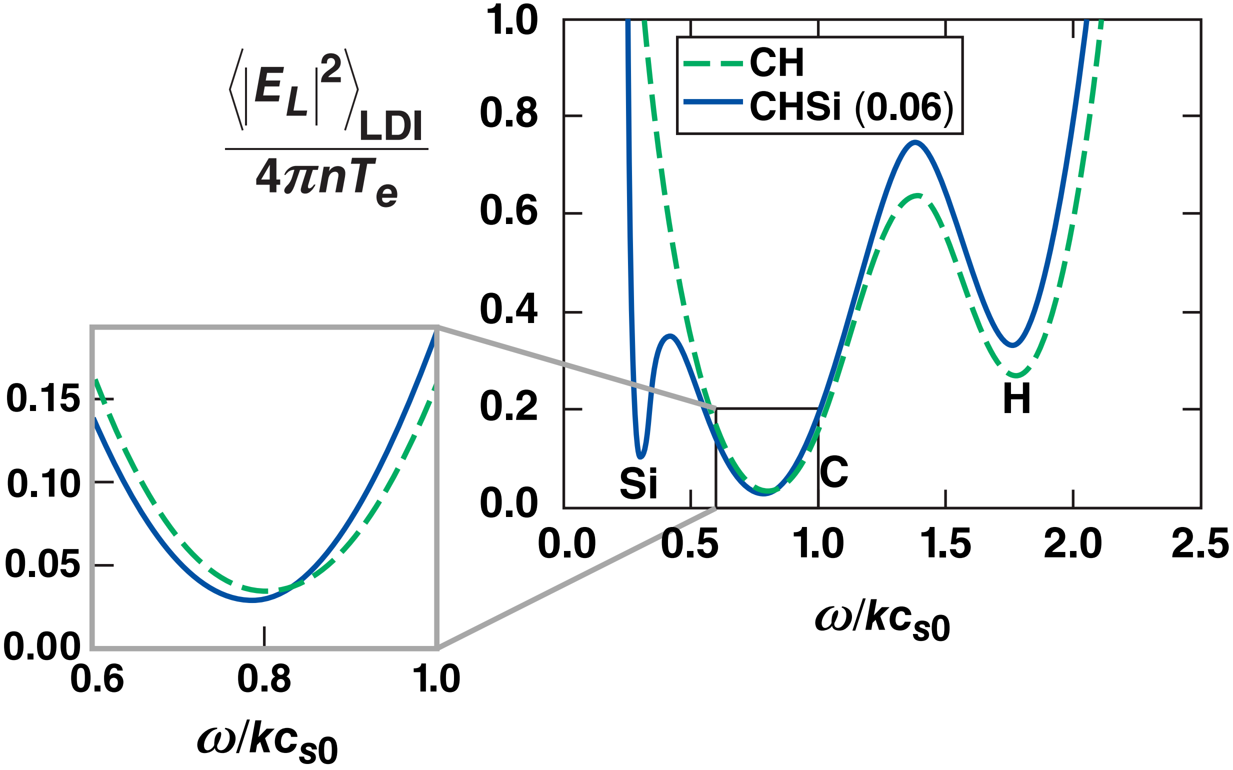
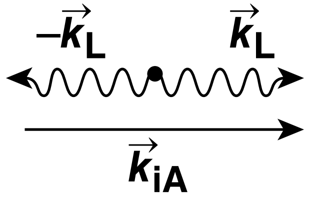
Growth and Saturation of Two-Plasmon-Decay Instability Driven by Crossing Laser Beams in OMEGA Plasmas





Langmuir decay

A. V. Maximov, J. F. Myatt, R. W. Short,
W. Seka, J. A. Delettrez, and C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

