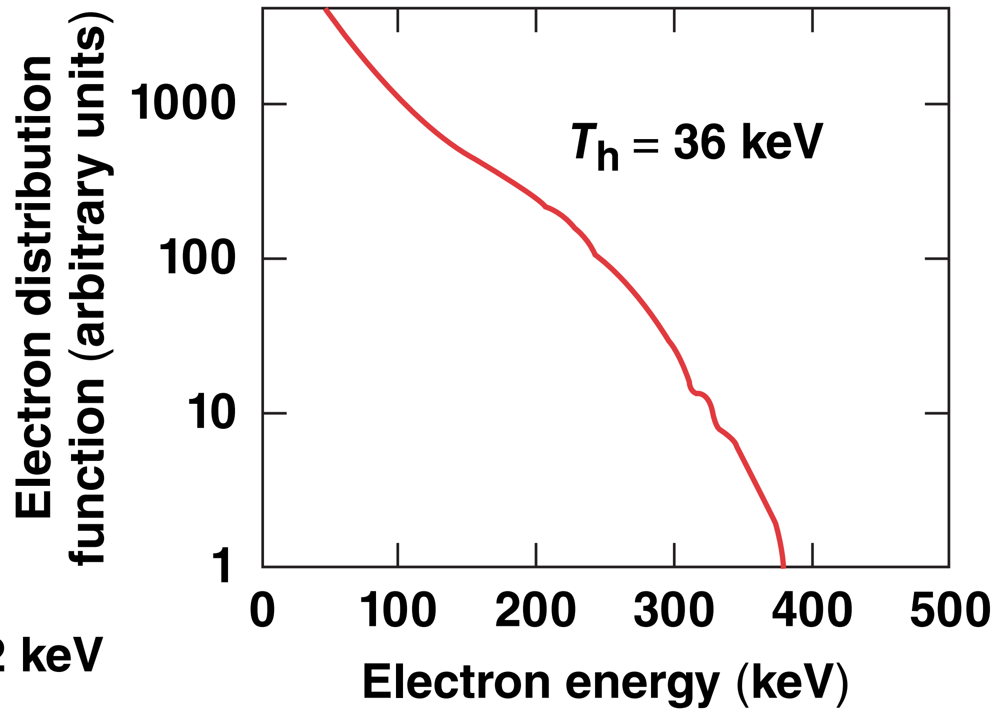
Two-Plasmon-Decay Instability and Stimulated Brillouin Scattering in Direct-Drive ICF Plasmas



T_e = 2 keV

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Summary

The saturation of the two-plasmon-decay instability is caused by low-frequency ion-acoustic density perturbations

- In the linear stage of the two-plamon-decay (TPD) instability, a broad spectrum of primary Langmuir waves is generated through absolute and convective growth
- In the nonlinear stage of the TPD instability, saturation is caused by low-frequency density perturbations that are caused by stimulated Brillouin scattering (SBS) and beating of primary Langmuir waves. The threshold of Langmuir decay instability (LDI) depends on the width of the Langmuir wave spectrum
- The temperature of hot electrons produced in TPD is defined by the spectrum of Langmuir waves, including the Landau cutoff

