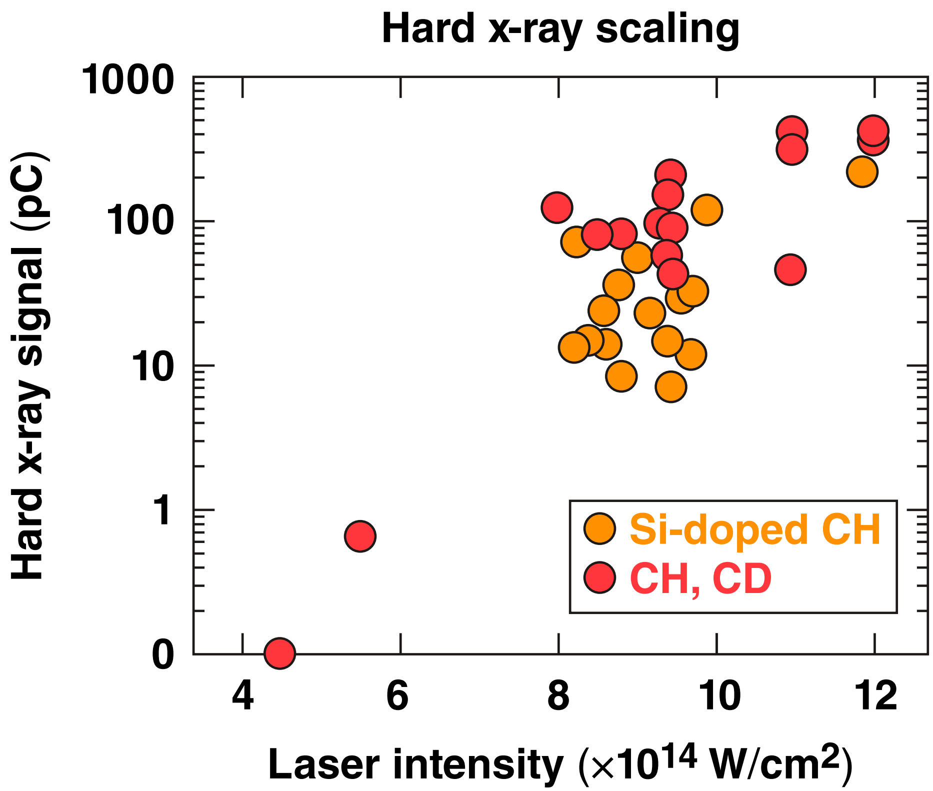
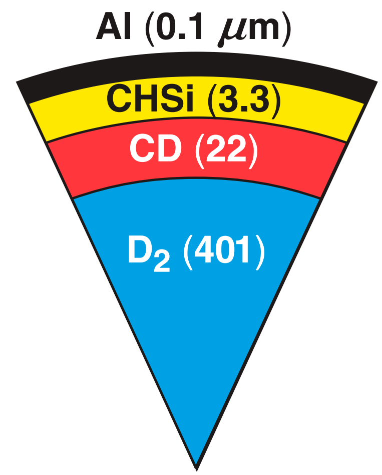
Modeling of Two-Plasmon-Decay Instability in OMEGA Plasmas





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50th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Dallas, TX
17–21 November 2008

Summary

The multispecies composition of plasmas has a strong effect on the two-plasmon-decay instability

- **The multispecies composition modifies the ion–ion collision properties and, therefore, the ion heat conductivity and ion viscosity.**
- **The presence of a high-*Z* dopant in the multispecies plasma changes the dispersion relation for the ion-acoustic modes, and decreases the ion-wave damping.**
- **The increased level of ion-acoustic perturbations limits the growth of the two-plasmon-decay instability.**

In plasmas with multispecies ions, the ion–ion collision frequency includes collisions with all ion species

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- Collision integral $\delta J_{i\Sigma} = \sum_A \delta J_{iA}, \left(\delta J_{iA} \sim \frac{e_i^2 e_A^2}{T_i^{3/2} m_{\mathrm{eff}}^{1/2}} \right)$ and $\nu_{i\Sigma} = \frac{4 \ln \Lambda}{3\sqrt{\pi}} \frac{e_i^2}{T_i^{3/2}} \sum_A \left(\frac{n_A e_A^2}{m_{\mathrm{eff}}^{1/2}} \right)$

