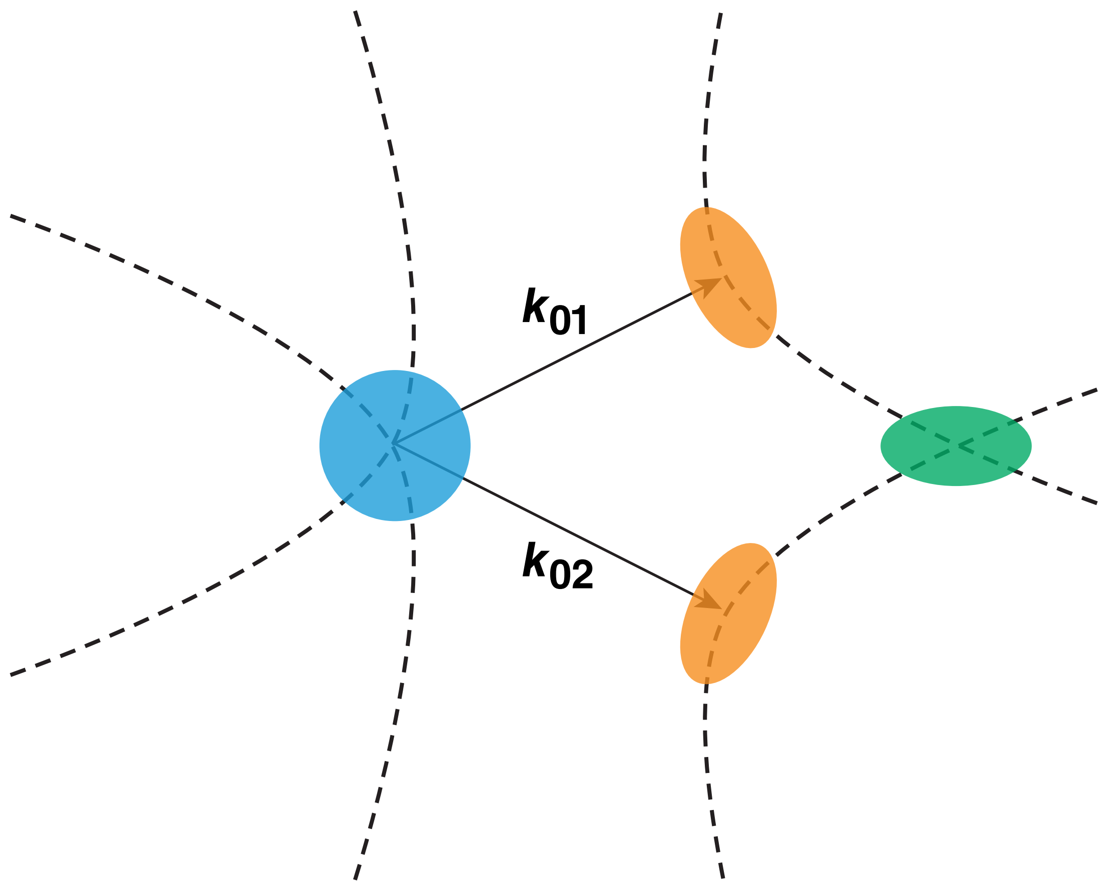
The Effects of Beam Geometry and Polarization on Two-Plasmon Decay Driven by Multiple Laser Beams



R. W. Short, J. F. Myatt, and J. Zhang
University of Rochester
Laboratory for Laser Energetics

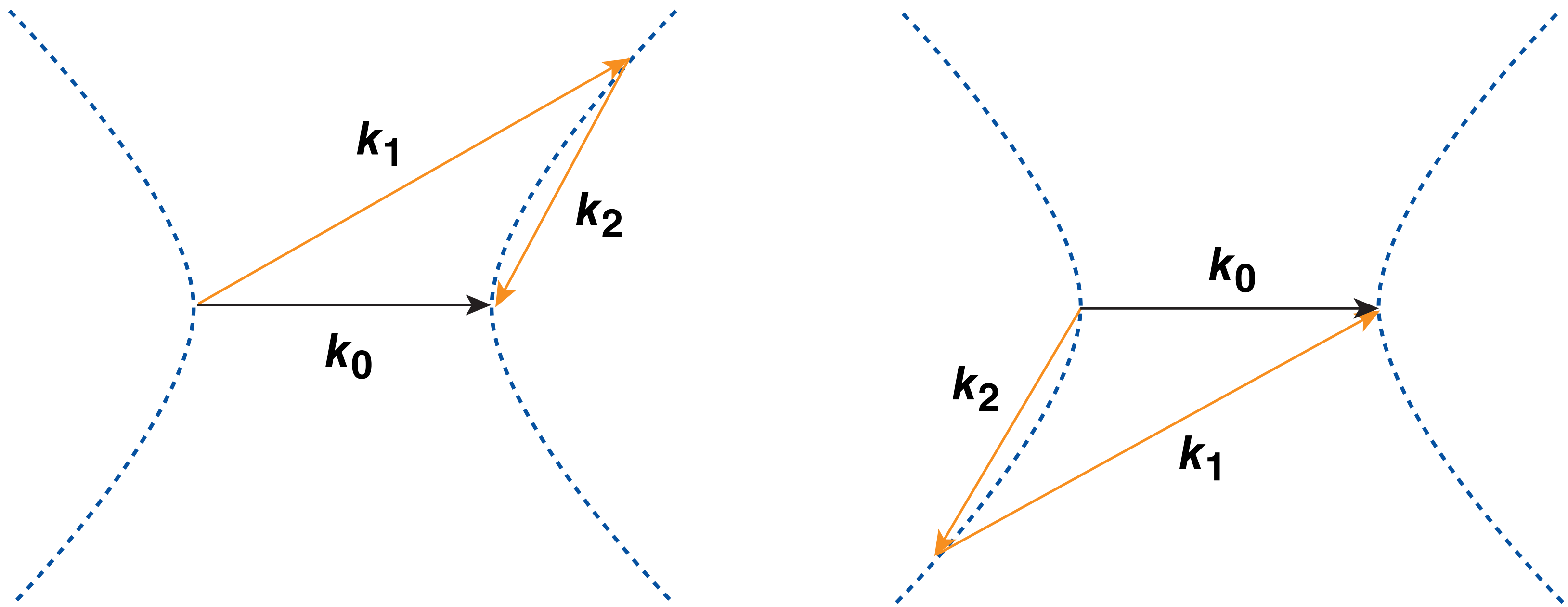
43rd Annual Anomalous
Absorption Conference
Stevenson, WA
7–12 July 2013