Collaborators

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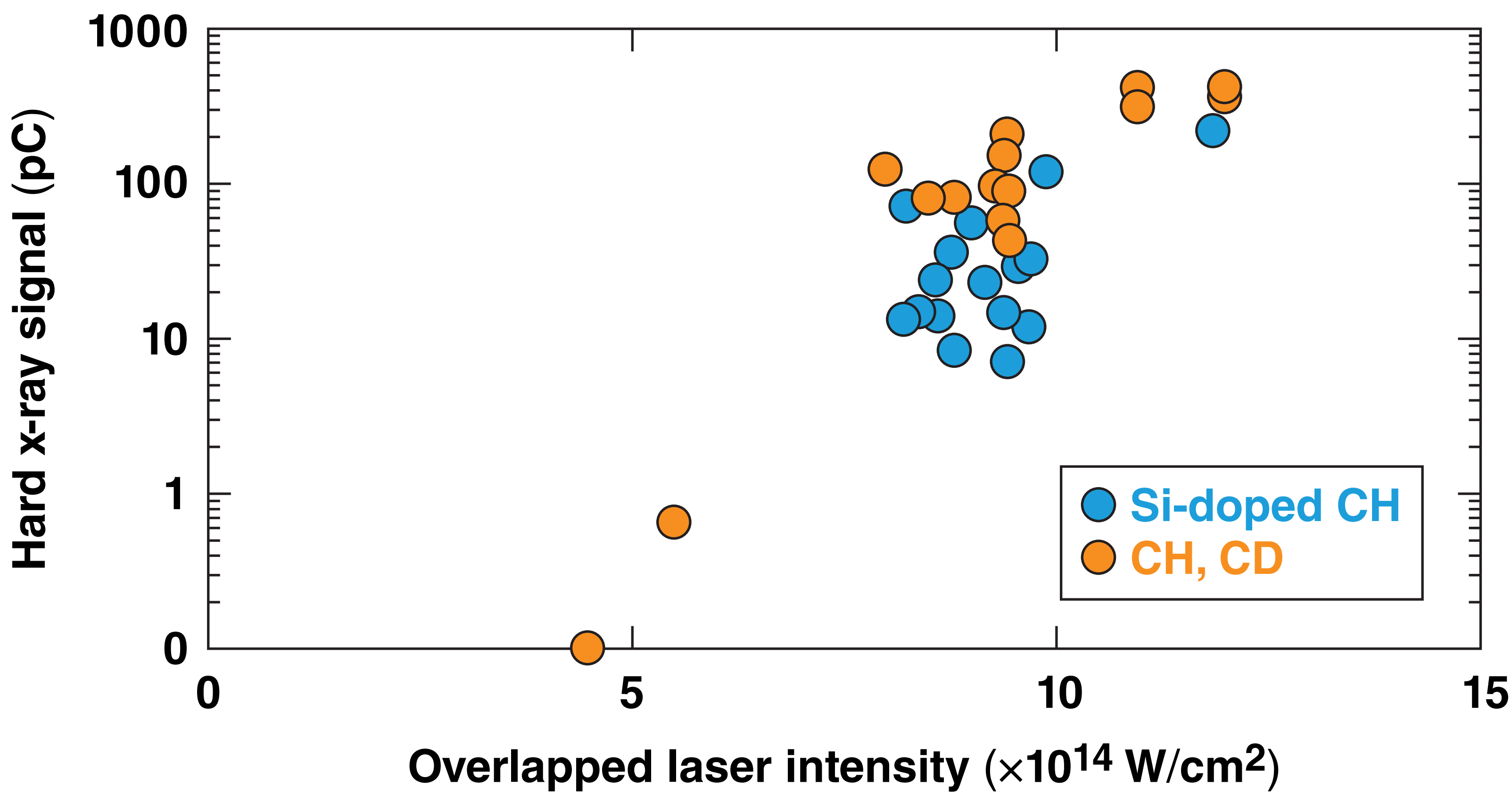
In OMEGA experiments, the hard x-ray production depends on ion composition and overlapped laser intensity*



TC8036e

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

The TPD instability threshold is influenced by the interplay of plasma inhomogeneity, wave damping, and resonance detuning caused by beam incoherence

- Plasma-wave damping

$$\left(\frac{\gamma_e}{\omega_{p0}}\right)_{\text{coll}} = 0.5 \times 10^{-3} \frac{(Z/5.3)}{(T_e/2\,\text{keV})^{3/2}}$$