  The ion heat flux $\vec{q}^{\,\Sigma} = \sum_i \vec{q}^{\,i} = -\kappa_\Sigma \frac{\partial T_i}{\partial \vec{r}}$

  Ion heat conductivity* $\boxed{\kappa_\Sigma = \sum_i 3.9 \frac{n_i T_i}{m_i \nu_{i\Sigma}} \sim \frac{\sum_i \left(n_i / e_i^2 m_i \right)}{\sum_i \left(n_i e_i^2 / m_{\mathrm{eff}}^{1/2} \right)} T_i^{5/2}}$

- Ion viscosity* $\boxed{\eta^\Sigma = \sum_i 0.96 \frac{n_i T_i}{\nu_{i\Sigma}} \sim \frac{\sum_i \left(n_i / e_i^2 \right)}{\sum_i \left(n_i e_i^2 / m_{\mathrm{eff}}^{1/2} \right)} T_i^{5/2}}$

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

TC8357

The coefficients for ion heat conductivity, and ion viscosity are significantly modified when the plasma composition changes

	$\frac{\nu_{e\Sigma}}{\sqrt{2}\,\nu_{ee}} = Z_{eff}$	$\frac{\nu_T^{\Sigma}}{\sqrt{2}\,\nu_{ee}}$	$\frac{\kappa_{\Sigma}}{\kappa_{D_2}}$	$\frac{\eta^{\Sigma}}{\eta_{D_2}}$
D_2	1.0	0.50 (m/m_p)	1.000	1.000
CD	5.3	0.50 (m/m_p)	0.032	0.027
CHSi(0.06)	7.1	0.56 (m/m_p)	0.032	0.017

- The rate of energy transfer between electrons and ions

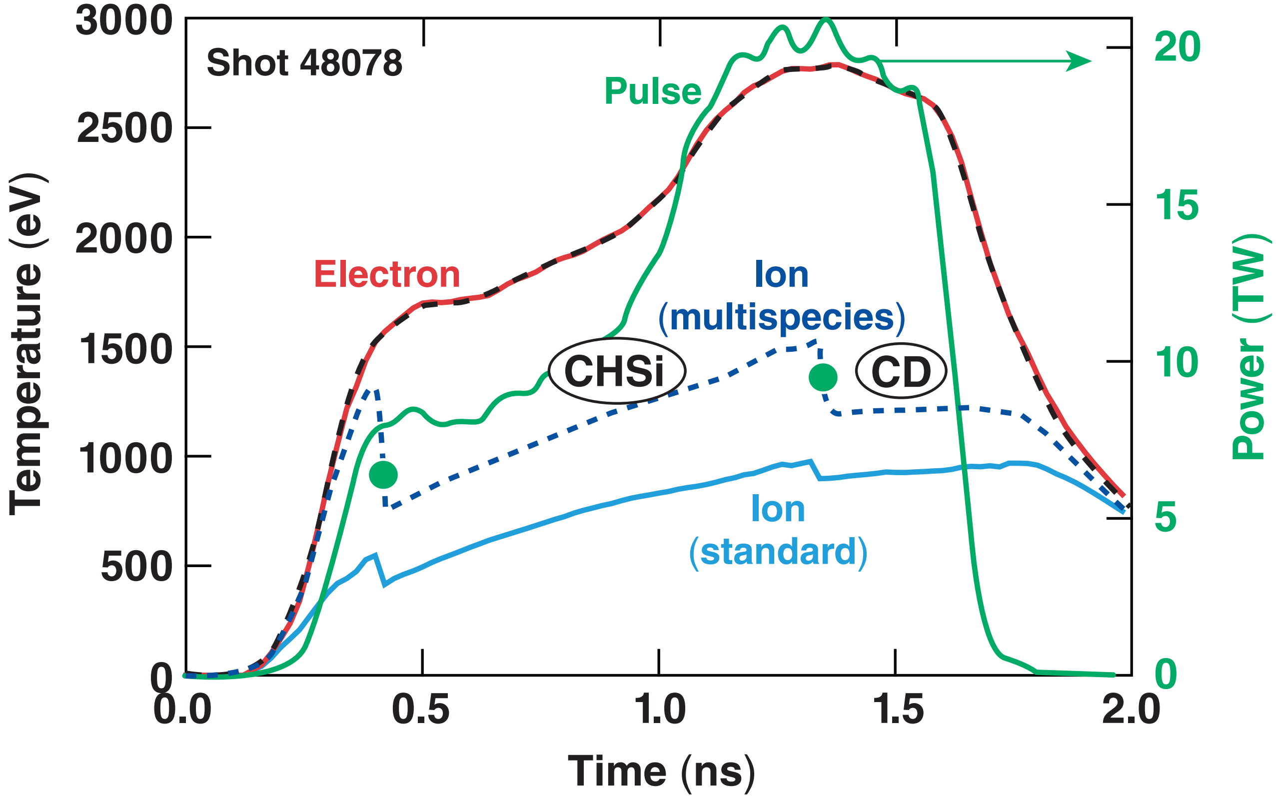
$$\nu_T^{\Sigma} = \sum_i 2\frac{m}{m_i}\nu_{ei}$$