Summary

For multibeam two-plasmon decay (TPD), the absolute instability usually dominates

- The TPD threshold is sensitive to the number, orientation, and polarization of the beams
- For two beams polarized out of their common plane a collective absolute mode near $k = 0$ dominates TPD
- For two beams polarized in their common plane there are two absolute TPD modes; the dominant one depends on angle of incidence
- The thresholds of multi-beam absolute modes decrease with larger incidence angles and increased polarization components in the plane of the common wave

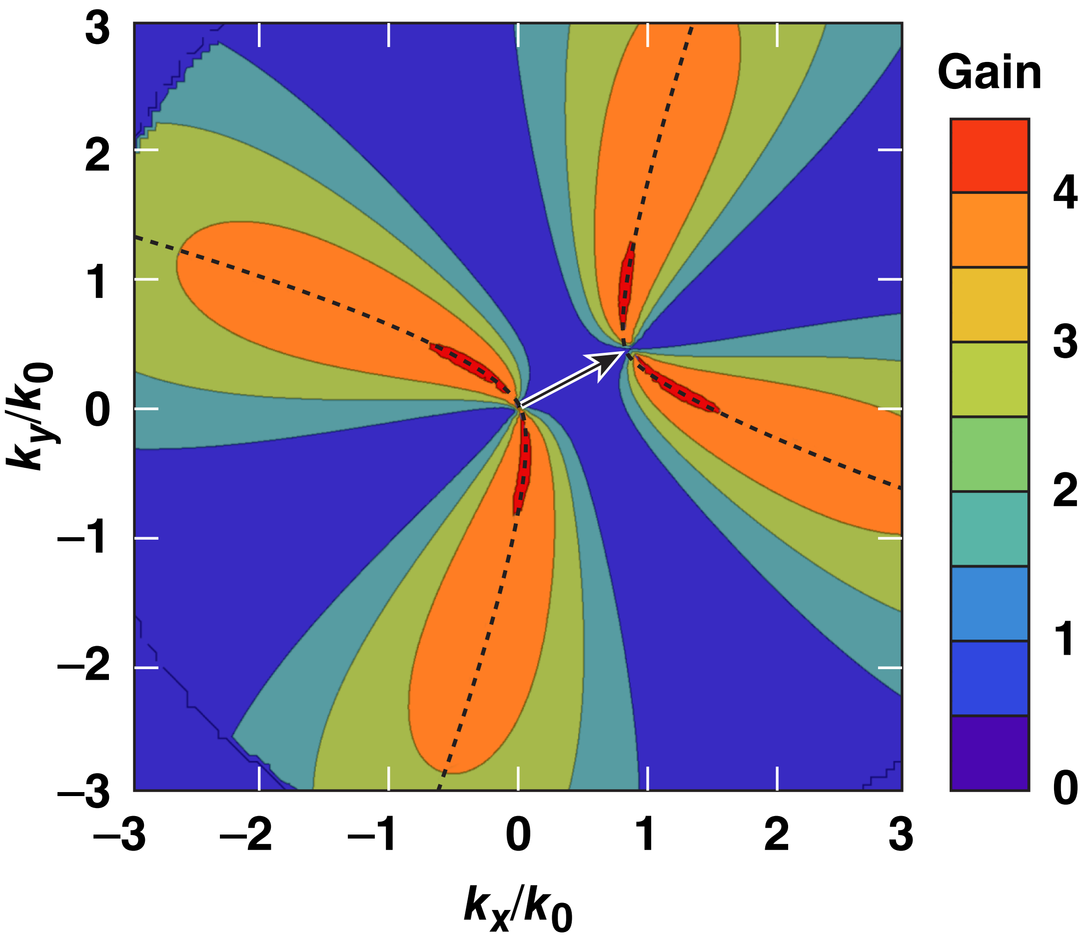
The temporal growth rate for single-beam TPD is maximized on a hyperbola in *k* space for a single beam



- The hyperbola lies in the plane of polarization
- Different points on the hyperbola correspond to decays occurring at different densities; larger wavev ectors → smaller densities

TC10083b

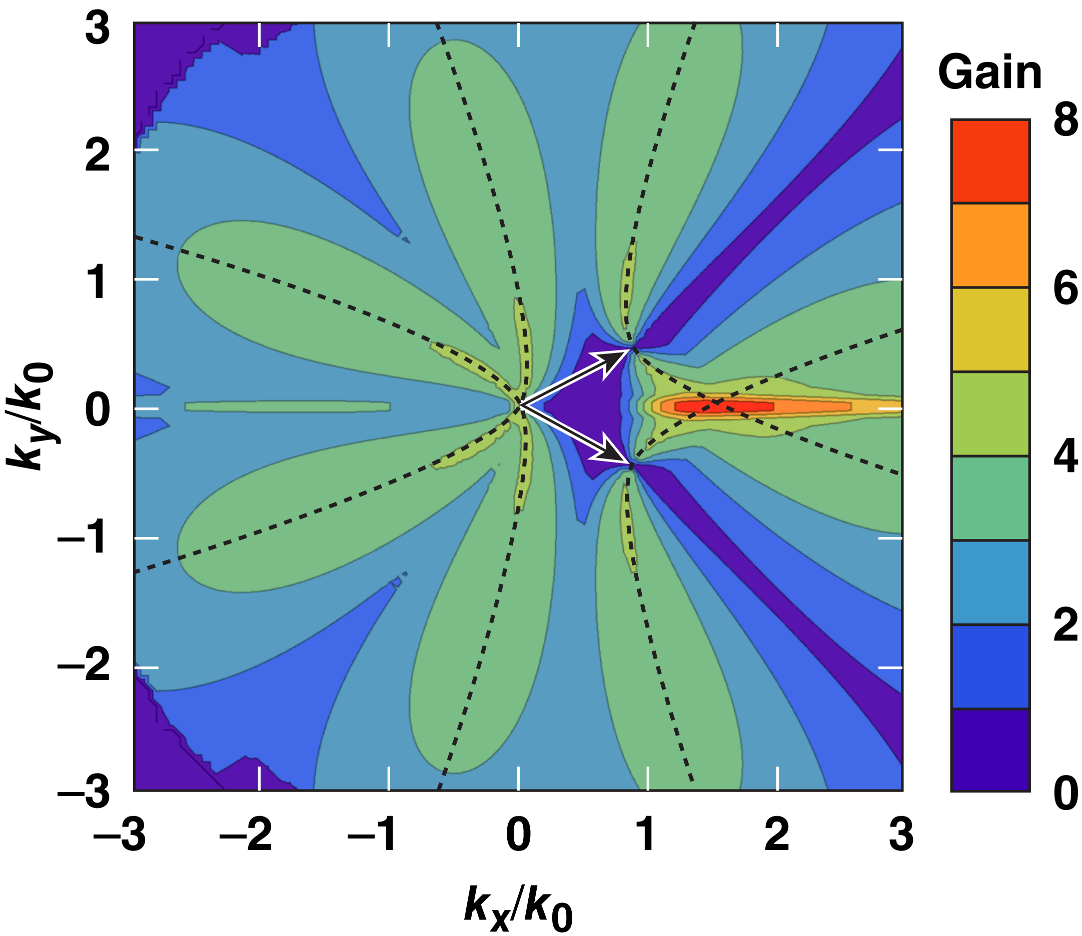
A single beam shows maximal convective gain along the hyperbola