- Detuning caused by inhomogeneity

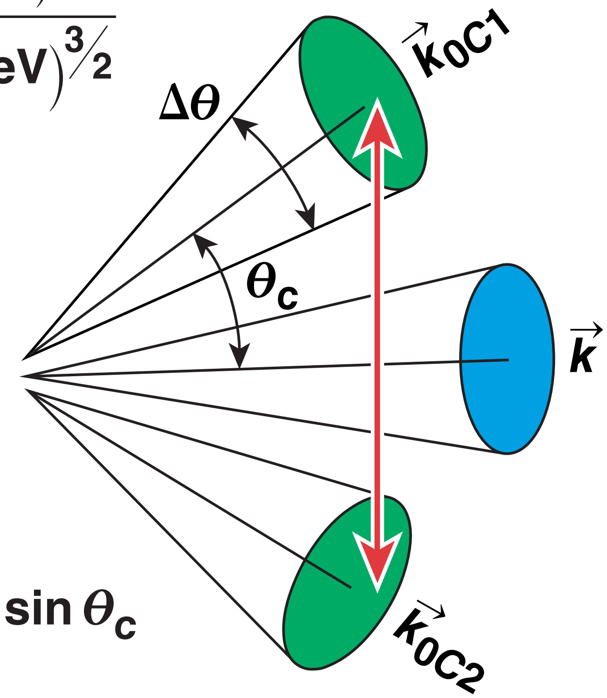
$$\frac{1}{2\,k_0 L} = \frac{2.1 \times 10^{-4}}{(L/150\,\mu m)}$$

$\wedge$

- Detuning caused by beam incoherence

$$\frac{\Delta\omega}{\omega_{p0}} = 3\,k\,k_0 \lambda_{De}^2 \left|\sin\theta_c\right| \Delta\theta$$

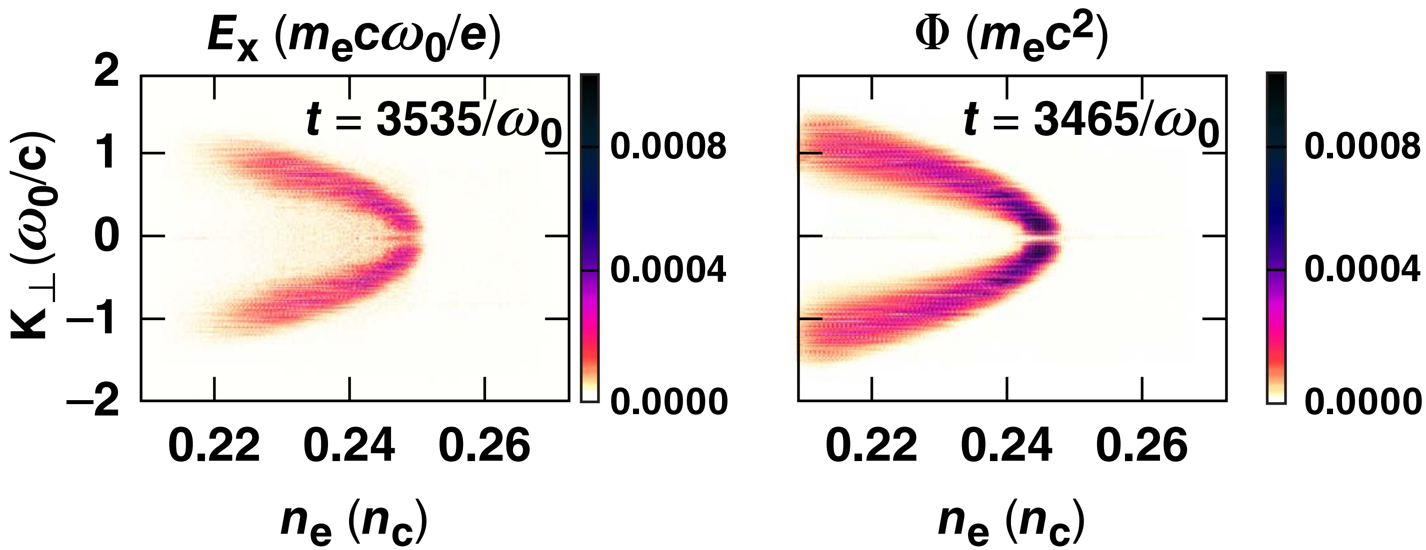
$$\frac{\Delta\omega}{\omega_{p0}} = 4 \times 10^{-2} (T_e/2\,\text{keV})\,\Delta\theta \sin\theta_c$$