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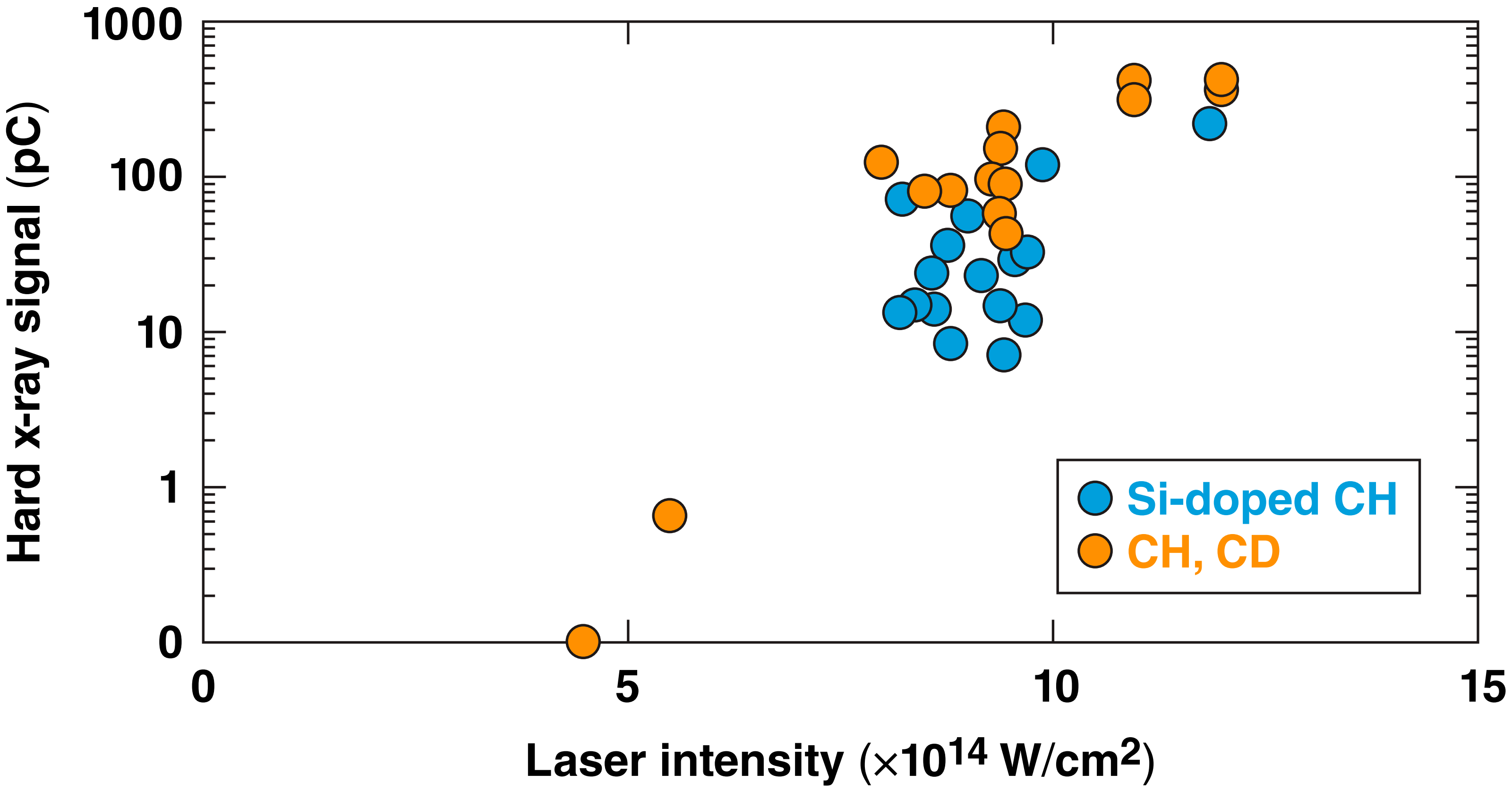
Summary

The saturation of the two-plasmon-decay (TPD) instability is influenced by the ion composition of plasmas and the angular structure of laser beams

- Low-frequency density perturbations, driven by crossing laser beams, interact with primary Langmuir waves generated in the linear stage of TPD.
- In multispecies plasmas, the presence of a high-*Z* dopant can increase the amplitude of density perturbations.
- The onset of the Langmuir decay instability contributes to the nonlinear saturation of TPD.
- The threshold of the Langmuir decay instability can be decreased by changing the ion composition and the laser-beam optics.