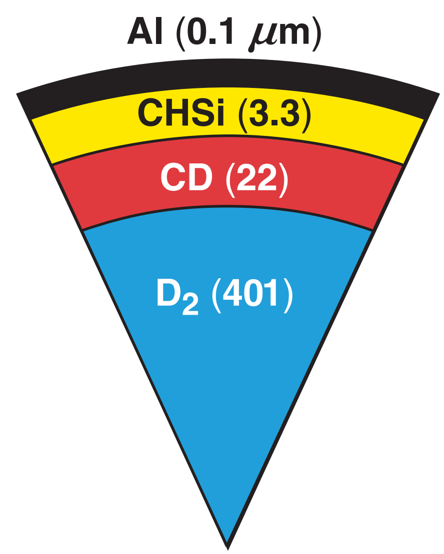
(~10% to 20% of ohmic heating for D_2)

TC8148a

The influence of multispecies effects on the plasma parameters has been studied with *LILAC*

- Temperatures at quarter-critical density





TC8149a

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

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

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.

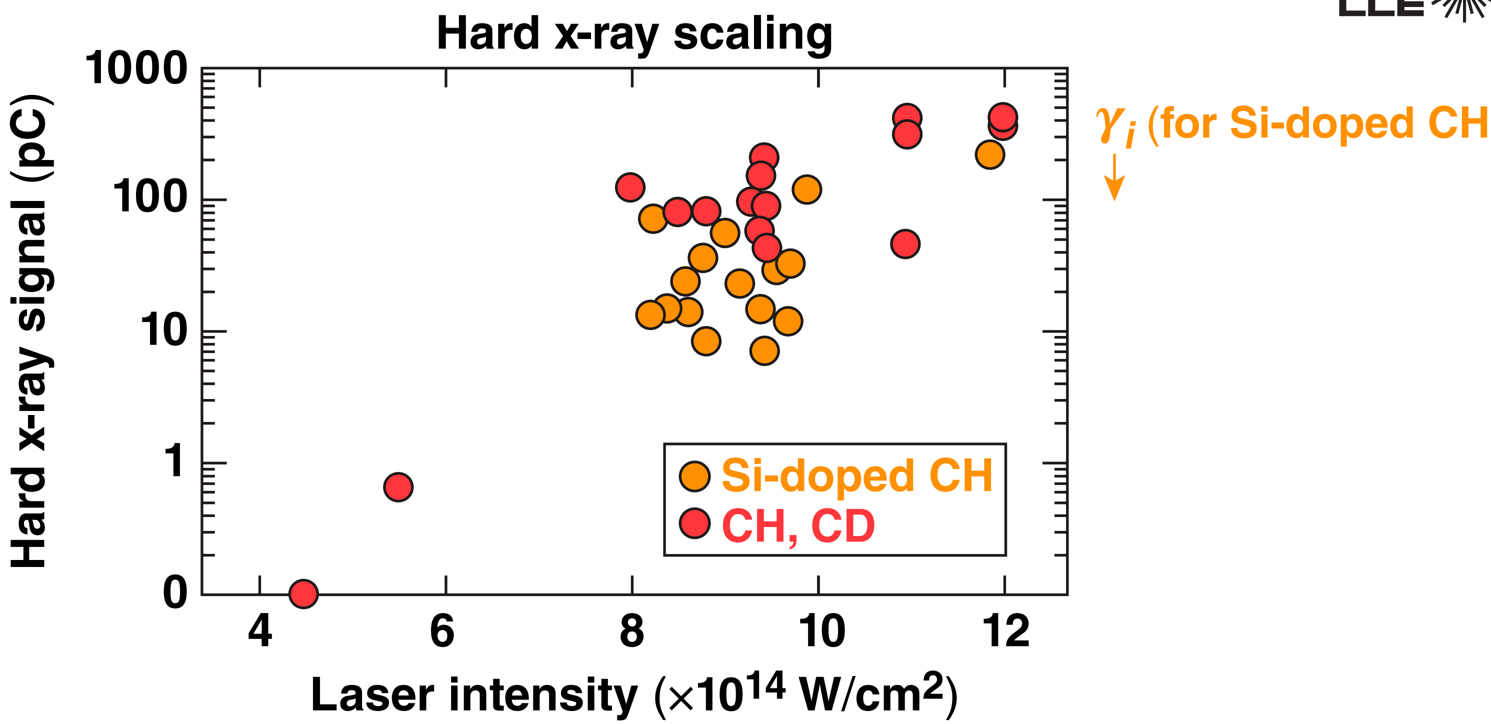
$$\gamma_i = k^2 \left(0.64 + 0.87 \frac{V_{Ti}^2}{c_s^2}\right) \frac{V_{Ti}^2}{\nu_{i\Sigma}}$$

$$\frac{1}{k} \geq \frac{c_s}{\nu_{i\Sigma}}$$

Strong collisions

TC8360

In OMEGA experiments, the hard x-ray production depends on the overlapped intensity of multiple laser beams and on the ion composition of plasmas



- For CHSi (0.06) the solutions are:

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

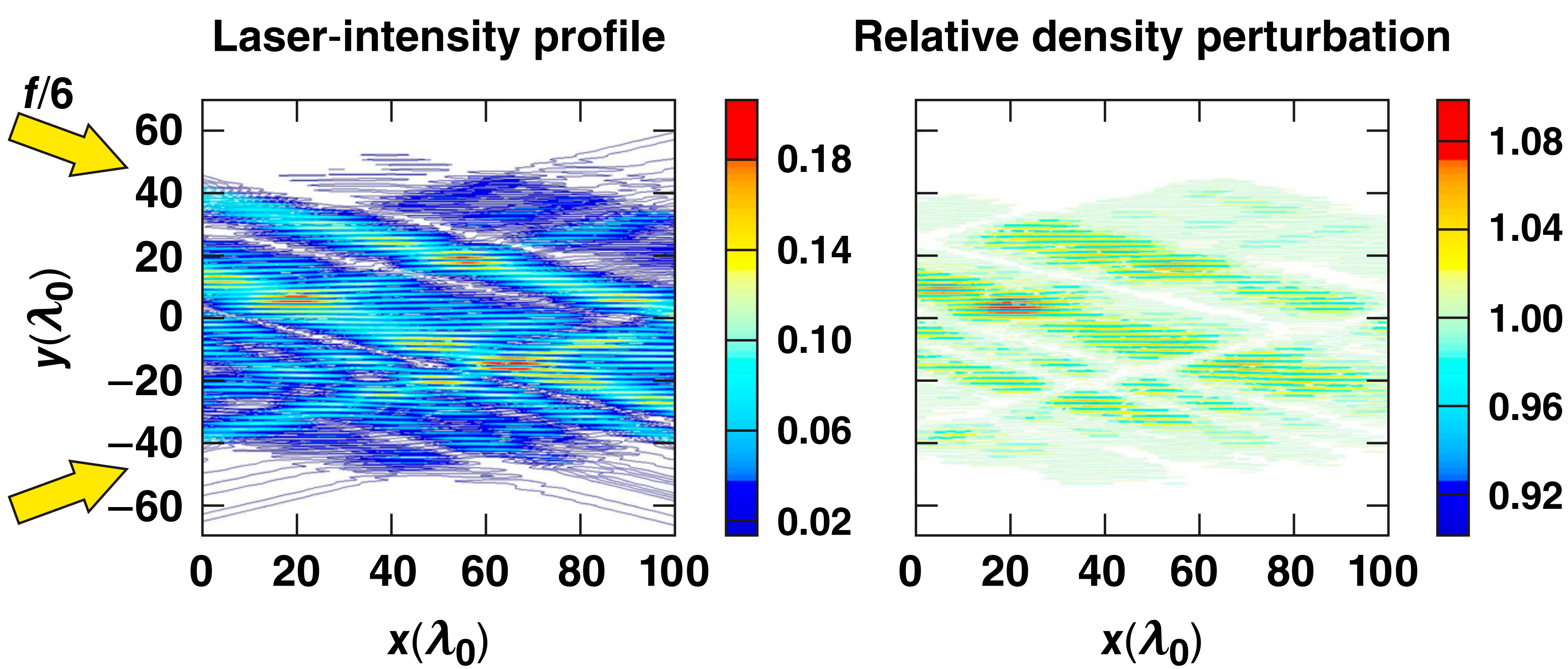
$$\left(\omega_r - \vec{k}\,\vec{V}\right)^2 = 0.43\,k^2 c_{s0}^2 \quad \text{and} \quad \gamma_i \approx 0.68\,\gamma_C + 0.32\,\gamma_{Si}$$

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

$$\boxed{\left(T_i/T_e\right) = 0.5}$$

TC8036b

Low-frequency perturbations in electron density are produced by the interaction of incoherent laser beams with plasmas