TC7846d

W. Seka (GO5.00006).

In simulations of TPD, the fastest-growing wave vectors change with the position in the inhomogeneous plasmas



PIC simulation *OSIRIS*

Fluid simulation*

$I = 10^{15}$ W/cm^2, $T_e = 2$ keV, $L_N = 150$ μm

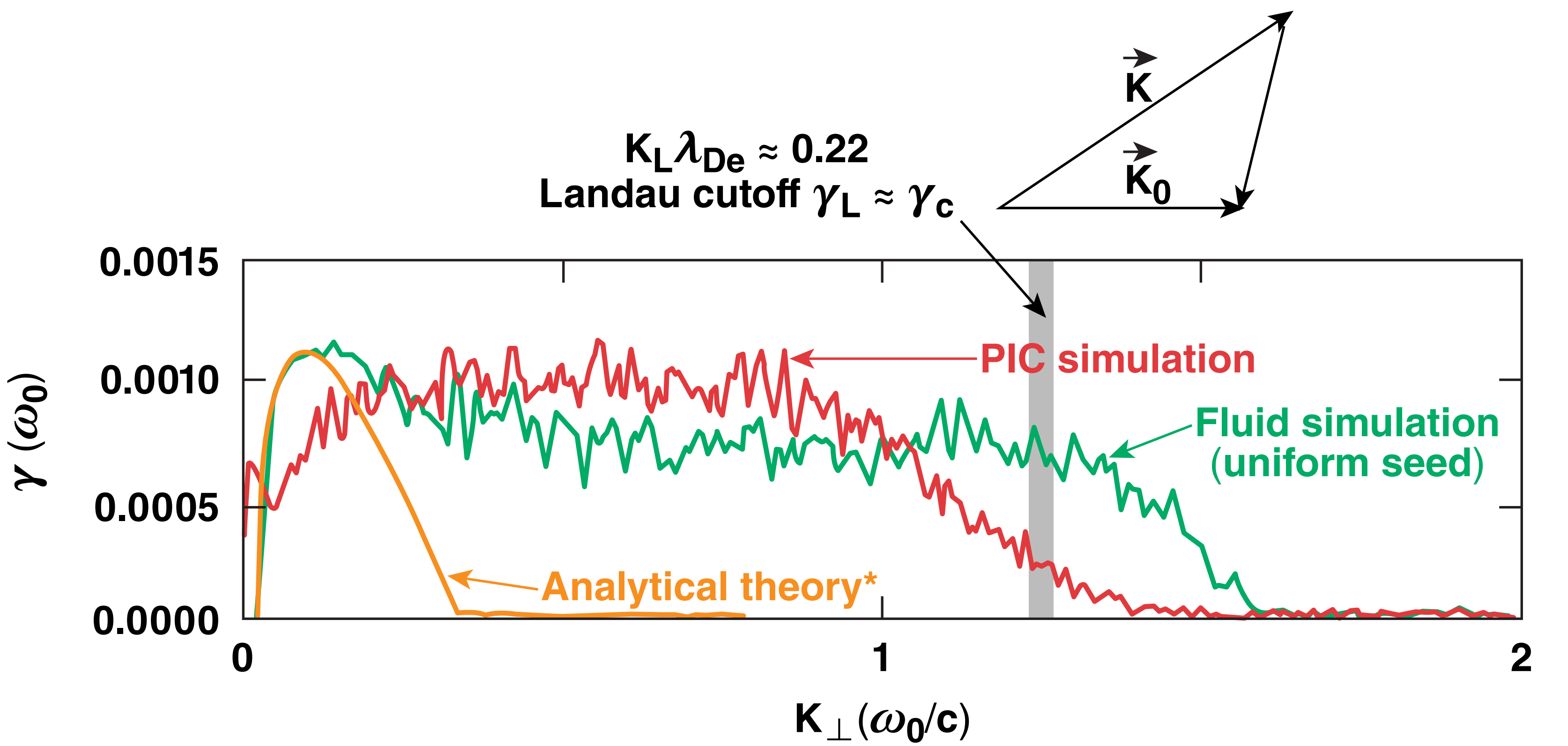
The longitudinal and transverse wave vectors lie on the TPD maximum-growth hyperbola.