In OMEGA experiments, the hard x-ray production depends on the ion composition



See also J. A. Delettrez (U05.00010).

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

- Plasma wave damping

$$\left(\frac{\gamma_e}{\omega_{p0}}\right)_{\mathrm{coll}} = 0.5\times10^{-3}\,\frac{(Z/5.3)}{\left(T_e/2\,\mathrm{keV}\right)^{3/2}}$$

- Detuning due to inhomogeneity

$$\frac{1}{2\,k_0 L} = \frac{2.1\times10^{-4}}{(L/150\,\mu m)}$$

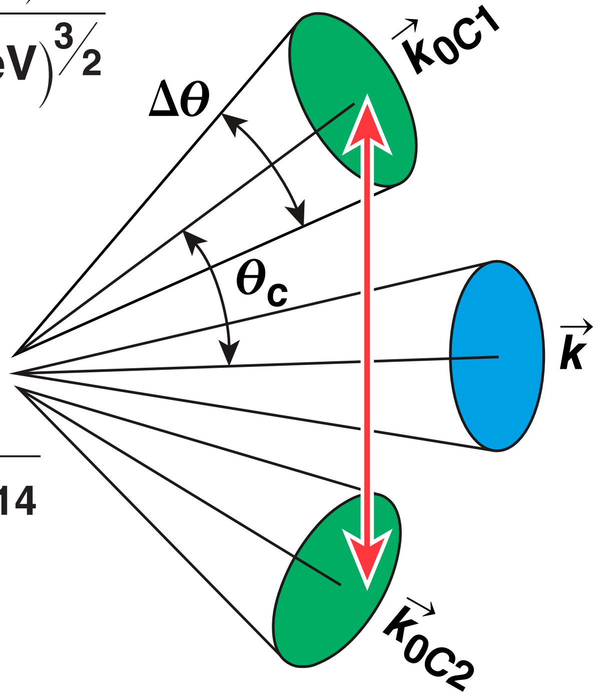
- Homogeneous 3-wave growth rate

$$\gamma^0 = \frac{k_0\left|V_{\mathrm{osc}}\right|}{\omega_{p0}} = 0.26\times10^{-2}\sqrt{I_{14}}$$

