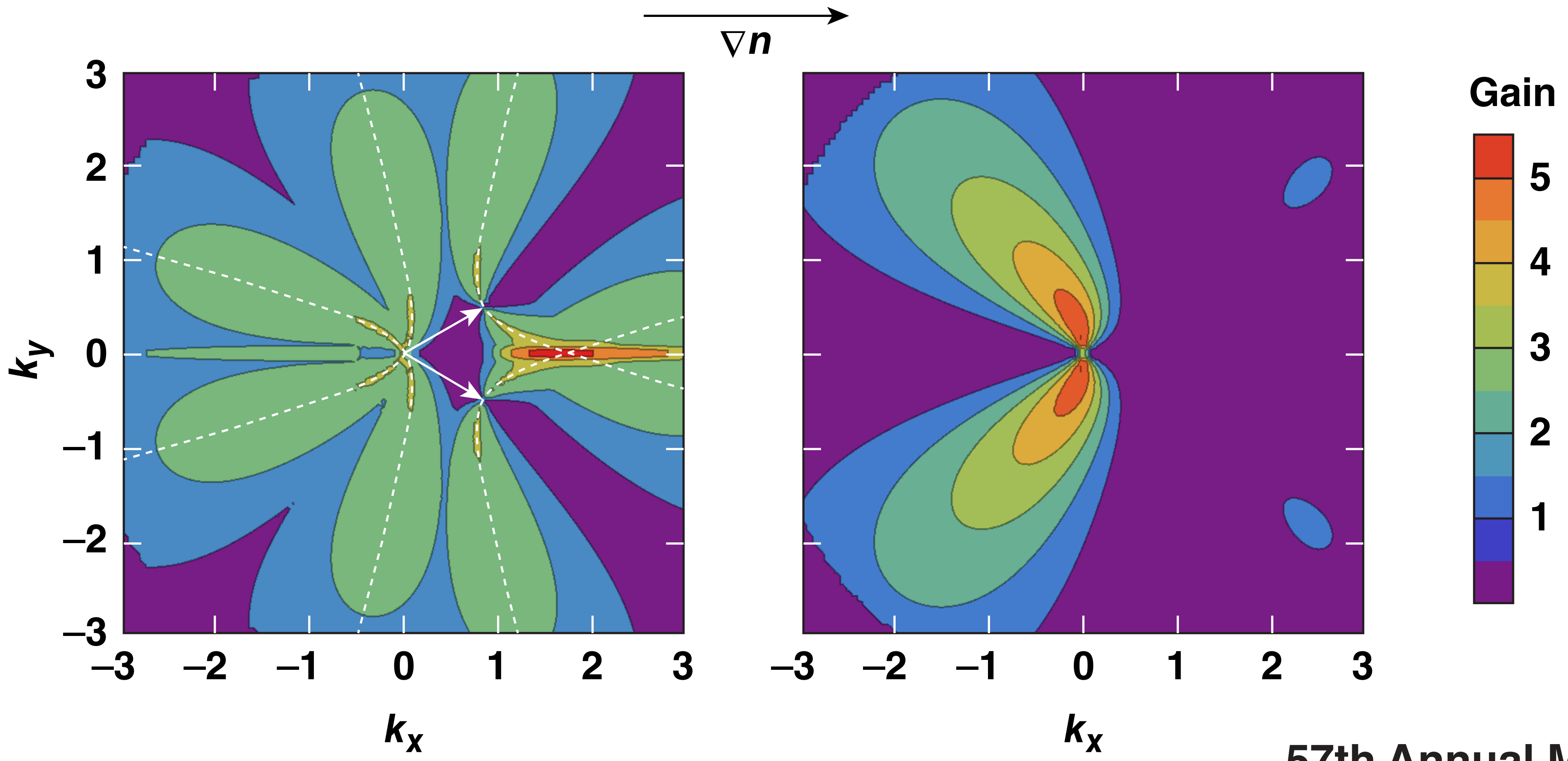
Absolute Two-Plasmon Decay and Stimulated Raman Scattering in Direct-Drive Irradiation Geometries