$$K_\perp^2 = K_{||}(K_{||} - K_0)$$

TC8856a

*R. Yan *et al*., Phys. Rev. Lett. 103, 175002 (2009).

In the linear stage of TPD, absolute and convective growth generates a broad spectrum of Langmuir waves



$I = 10^{15}$ W/cm^2, $T_e = 2$ keV, $L_N = 150\ \mu$m

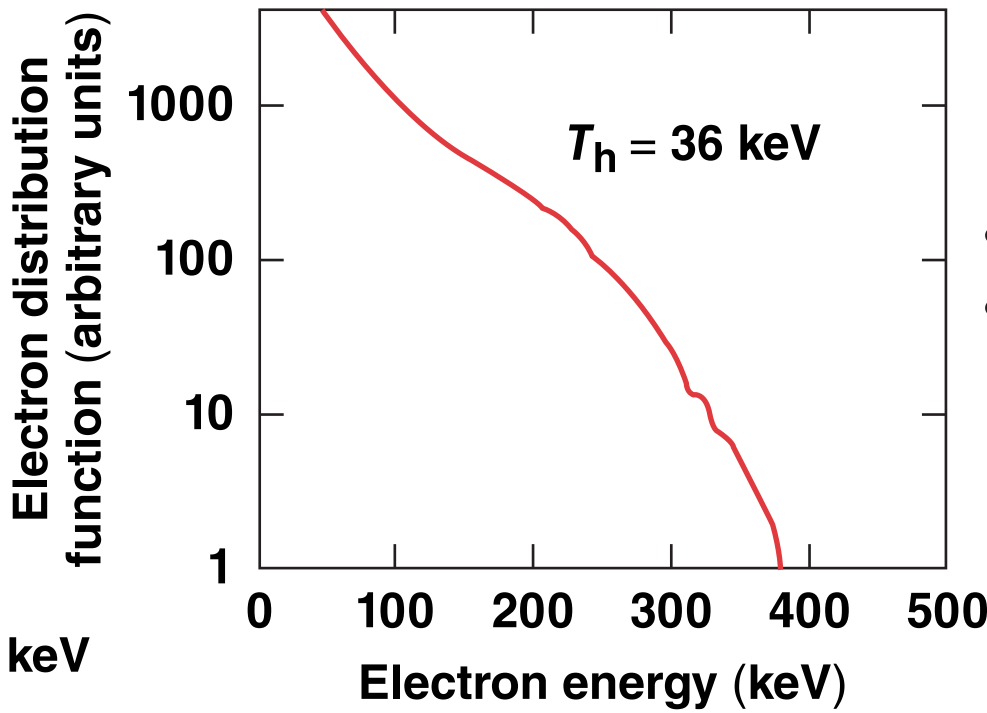
TC8855a

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

The distribution of fast electrons generated in the TPD is characterized by the hot-electron temperature

UR LLE

$$f(\varepsilon) \sim \sqrt{\varepsilon} \cdot \exp\left(-\varepsilon / T_h\right)$$



T_e = 2 keV

Boundary conditions in PIC:

- periodic (transverse)
- thermal (longitudinal)