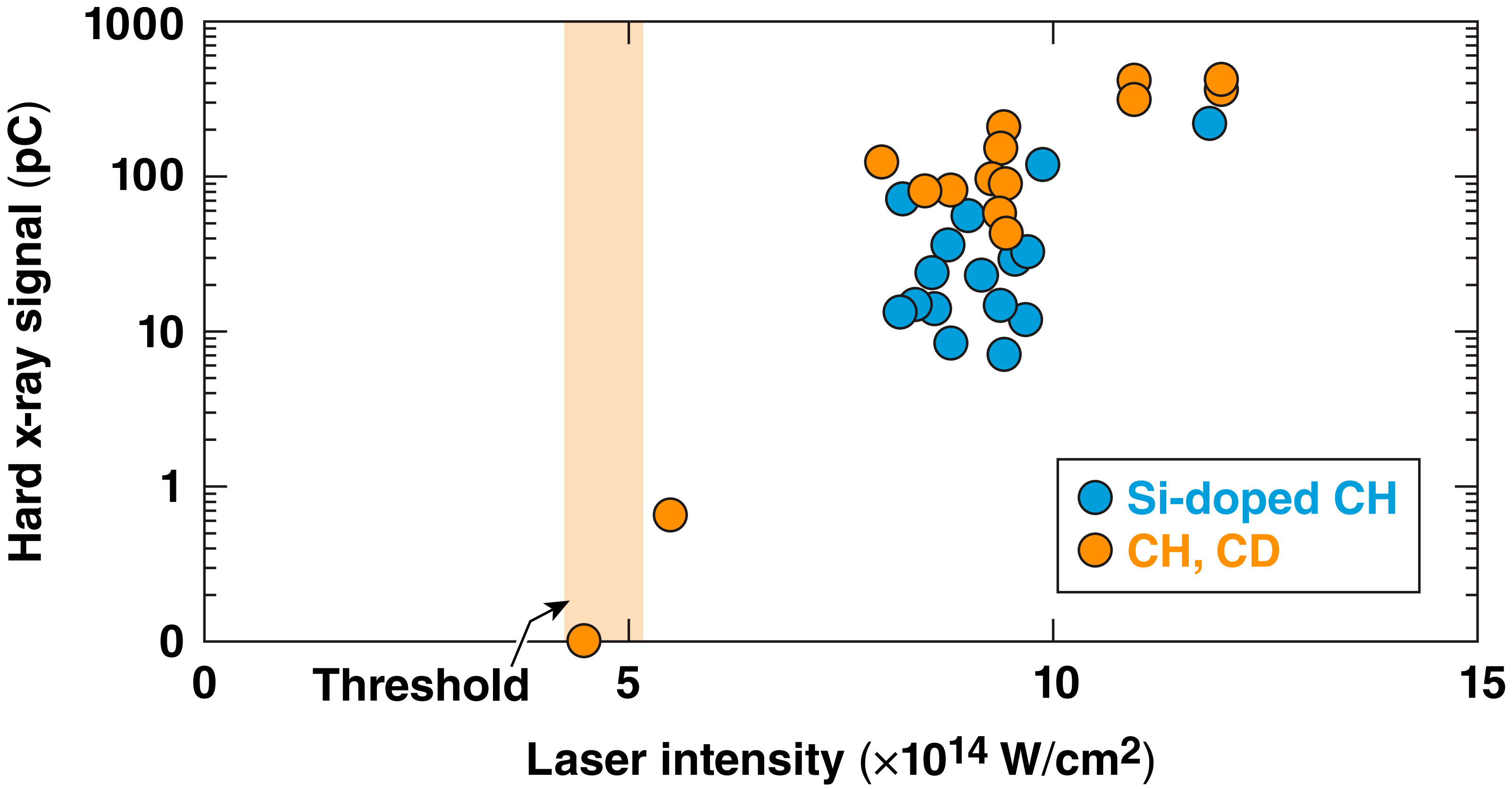
- Detuning due to beam incoherence

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

$$\frac{\Delta\omega}{\omega_{p0}} = 4\times10^{-2}\left(T_e/2\,\mathrm{keV}\right)\Delta\theta\sin\theta_c$$



The calculated TPD threshold is in reasonable agreement with the hard x-ray onset intensity