R. W. Short
University of Rochester
Laboratory for Laser Energetics

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Summary

In general, both stimulated Raman scattering (SRS) and two-plasmon decay (TPD) will play a role in direct-drive laser–plasma interactions

- Absolute TPD and SRS thresholds have different dependencies on laser and plasma parameters, but are comparable
- The modes with the lowest thresholds tend to be either SRS or TPD; mixed polarization modes seem unimportant
- Larger scale lengths and temperatures favor SRS; larger incidence angles favor TPD
- The analysis presented here is linear; however, there is evidence that the absolute SRS/TPD it describes persists well into the nonlinear regime

Collaborators

A. V. Maximov, J. F. Myatt, W. Seka, and J. Zhang

University of Rochester
Laboratory for Laser Energetics

The origin in *k* space corresponds to the plasma-wave turning point, allowing SRS and TPD to be absolute

- In general, instabilities can be convective only in inhomogeneous plasmas*
- Near the turning point, however, there is a finite threshold for absolute instability**
- Enhanced multibeam convective gain near the origin in *k* space suggests the potential for absolute instability
- Convective SRS occurs for $n/n_c \leq 1/4$; for absolute SRS, the electromagnetic (EM) decay wave must have $k \cong 0$ and originate at $n/n_c \cong 1/4$

*M. N. Rosenbluth, Phys. Rev. Lett. 29, 565 (1972).
**C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Rev. Lett. 31, 697 (1973); A. Simon *et al*., Phys. Fluids 26, 3107 (1983).

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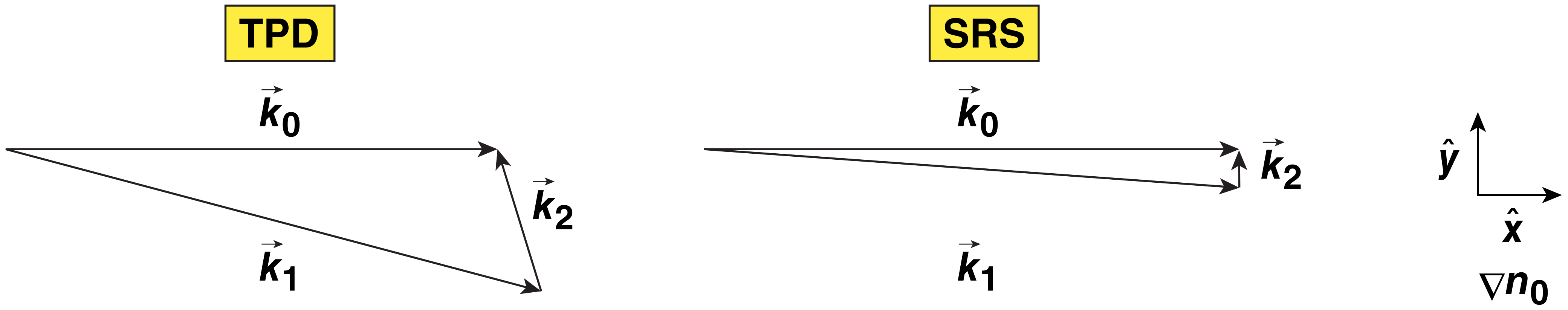
Absolute SRS requires the component of *k* perpendicular to the density gradient to vanish



- The *y* components of the plasma-wave group velocity $v_g = 3v_T^2\, k/\omega$ are equal and opposite, so TPD is absolute in the *y* direction
- For SRS, $v_{g1y} = 3v_T^2\, k_{1y}/\omega$ and $v_{g2y} = c^2\, k_{2y}/\omega$, so SRS will be convective in *y* unless $k_{2y} \cong 0$

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For a single beam, the absolute TPD threshold* is lower than the Rosenbluth convective threshold

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- The Simon threshold (adjusted for *s*-polarized oblique incidence) is $\eta \equiv \frac{I_{14} L_{\mu}}{233\, T_{\text{keV}} \cos\theta} > 1$

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

- The nominal convective threshold is $G_{\text{R}} > 2\pi$ or $\eta > \frac{2\pi}{4.35} \cong 1.44$

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

- The threshold for absolute SRS is comparable**

*A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).
**C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Fluids 17, 1211 (1974).