I_{14} (single beam) = 1.0
L_μ = 300
T_{keV} = 1.5
In-plane polarization
θ = 30°

TC10084a

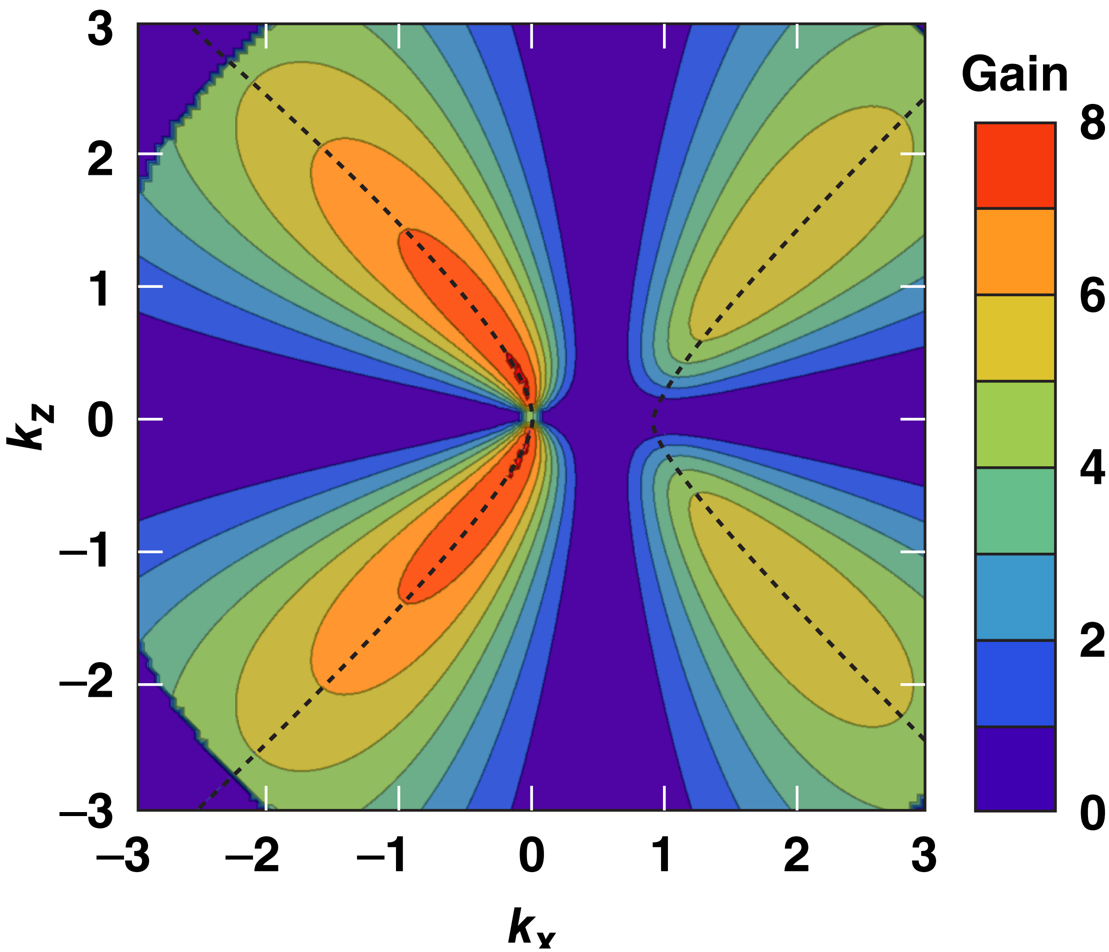
The expected convective gain enhancement is seen for two pump beams polarized in their common plane



I_{14} (single beam) = 1.0
L_μ = 300
T_{keV} = 1.5
In-plane polarization
$\theta = \pm 30°$