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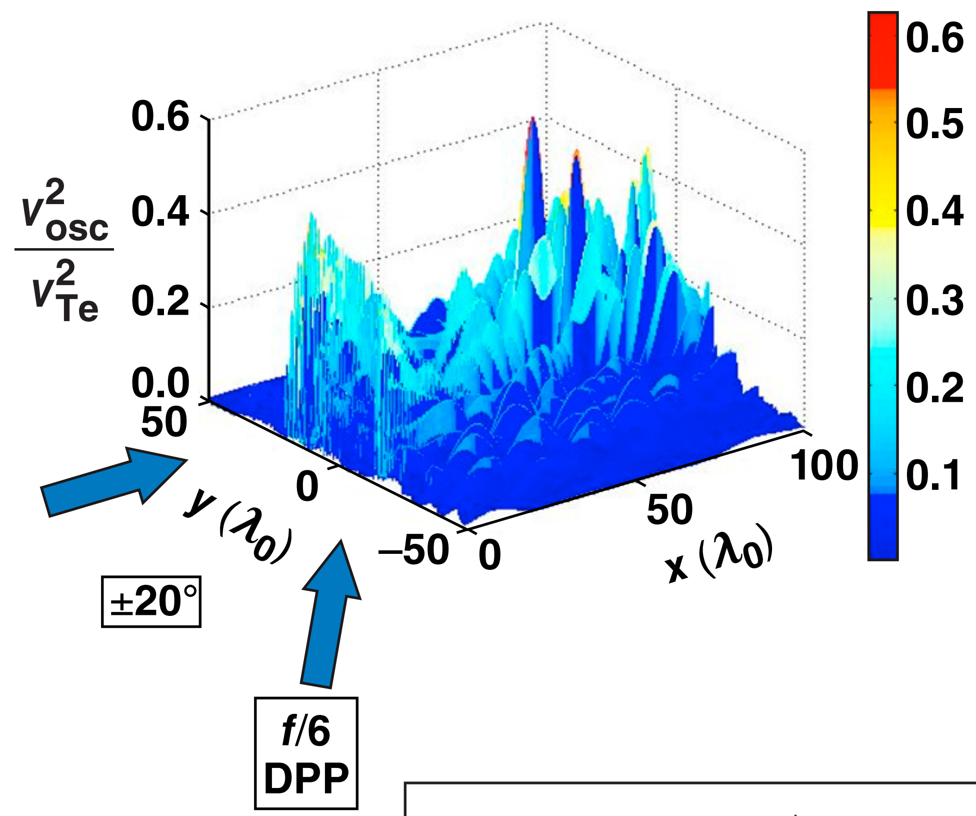
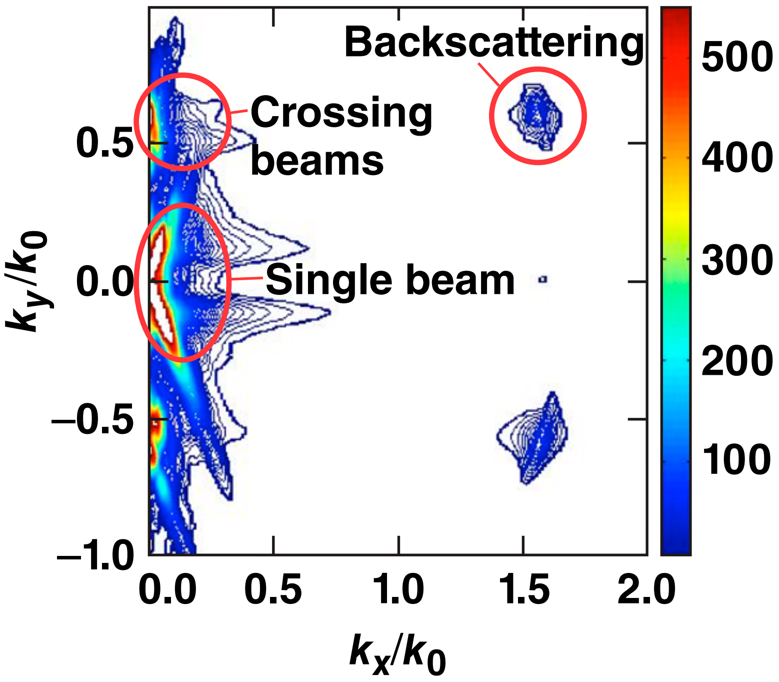
The interaction of incoherent laser beams with plasmas produces low-frequency perturbations in electron density



Laser intensity



Density perturbation spectrum

$$\langle I \rangle = 9 \times 10^{14}\ \text{W/cm}^2,\ T_e = 2\ \text{keV},\ n_0 \approx \frac{n_c}{4}$$

The dispersion equation for ion-acoustic waves in multispecies plasmas includes a sum of contributions from different ion species

$$\frac{k^2 c_{s0}^2}{n_e} \sum_i \frac{Z_i^2 n_i / M_i}{\left(\omega - \vec{k}\,\vec{V}\right)^2 + 2i\gamma_i \left(\omega - \vec{k}\,\vec{V}\right) - (5/3)\, k^2 V_{Ti}^2} = 1$$

Fluid model

- $\vec{V}$-flow velocity; Z_i and M_i -ion charge and mass; $c_{s0}^2 = \left(T_e / m_p\right)$
- In the collisional (i–i) regime, the ion-acoustic damping is determined by the ion viscosity and ion heat conductivity.

$$\gamma_i = k^2 \left(0.64 + 0.87 \frac{V_{Ti}^2}{c_s^2}\right) \frac{V_{Ti}^2}{\nu_{i\Sigma}}$$

where $\nu_{i\Sigma} = \dfrac{4 \ln \Lambda}{3\sqrt{\pi}} \dfrac{e_i^2}{T_i^{3/2}} \sum_A \left(\dfrac{n_A e_A^2}{m_{\text{eff}}^{1/2}}\right)$

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* S. I. Braginskii, in *Reviews of Plasma Physics,* edited by Acad. M. A. Leontovich (Consultants Bureau, New York, 1965), Vol. 1, p. 205.

