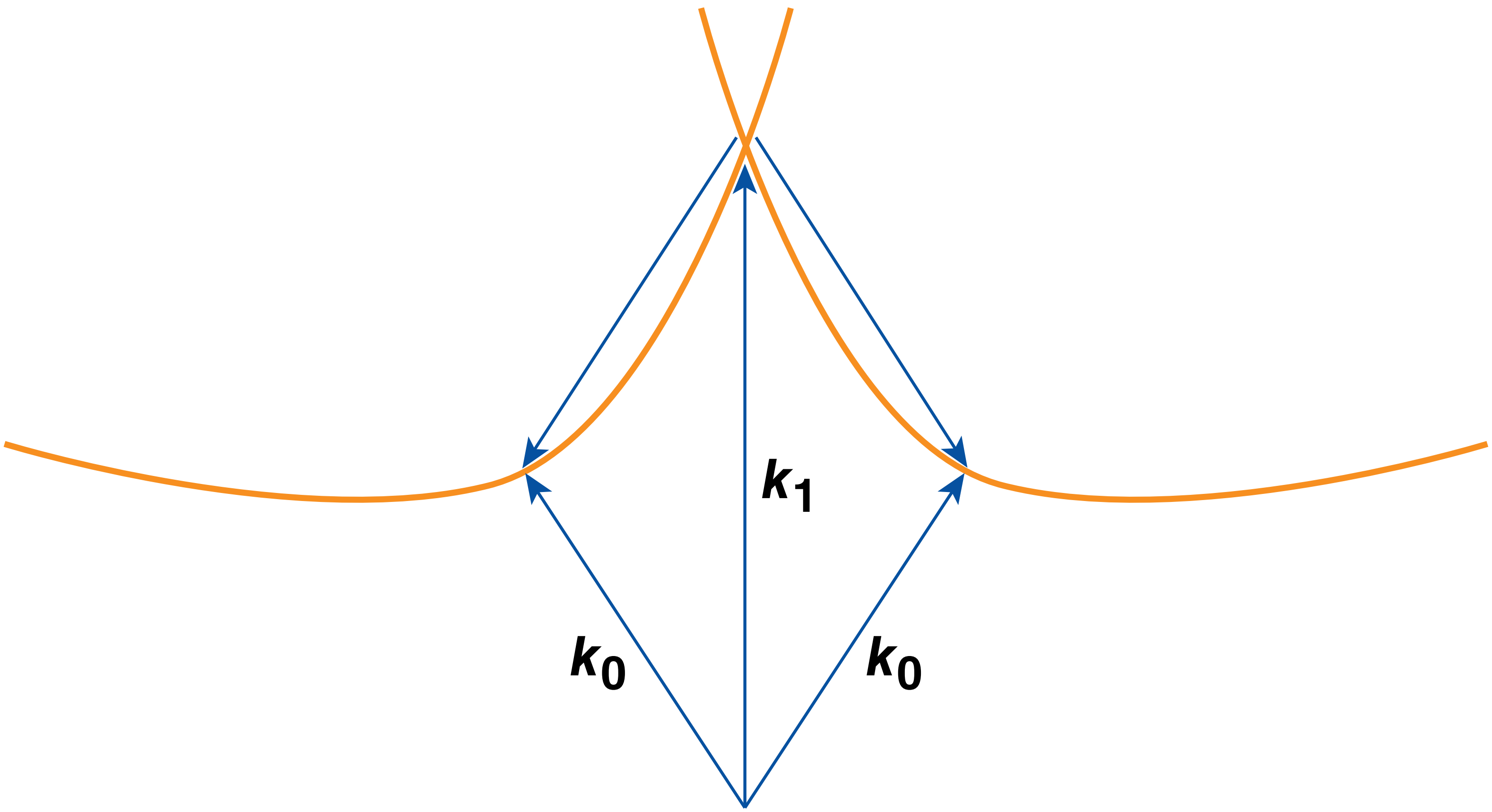
Two-Plasmon Decay of Multiple Obliquely Incident Laser Beams in Direct-Drive Geometry



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Summary

Two-plasmon decay (TPD) on OMEGA is convective and driven by several laser beams in combination