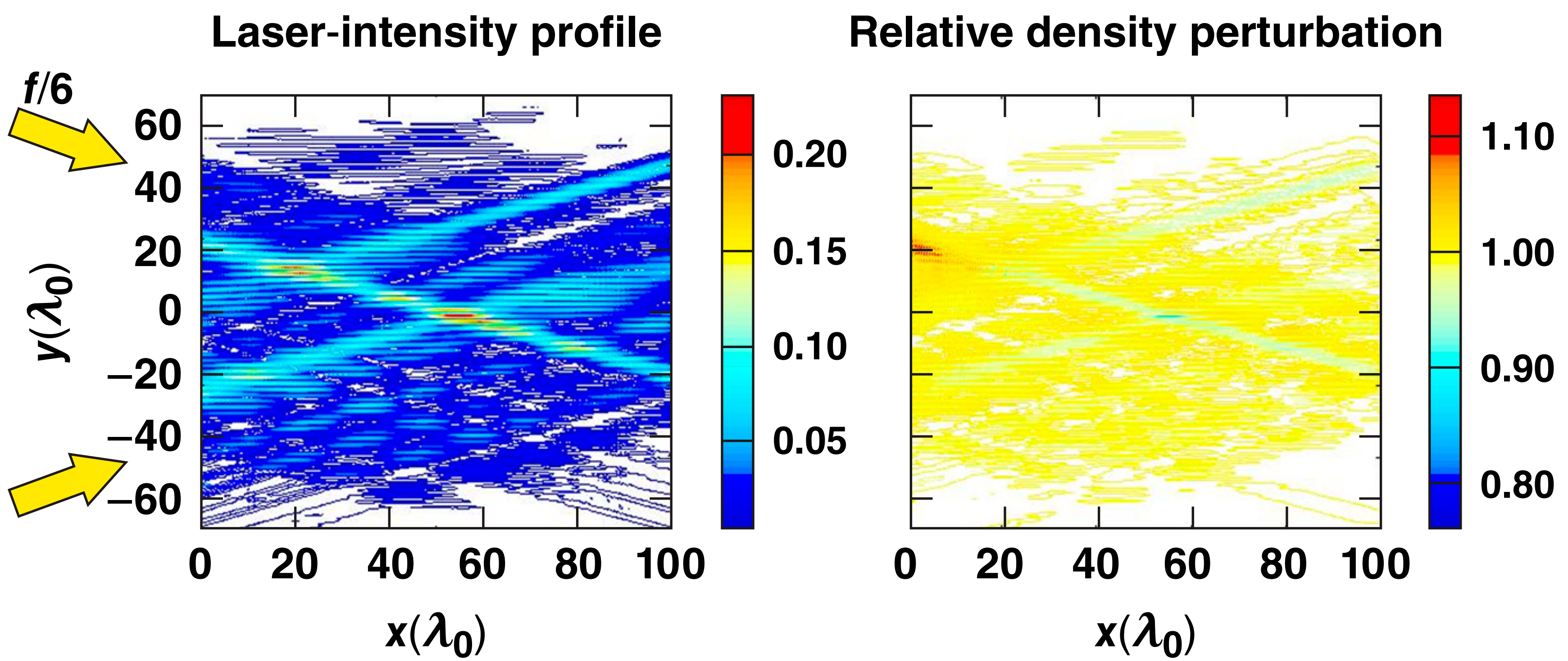


$\langle I \rangle = 9 \times 10^{14}\ \mathrm{W/cm^2}$, $T_e = 2\ \mathrm{keV}$, $n_0 \approx \dfrac{n_c}{4}$, CH

$$\left(\frac{n_e}{n_0} - 1\right) \sim \frac{I}{\langle I \rangle}$$

TC7801b

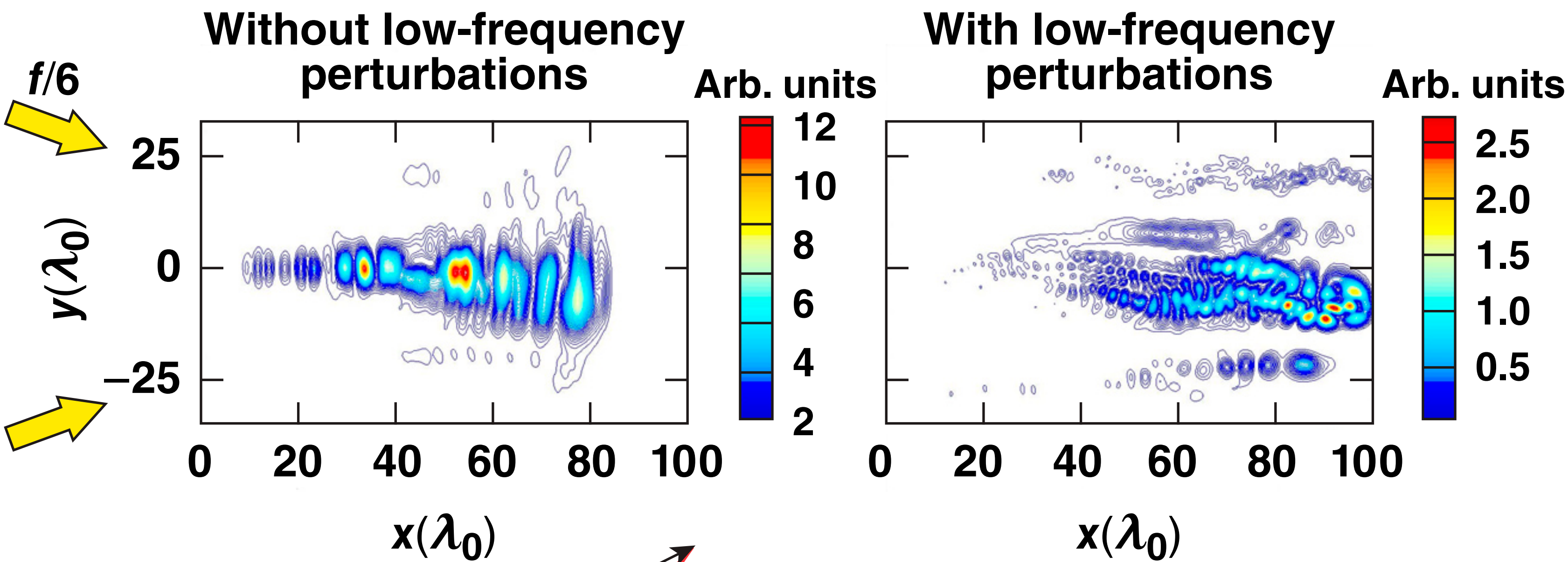
With the decrease of the ion-acoustic damping, the level of low-frequency density perturbations increases