The dispersion equation for ion-acoustic waves in multispecies plasmas has several solutions

- For CHSi (0.06) the solutions are:

$(T_i/T_e) = 1$

$$\left(\omega_r - \vec{k}\,\vec{V}\right)^2 = 0.94\,k^2 c_{s0}^2 \quad \text{and} \quad \gamma_i \approx \gamma_H$$

$$\left(\omega_r - \vec{k}\,\vec{V}\right)^2 = 0.43\,k^2 c_{s0}^2 \quad \text{and} \quad \gamma_i \approx 0.68\,\gamma_C + 0.32\,\gamma_{Si}$$

$$\left(\omega_r - \vec{k}\,\vec{V}\right)^2 = 0.04\,k^2 c_{s0}^2 \quad \text{and} \quad \gamma_i \approx \gamma_{Si}$$

In the Zakharov model* of TPD, saturation depends on the ion-acoustic damping.

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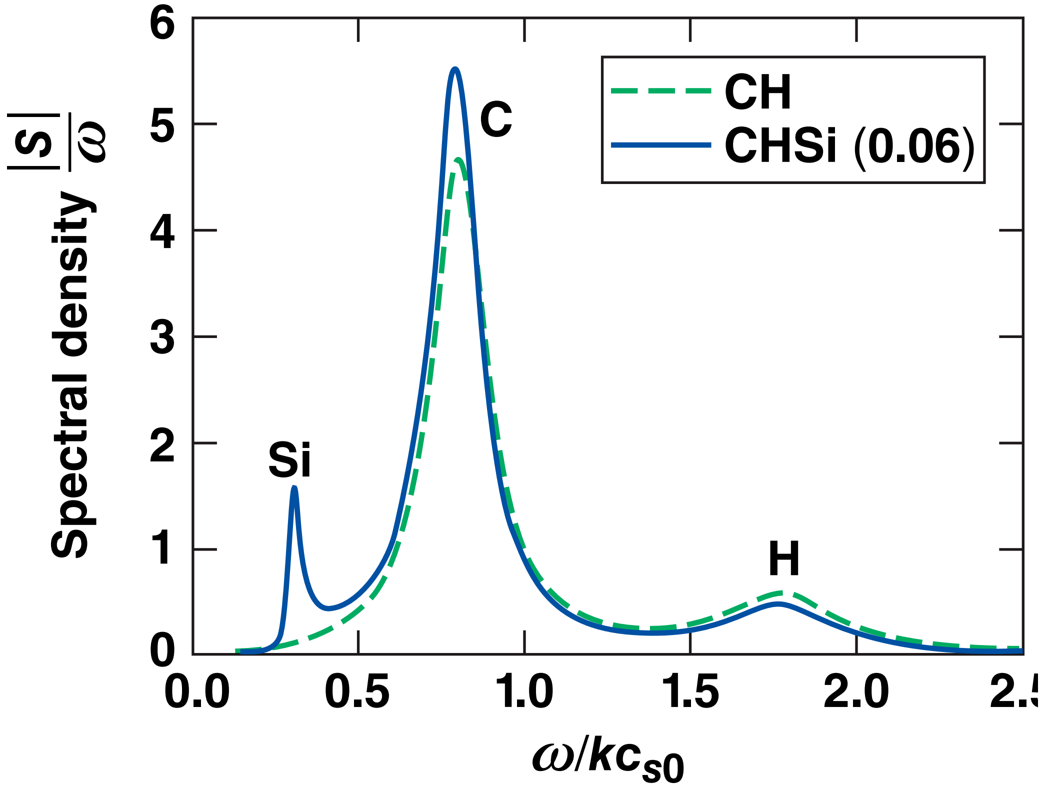