TC10086

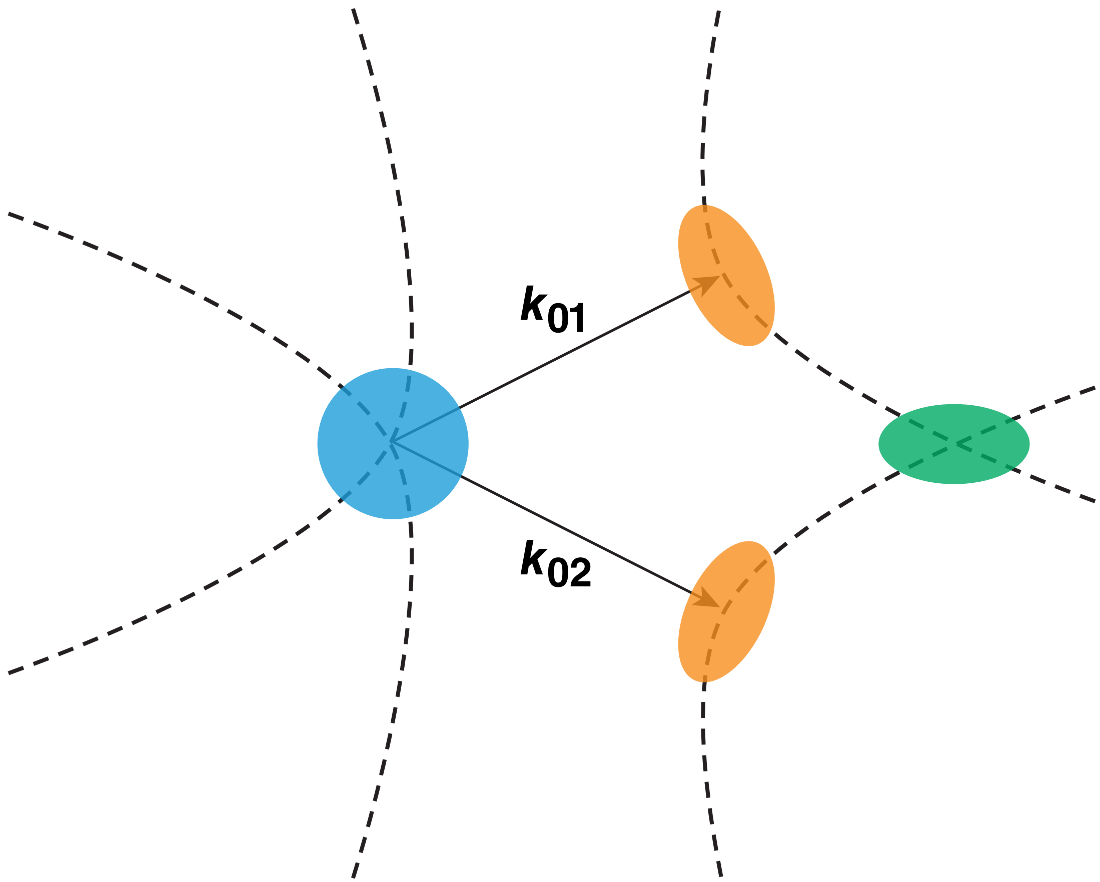
When the beams are polarized out of their common plane, enhanced gain is seen near the origin



I_{14} (single beam) = 1.0
L_{μ} = 300
T_{keV} = 1.5
In-plane polarization
$\theta = \pm 30°$ out of plane

TC10090b

The presence of enhanced gain near the origin raises the possibility of absolute instability there



Two beams polarized in their common plane

Orange: region of absolute instability
Green: region of overlapped convective gain

Two beams polarized out of their common plane

Blue: region of overlapped absolute instability

TC10092

For a single beam, the absolute TPD threshold (Simon *et al.*) is lower than the Rosenbluth convective threshold

- The Simon threshold is $\eta \equiv \dfrac{I_{14} L_{\mu}}{233\, T_{keV}} > 1$

- The Rosenbluth convective gain is $G_R = \dfrac{2\pi\gamma_0^2}{\kappa' V_1 V_2} = \dfrac{I_{14} L_{\mu}}{53.6\, T_{\text{keV}}} \cong 4.35\,\eta$

- The nominal convective threshold is $G_R > 2\pi, or\ \eta > \dfrac{2\pi}{4.35} \cong 1.44$

- Therefore, the absolute instability appears below the convective instability threshold; this, in general, remains true for multiple beams

TC10637

Fourier analysis of the time-dependent TPD equations results in a set of first-order linear equations that can be integrated numerically

$$\frac{du}{dk_x} = \frac{1}{2} e^{i\alpha\beta^{1/2} k_{01x}(k_x - k_{xr})^2} \left(\frac{k^2 - k_{d1}^2}{kk_{d1}}\right) \alpha_1 \left(\hat{\varepsilon}_1 \cdot k\right) u_{d1}$$

$$+ \frac{1}{2} e^{i\alpha\beta^{1/2} k_{02x}(k_x - k_{xr})^2} \left(\frac{k^2 - k_{d2}^2}{kk_{d2}}\right) \alpha_2 \left(\hat{\varepsilon}_2 \cdot k\right) u_{d2}$$

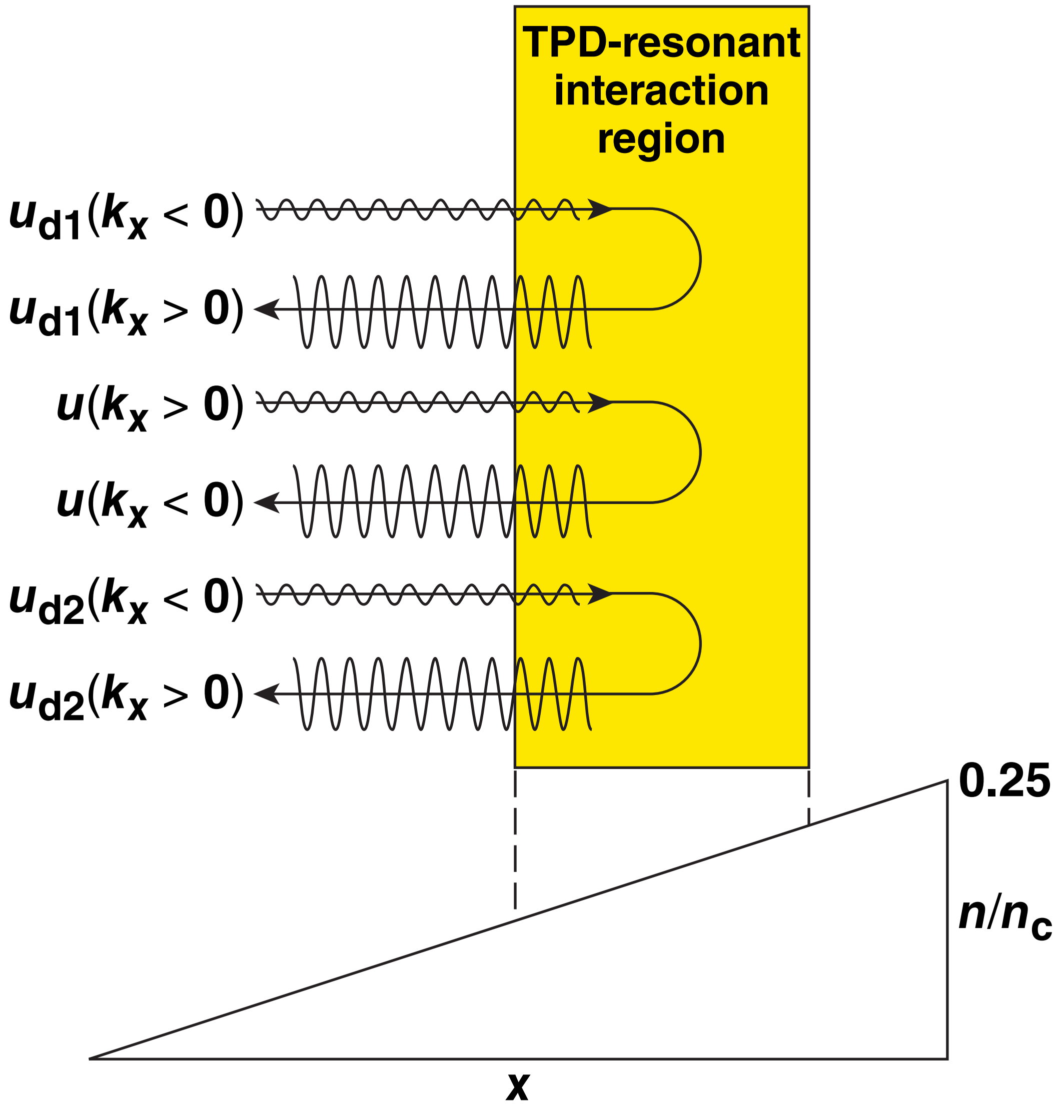
$$\frac{du_{d1}}{dk_x} = -\frac{1}{2} e^{-i\alpha\beta^{1/2} k_{01x}(k_x - k_{xr})^2} \left(\frac{k^2 - k_{d1}^2}{kk_{d1}}\right) \alpha_1 \left(\hat{\varepsilon}_1 \cdot k\right) u$$