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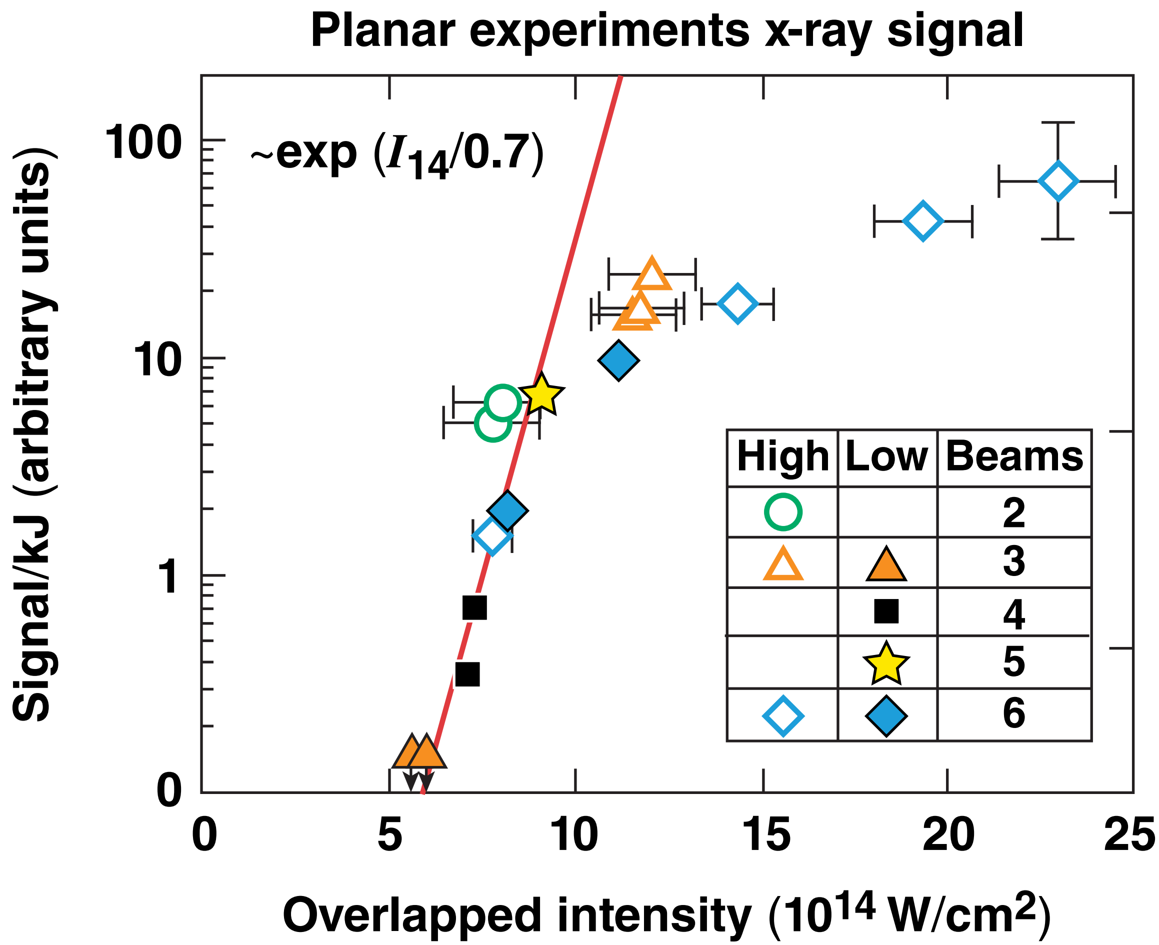
- Previous analysis of the absolute TPD instability for a single laser beam at normal incidence[1] suggests that the absolute instability is near threshold for OMEGA experimental parameters.
- The Fourier transform analysis of TPD used in Simon *et al*. has been extended to multiple obliquely incident laser beams.
- The results show that the absolute instability is actually below threshold for OMEGA parameters.
- The absolute instability may still play a role in geometries with a smaller angular separation between beams.

[1] A. Simon *et al*., Phys. Fluids 26, 3107 (1983).

TPD is observed to depend on the overlapped intensity for multiple-beam experiments



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C. Stoeckl *et al.*, Phys. Rev. Lett. 90, 235002 (2003).

The equations describing TPD are difficult to treat in configuration space

- The equations governing TPD 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 $G = \exp\left(\frac{2\pi\gamma_0^2}{\left|\kappa' \upsilon_1 \upsilon_2\right|}\right)$.
  - exponential function of intensity
  - must break down at absolute threshold ($G \rightarrow \infty$ for finite intensity.)