TC10637b

Fourier analysis of the time-independent TPD equations results in a set of first-order linear differential equations

- **Absolute TPD and SRS occur near quarter-critical, so the local density profile may be approximated by a linear gradient**
- **Fourier transforming in space, the wave equations become first-order linear equations for the longitudinal and transverse components of the small-*k* decay wave**
- **The larger-*k* decay wave may be taken to be longitudinal**
- **For *N* beams there are, therefore, $3N + 1$ linear differential equations that are integrated from $k_x \to -\infty$ to $k_x \to +\infty$ to obtain the spatial gain**
- **Divergence of the gain indicates an onset of absolute instability; optimizing over ω gives the threshold and frequency**

Light from absolute SRS will be emitted along the density gradient

- The much-higher group velocity of the EM wave means the instability must be absolute in the direction perpendicular to the density gradient, i.e., $k_y \sim k_z \sim 0$ and the wave is purely transverse
- Phase matching, and therefore threshold, will be insensitive to temperature
- The spectrum of the emitted light will have the same dependence on temperature as for TPD
- For *s*-polarization the threshold will be independent of pump incidence angle; for *p*-polarization the coupling is reduced for oblique incidence and the threshold increases with angle
- Analysis of the *k*-space equations for a normally incident beam gives a threshold of $I_{14} > \frac{1995}{L_{\mu}^{4/3}}$, close to the Liu, Rosenbluth, and White result

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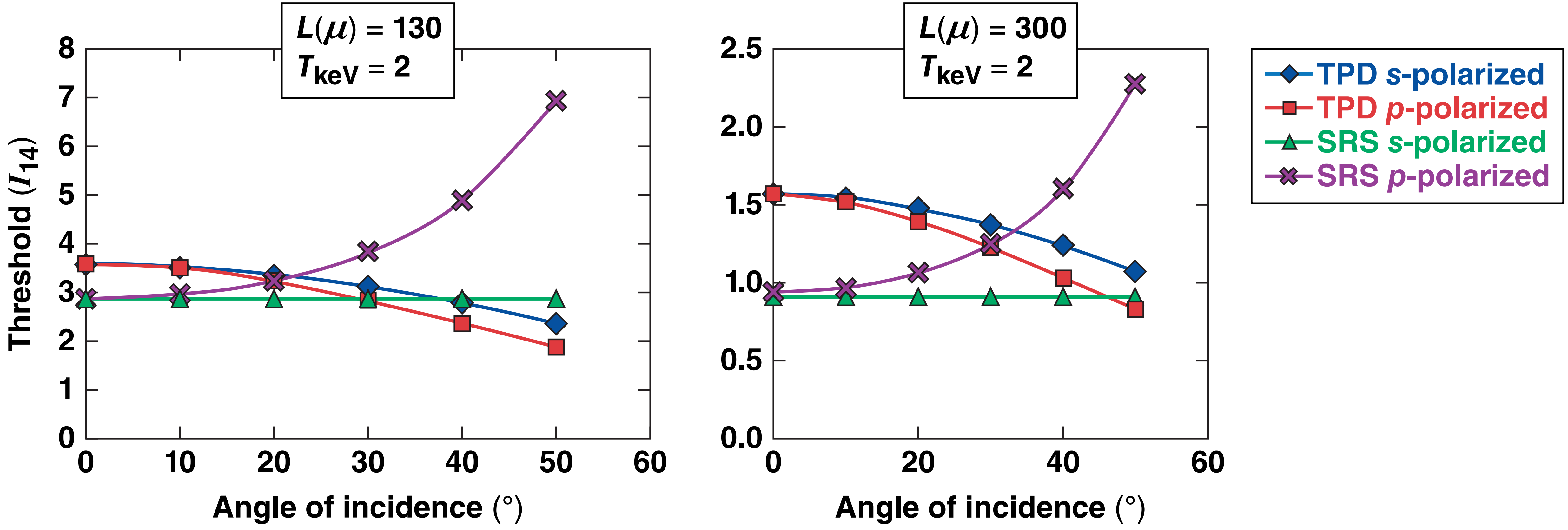
For oblique incidence, TPD and SRS behave differently as a function of incidence angle

