The Effects of Beam Polarization on Convective and Absolute Two-Plasmon Decay (TPD) Driven by Multiple Laser Beams

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Summary

For multibeam TPD, the relative polarizations of the beams affect the absolute/convective nature of the instability as well as the gain

- For two beams polarized in their common plane, there is a collectively driven convective mode at large plasmon wave vectors
- Two beams polarized out of their common plane drive a collective mode near \( k = 0 \); this mode may be absolute
- Polarization smoothing divides the gain between large- and small-\( k \) modes
- For larger numbers of beams, the small-\( k \) modes appear to be driven more strongly
Collaborators


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The temporal growth rate for single-beam TPD is maximized on a hyperbola in $k$ space

- The hyperbola lies in the plane of polarization
- Different points on the hyperbola correspond to decays occurring at different densities; larger wavevectors $\rightarrow$ smaller densities
A single beam shows maximal gain along the hyperbola

\[ I_{14} \text{ (single beam)} = 1.0 \]
\[ L_\mu = 300 \]
\[ T_{keV} = 1.5 \]

In-plane polarization
The gain extends out of the plane of polarization

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Out-of-plane polarization
The expected gain enhancement is seen for two pump beams polarized in their common plane.
Similar features are seen in Zakharov simulations*, indicating that they persist in the nonlinear regime.

\[
|E_K|^2 \text{ (arbitrary units)}
\]

\[k\lambda_{De} = 0.25\]

Out of the plane of polarization, the gain extends over a larger range of $k$

$I_{14} \text{ (single beam)} = 1.0$

$L_{\mu} = 300$

$T_{\text{keV}} = 1.5$

Out-of-plane polarization
The multibeam gain enhancement depends on the polarization of the beams

- When the beams are polarized in the plane of their wave vectors, enhanced gain is seen near the intersection of their associated hyperbolas.
- The hyperbolas lie in the plane of polarization of the beams.
- When the beams are polarized out of the plane of their wave vectors, one expects less enhancement because the hyperbolas no longer intersect (except for the singular point at the origin).
- But near the origin they are very close....
When the beams are polarized out of their common plane, enhanced gain is seen near the origin (but not on the axis of symmetry of the beams)

$I_{14}$ (single beam) = 1.0
$L_\mu = 300$
$T_{keV} = 1.5$
Out-of-plane polarization
Polarization smoothing distributes the gain between the large- and small-k modes.

\[ I_{14} \text{ (single beam)} = 1.0 \]
\[ L_\mu = 300 \]
\[ T_{keV} = 1.5 \]
Polarization smoothing
The presence of enhanced gain near the origin raises the possibility of absolute instability there.
As in the normal incidence case, the absolute instability is localized at small $k$.
The absolute TPD thresholds diminish with increasing angle of incidence

\[ L_\mu = 300 \]
\[ T_{\text{keV}} = 1.5 \]
The enhancement of TPD with increasing angle of incidence appears to result largely from the increasing effective scale length.

\[
\frac{\omega_0}{3\nu_e k_0^2} \text{Im}(\omega)
\]

- Actual with \(L_\mu = 300\)
- Normal incidence \(L_\mu = 300/\cos\theta\)

Parameters:
- \(T_{\text{keV}} = 1.5\)
- \(I_{14} = 2.0\)
- \(k_z = 1.0\)
For four beams the maximum TPD gain occurs off the axis of symmetry.

All beams polarized in the x–y plane

$I_{14}$ (single beam) = 1.0
$L_\mu = 300$
$T_{\text{keV}} = 1.5$
For four beams, the maximum convective gain (~75% of single-beam gain) occurs at small $k$; these modes are likely above the absolute threshold (infinite gain)

- All beams polarized in the x–y plane
- $I_{14}$ (single beam) = 1.0
- $L_\mu = 300$
- $T_{\text{keV}} = 1.5$
Summary/Conclusions

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- For two beams polarized in their common plane, there is a collectively driven convective mode at large plasmon wave vectors
- Two beams polarized out of their common plane drive a collective mode near $k = 0$; this mode may be absolute
- Polarization smoothing divides the gain between large- and small-$k$ modes
- For larger numbers of beams, the small-$k$ modes appear to be driven more strongly