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

- 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 ODE's in *k*-space:

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

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

- Previous studies have employed this *k*-space formulation to treat the absolute instability.*

*C. S. Liu and M. N. Rosenbluth, Phys. Fluids 19, 967 (1976); A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

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

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- Absolute modes are found by searching for temporally growing modes localized in k-space. This involves complicated contour integrations in complex k-space for complex frequencies.*
  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 large negative x are represented by $W_\pm(\kappa \to \pm\infty)$ and outgoing waves by $W_\pm(\kappa \to \mp\infty)$.

*A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

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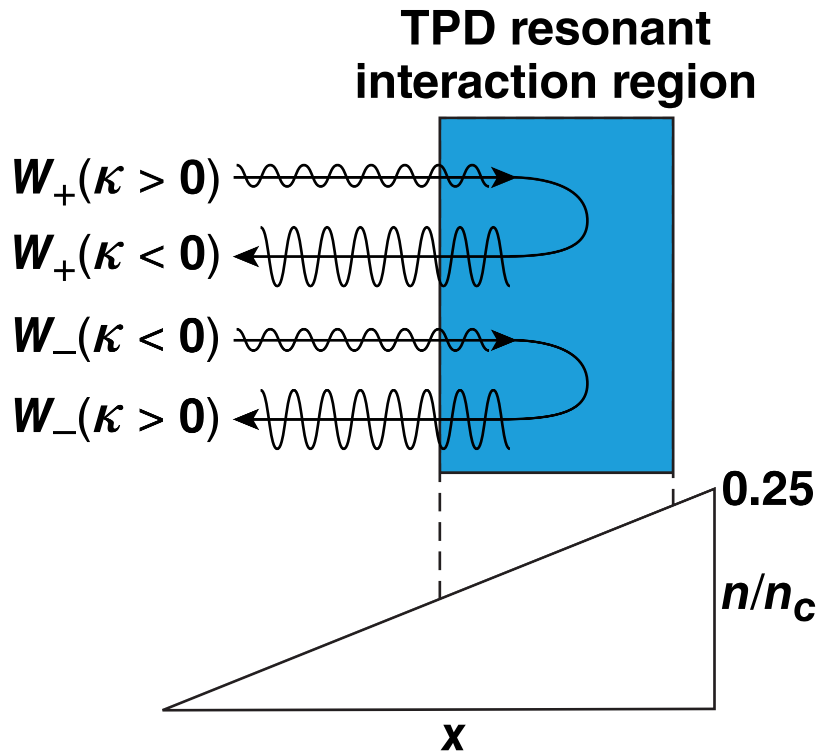
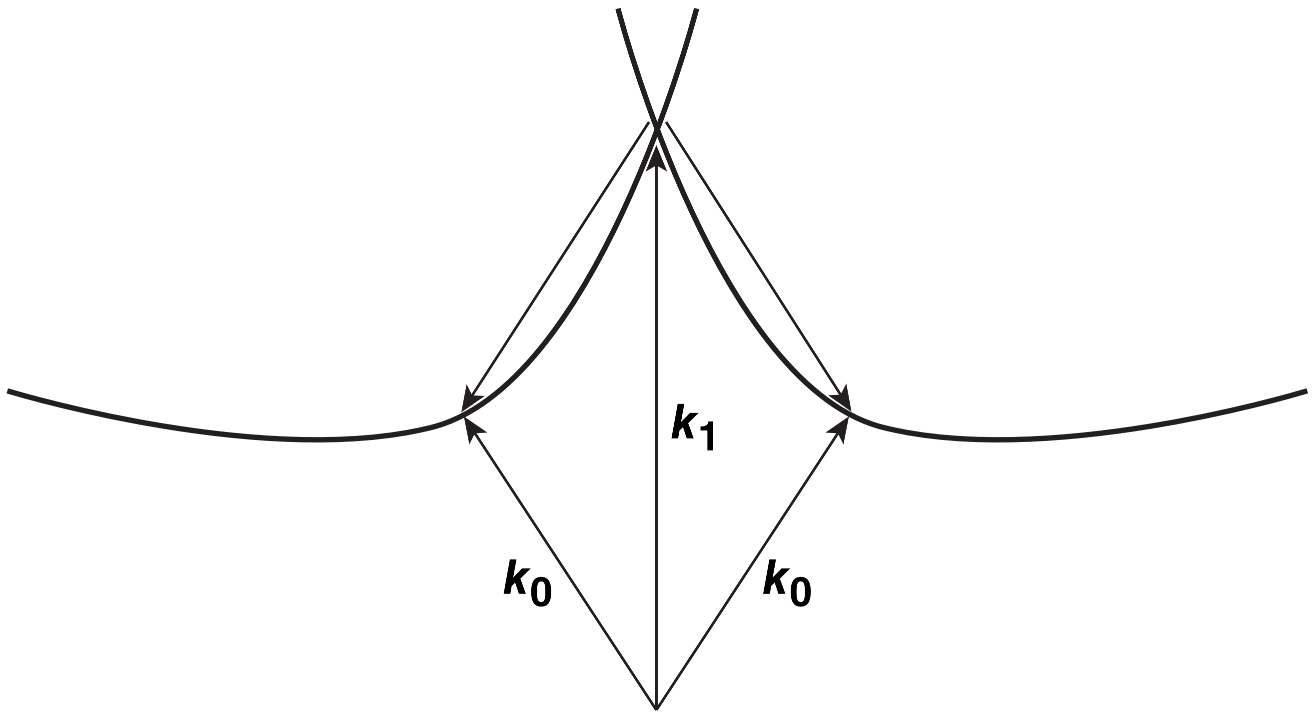
TPD amplification factors can be obtained by numerical integration of the k-space equations