- Increasing temperatures and scale lengths favor SRS; increasing incidence angles favor TPD



- Upper points show poor convergence when hybrid terms are included; absolute mode may not exist for these angles

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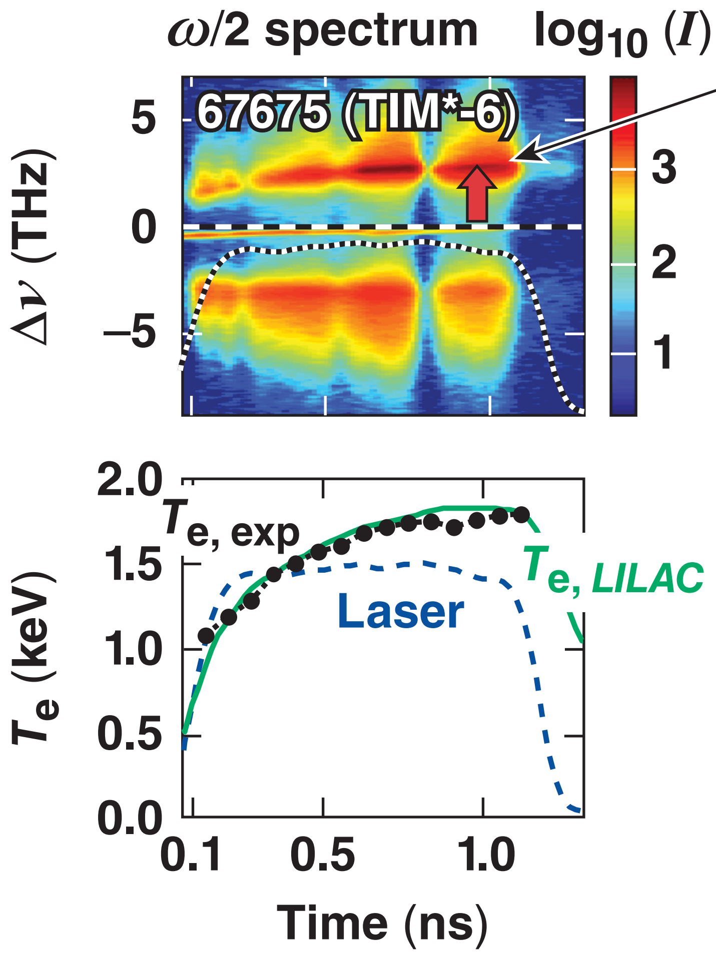
The spectral signature of the absolute instability near $n_c/4$ is a sharp red-shifted feature that can be used for T_e measurements



$\Delta\lambda_{nm} = 4.4 \times 10^{-3}\, T_{e,\,keV}$

At $I \lesssim 5 \times 10^{14}$ $T_{e,\,keV} \sim T_{e,\,LILAC}$

$I_{14} = 5.6$

- Although the absolute instability is obtained from linear analysis, it can remain the most-intense TPD mode in the nonlinear regime, persisting throughout the pulse

*TIM: ten-inch manipulator

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