Saturation caused by mobile ions*

Immobile ions:	longitudinal $\left\langle \left\| E_{\parallel} \right\|^2 \right\rangle \sim$ transverse $\left\langle \left\| E_{\perp} \right\|^2 \right\rangle$
Mobile ions:	$\left\langle \left\| E_{\parallel} \right\|^2 \right\rangle \lesssim 0.1 \left\langle \left\| E_{\perp} \right\|^2 \right\rangle$

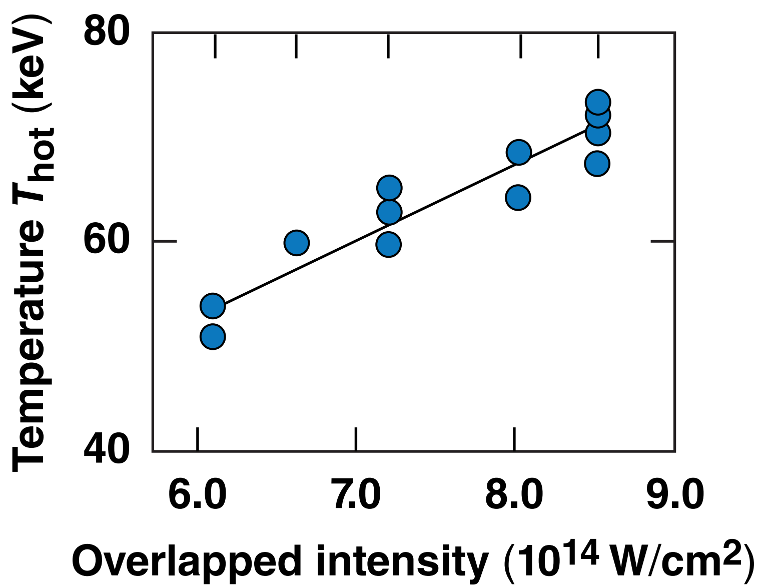
TC8857a

*A. B. Langdon, B. F. Lasinski, and W. L. Kruer, Phys. Rev. Lett. 43, 133 (1979).

The temperature of hot electrons, generated in the TPD, depends on the spectrum of Langmuir waves