- Define the growth factor $G = \dfrac{\text{out}}{\text{in}} = \dfrac{\left|W_+(\kappa \to -\infty)\right|^2 + \left|W_-(\kappa \to +\infty)\right|^2}{\left|W_+(\kappa \to +\infty)\right|^2 + \left|W_-(\kappa \to -\infty)\right|^2}$.

OMEGA beam angles make it difficult to drive multiple-beam absolute TPD



- The closest beams are separated by about 23°.
- The absolute instability is most readily driven in a region near the apex of the hyperbola in k-space.
- The gain in intensity from combined beams appears insufficient to drive absolute TPD at the necessary angles.

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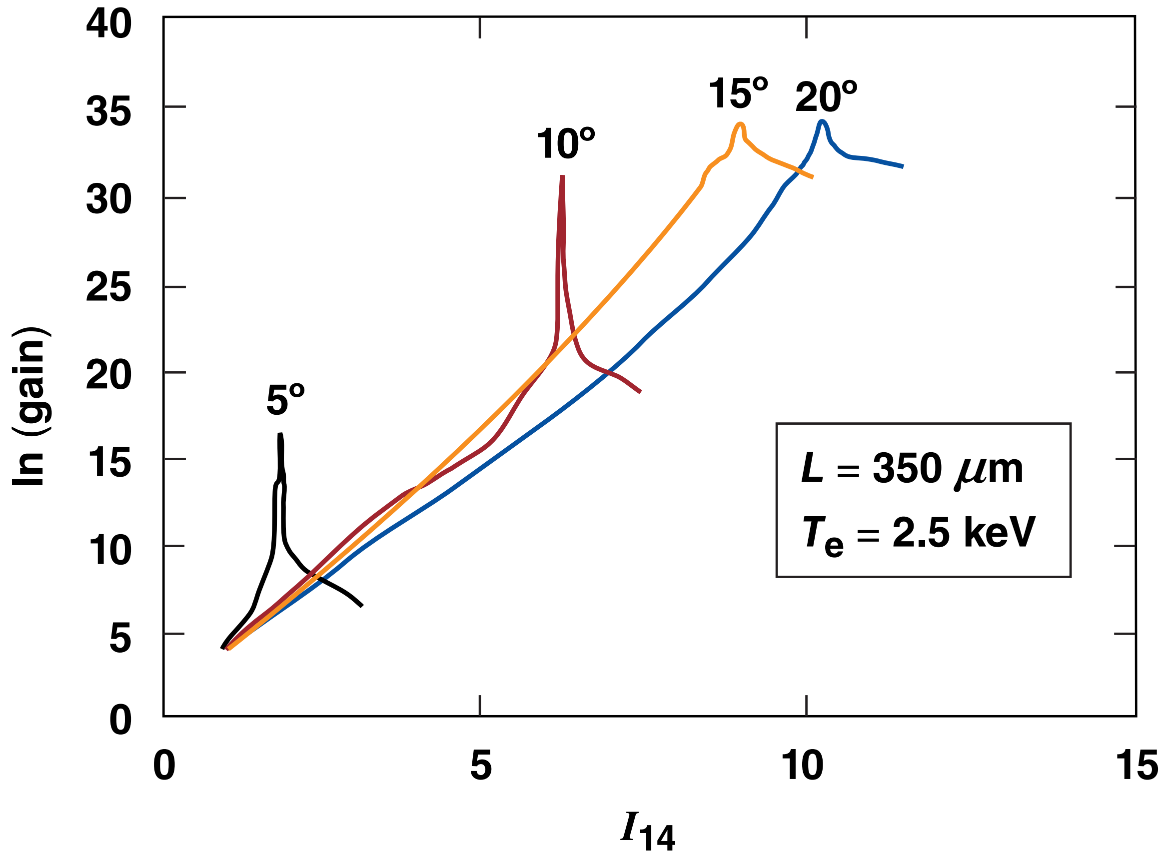
Under "low-intensity" conditions (low temperature, long scale length), angular separation of beams prevents absolute instability