$$\frac{du_{d2}}{dk_x} = -\frac{1}{2} e^{-i\alpha\beta^{1/2} k_{02x}(k_x - k_{xr})^2} \left(\frac{k^2 - k_{d2}^2}{kk_{d2}}\right) \alpha_2 \left(\hat{\varepsilon}_2 \cdot k\right) u$$

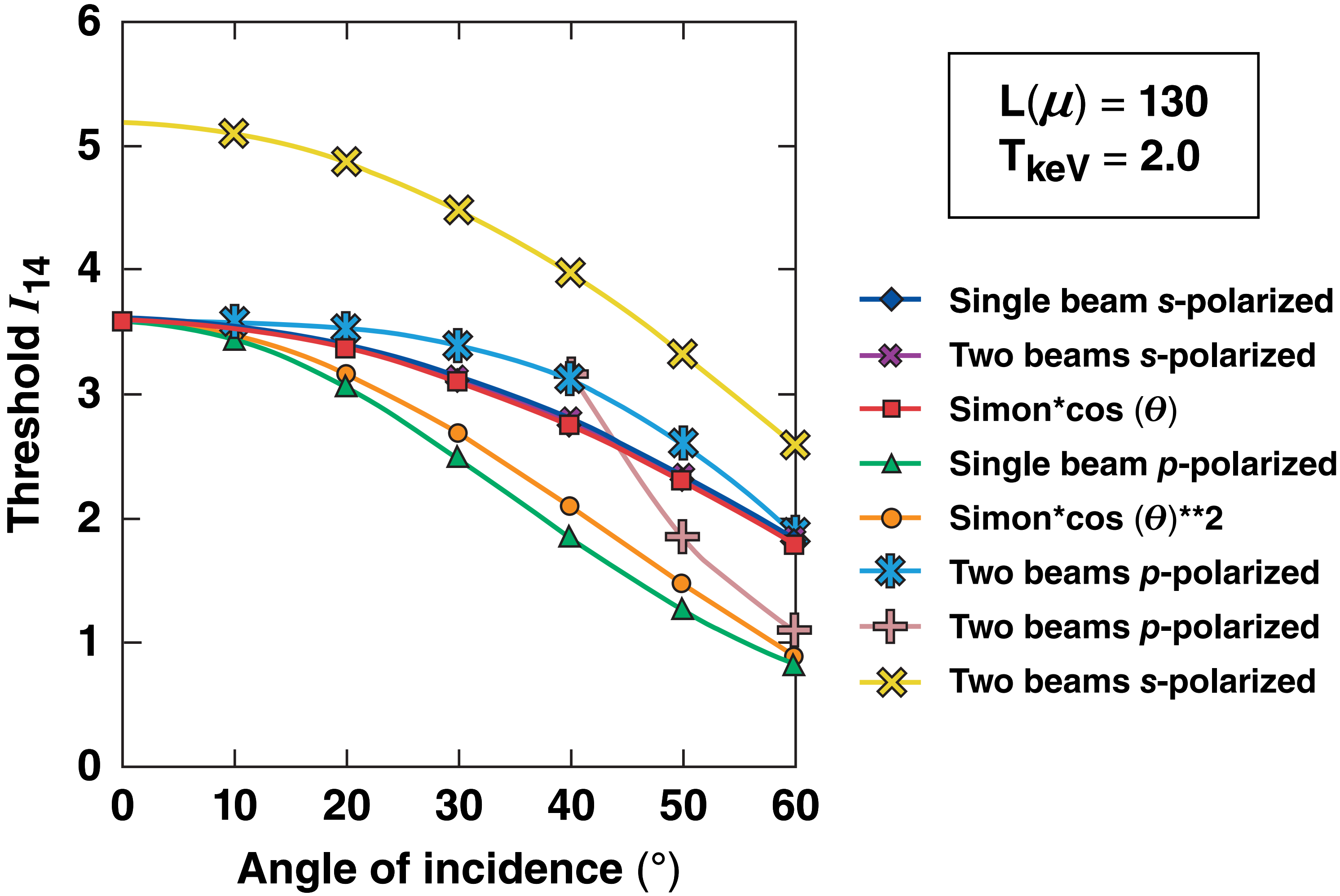
where $\alpha_i = \frac{4k_0 \left|\upsilon_{0i}\right|}{\omega_0} k_0 L$ and $\beta_i = \frac{9\upsilon_e^4 k_0^2}{\left|\upsilon_{0i}\right|^2 \omega_0^2}$

TC8468c

Numerical integration of these equations gives spatial gain; divergent gain indicates absolute threshold