$$T_h \sim \frac{m_e}{2}\left(\frac{\omega}{k_L}\right)^2 \sim 20 \cdot T_e$$

Simulations: $T_h \sim 36$ keV for $T_e \sim 2$ keV



Experiment*: $T_h \sim (50 \div 80)$ keV for $T_e \sim (2.5 \div 4)$ keV

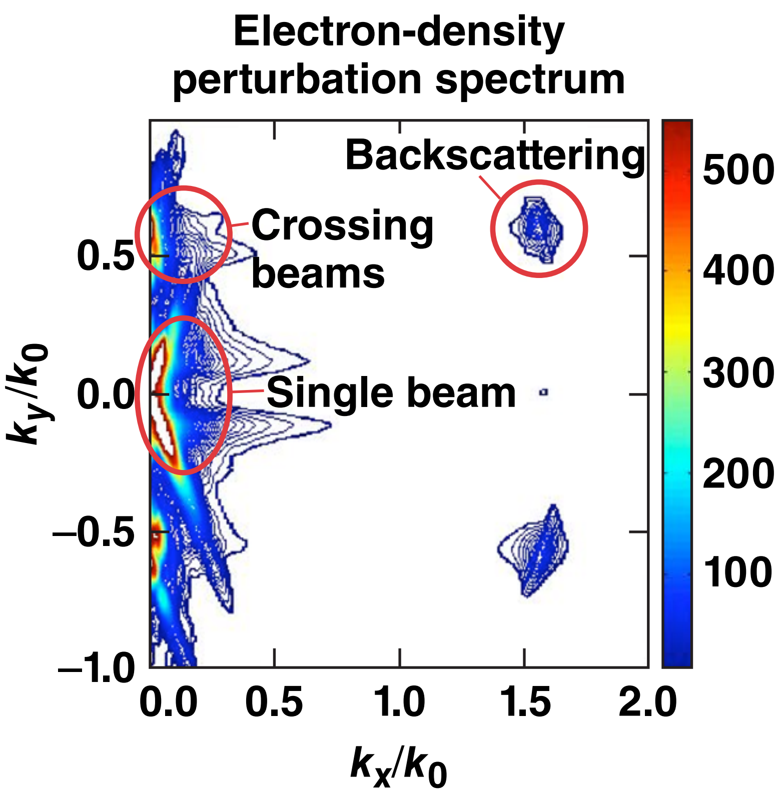
TC9141

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

Stimulated Brillouin scattering (SBS) driven by the interaction of incoherent laser beams produces low-frequency perturbations in electron density

- Two crossing laser beams at ±20° with $f/6$ DPP
- $\langle I \rangle = 9 \times 10^{14}\ \mathrm{W/cm^2}$,

  $T_e = 2\ \mathrm{keV},\ n_0 \approx \frac{n_c}{4}$



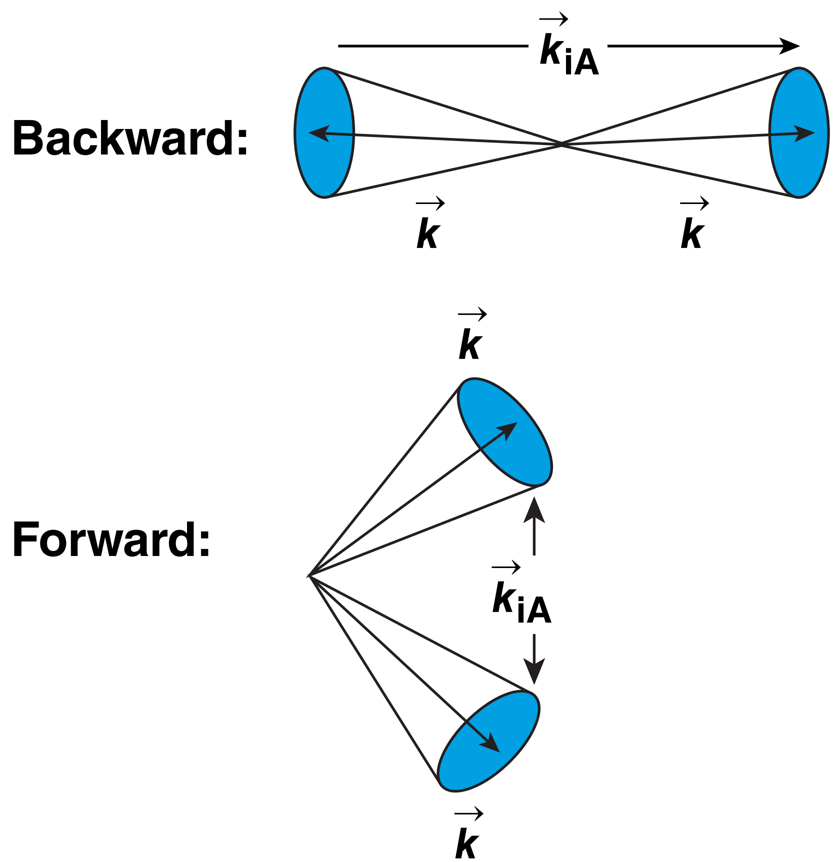
TC8683b

In the nonlinear stage of TPD, the threshold of the Langmuir decay instability depends on the spectra of primary Langmuir waves

LDI threshold in the random-phase approximation

$$\frac{\langle |E_L|^2 \rangle}{16\pi n T_e} \cdot \left| \frac{S}{\omega} \right| = \frac{|\Delta\omega_L|}{\omega_p} \cdot 4$$

$\Delta\omega_L$: resonance width
S: spectral density



Seeding by perturbations caused by SBS

TC8476c

Summary/Conclusions

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