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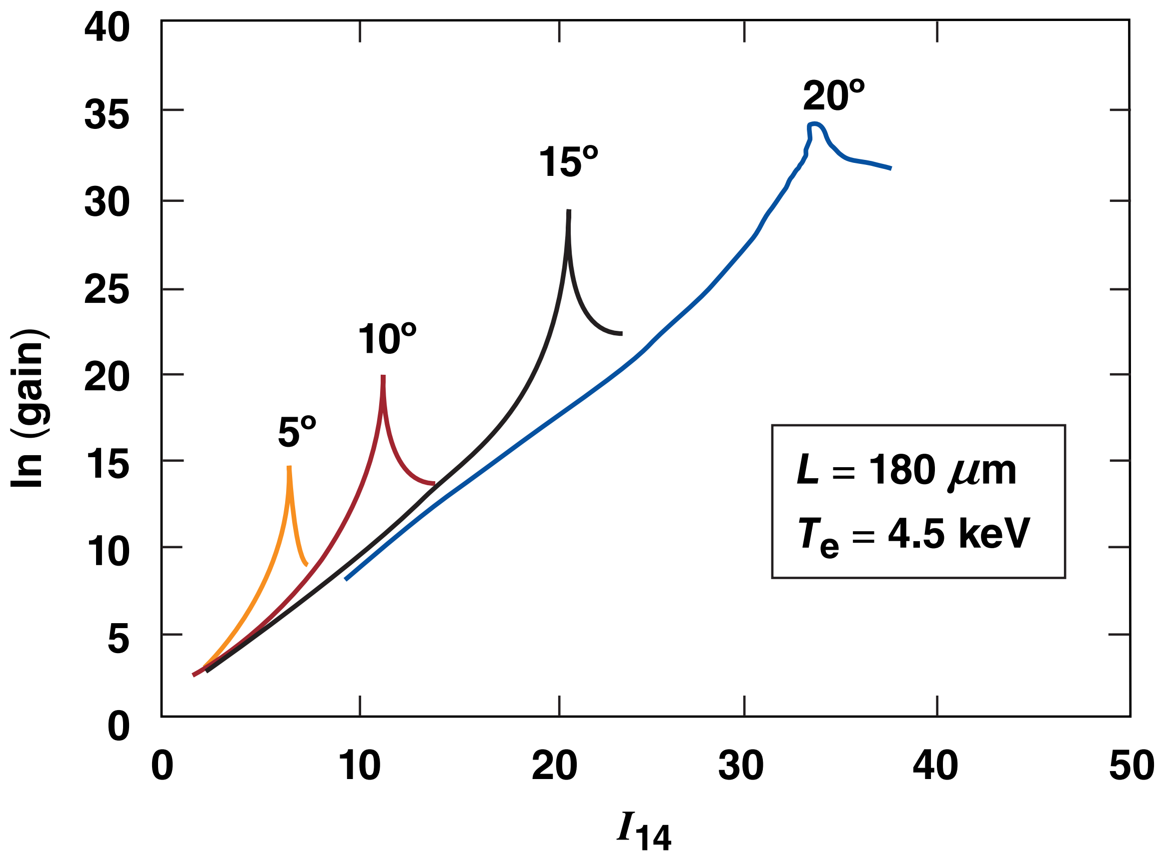
Under "high-intensity" conditions (high temperature, short scale length), TPD remains convective, although large gains can occur



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Summary/Conclusions

Two-plasmon decay (TPD) on OMEGA is convective and driven by several laser beams in combination

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