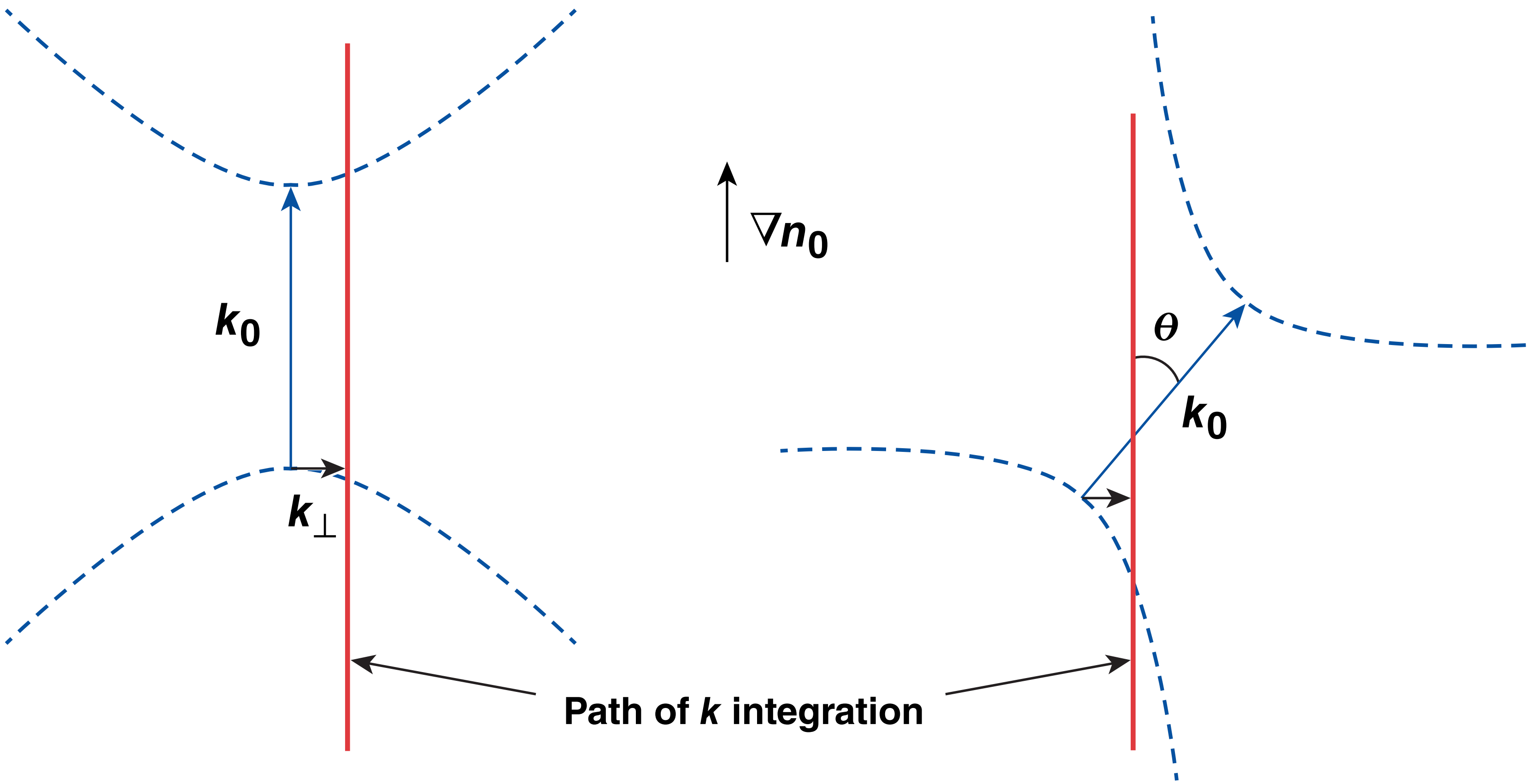


The absolute threshold for TPD depends on the angle of incidence and polarization



TC10640

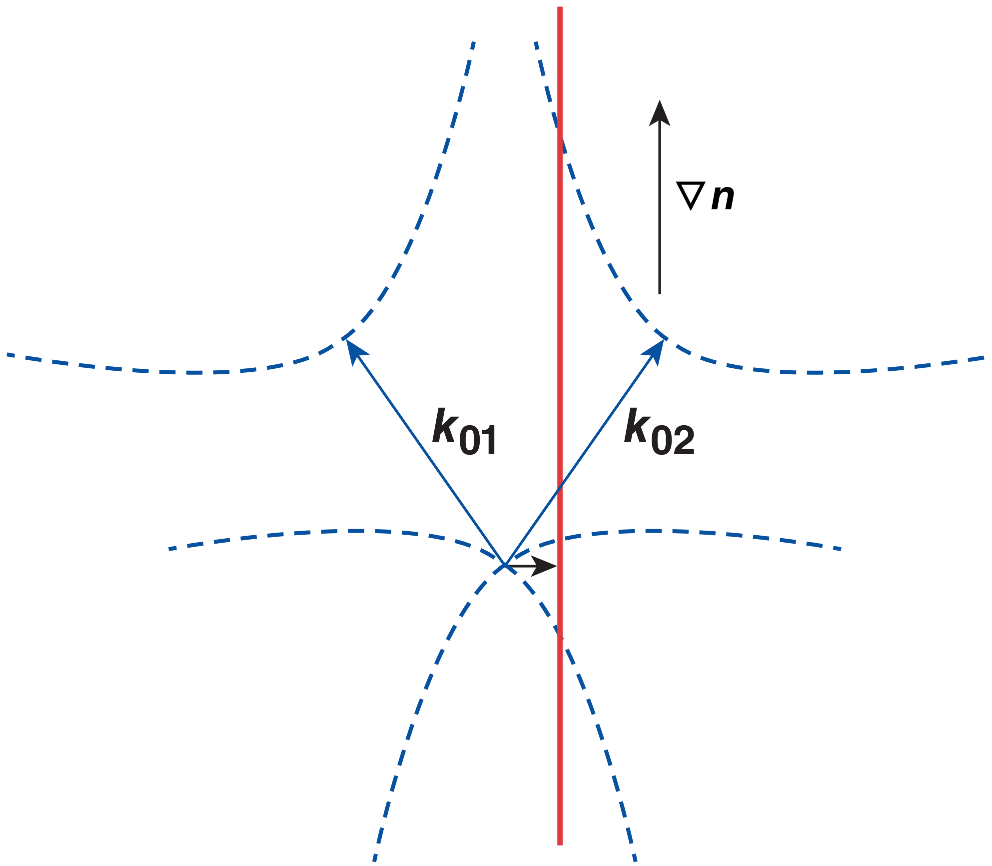
For a single *p*-polarized beam, the interaction lengths in both *k*-space and real space are increased by ~ 1/cosθ