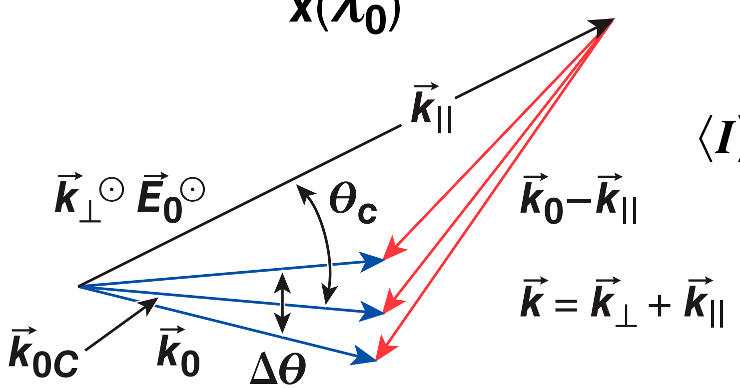


CHSi

TC78388

The low-frequency perturbations in the electron density can detune the TPD resonance and reduce the TPD growth





$\langle I \rangle = 9 \times 10^{14}$ W/cm^2, $\gamma_e/\omega_{p0} = 10^{-3}$

TC7802a

Summary/Conclusions

The multispecies composition of plasmas has a strong effect on the two-plasmon-decay instability

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- The presence of a high-*Z* dopant in the multispecies plasma changes the dispersion relation for the ion-acoustic modes, and decreases the ion-wave damping.
- The increased level of ion-acoustic perturbations limits the growth of the two-plasmon-decay instability.

The multispecies composition of plasmas influences the hydrodynamic equations

$$\partial_t \rho + \vec{\nabla}(\rho \vec{V}) = 0$$

ion density $n_\Sigma = \sum_i n_i$

mass density $\rho = \sum_i n_i m_i$

$$\rho\left[\partial_t V_j + (\vec{V}\cdot\vec{\nabla})V_j\right] = -\nabla_j\left(n_e T_e + n_\Sigma T_i\right) - \nabla_k \sigma_{jk}^{\Sigma} - \frac{e^2}{4m\omega_0^2}\left\{n_e \nabla_j |E|^2 - \nabla_k\left[n_e\left(E_k E_j^* + E_j E_k^*\right)\right]\right\}$$

Ion

Electron

$$\partial_t T_e + (\vec{V}\cdot\vec{\nabla})T_e + \frac{2T_e}{3}\vec{\nabla}\cdot\vec{V} + \frac{2}{3n_e}\vec{\nabla}\cdot\vec{q}^{\,e} = \frac{e^2|E|^2\,\nu_{e\Sigma}}{3m\,\omega_0^2} - \sum_i \frac{2m\,\nu_{ei}}{m_i}\left(T_e - T_i\right)$$

Electron–Ion

$$\partial_t T_i + (\vec{V}\cdot\vec{\nabla})T_i + \frac{2T_i}{3}\vec{\nabla}\cdot\vec{V} + \frac{2}{3n_\Sigma}\vec{\nabla}\cdot\vec{q}^{\,\Sigma} = \sum_i \frac{2m\,\nu_{ei}}{m_i}\left(T_e - T_i\right)$$

- The ion temperatures of different species are assumed to be the same.

TC8144