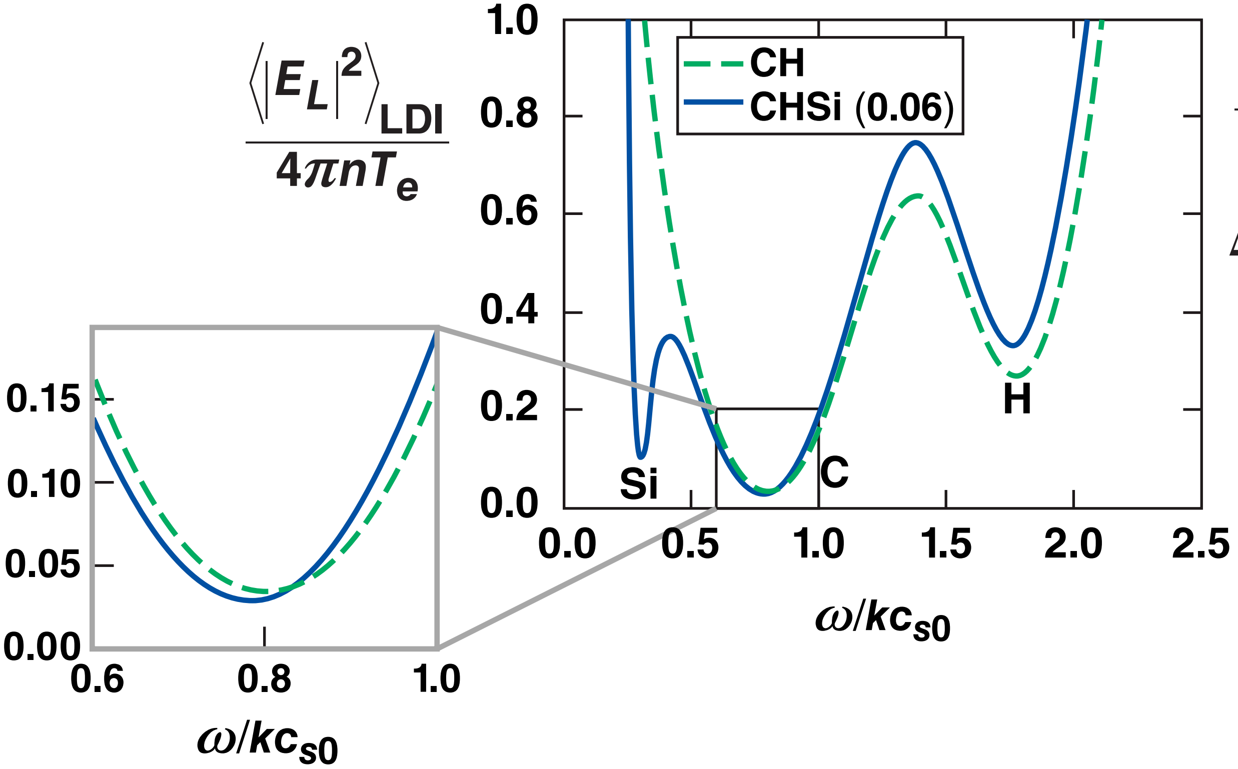
*See J. F. Myatt (JO5.00013).

The plasma spectral density characterizes the low-frequency density perturbations driven by the ponderomotive force



$$\text{Spectral density } \frac{S}{\omega} = \mathrm{Im}\left[\frac{(\delta n_e/n_e)_{\omega,k}}{|E|^2_{\omega,k}/16\pi n T_e}\right]$$

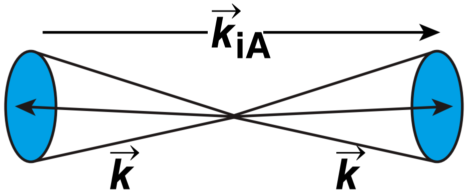
The threshold of the Langmuir Decay Instability depends on the characteristics of ion-acoustic waves



LDI threshold in the random-phase approximation

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

$\Delta\omega$ = resonance width



Seeding by laser-driven perturbations

Summary/Conclusions

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