- As a result, the threshold is reduced by ~cos$^2\theta$

TC10641

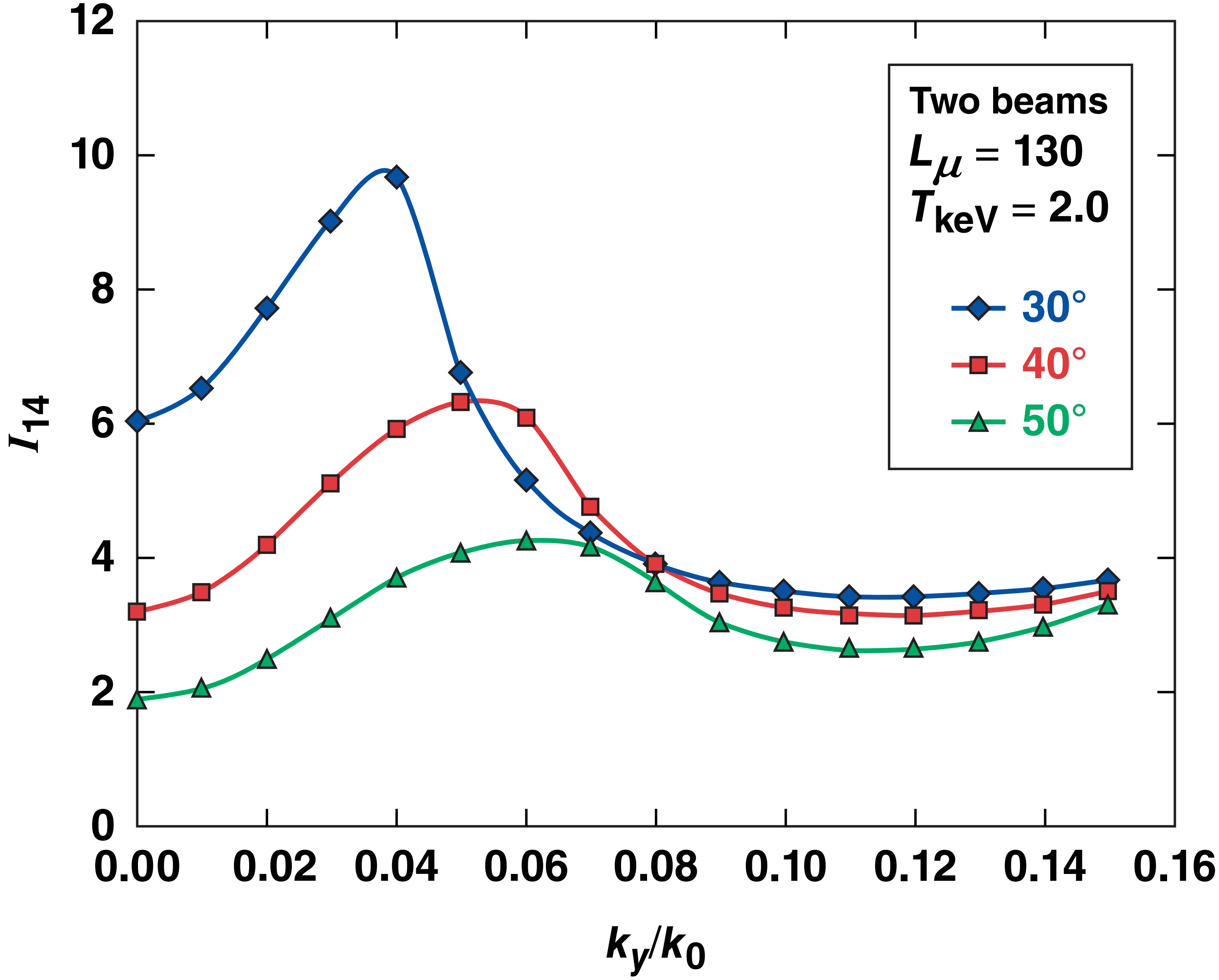
For two *p*-polarized beams, the interaction regions are separated, reducing synergy



- For two *s*-polarized beams the separation is much smaller

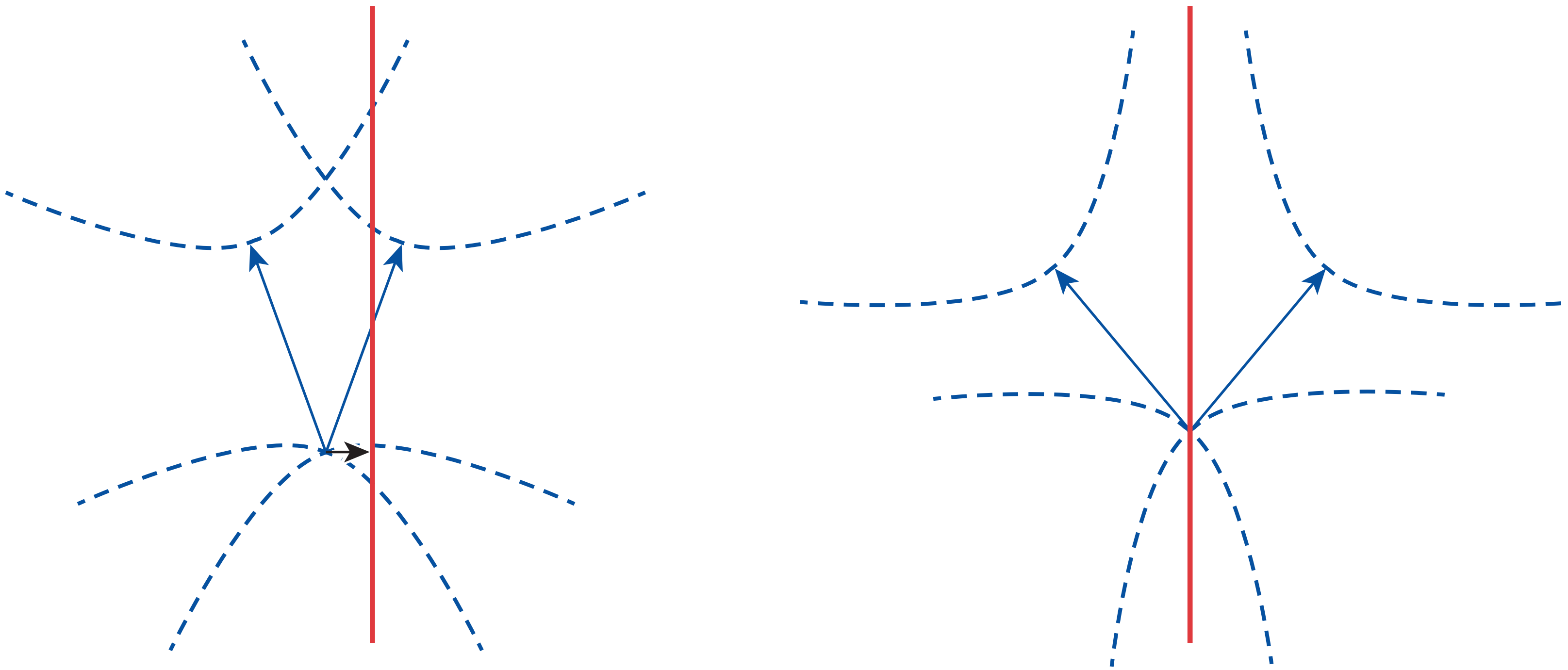
TC10642

For two *p*-polarized beams, an on-axis absolute mode with $k_y = 0$ has the lowest threshold at larger angles



TC10643

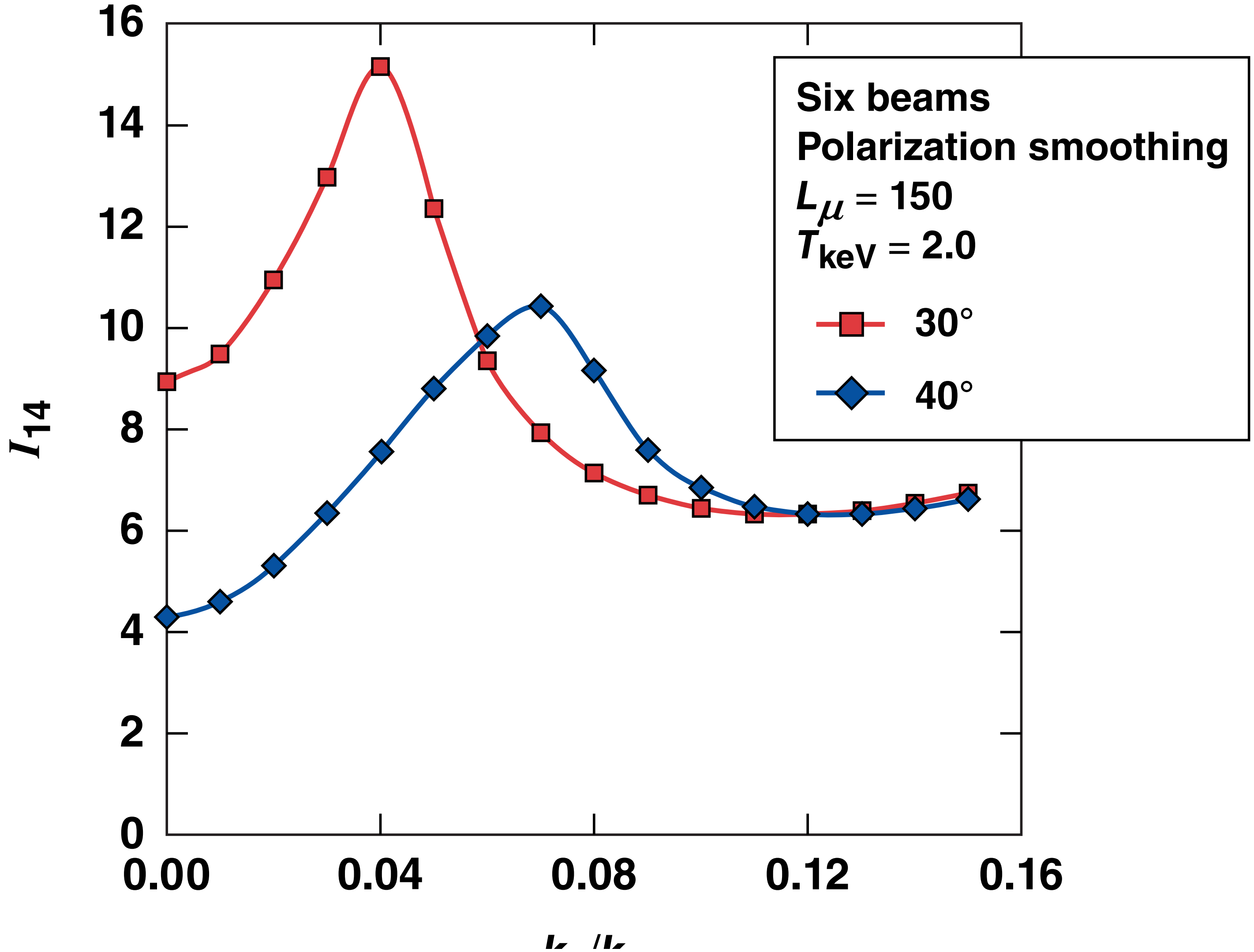
At larger angles, the on-axis mode is closer to the hyperbolas than the off-axis modes



$\theta = 20°$ $\theta = 40°$

TC10644

With more beams, the absolute TPD threshold for the on-axis mode is quite sensitive to the cone angle



TC10645

Summary/Conclusions

For multibeam two-plasmon decay (TPD), the absolute instability usually dominates

- The TPD threshold is sensitive to the number, orientation, and polarization of the beams
- For two beams polarized out of their common plane a collective absolute mode near $k = 0$ dominates TPD
- For two beams polarized in their common plane there are two absolute TPD modes; the dominant one depends on angle of incidence
- The thresholds of multi-beam absolute modes decrease with larger incidence angles and increased polarization components in the plane of the common wave