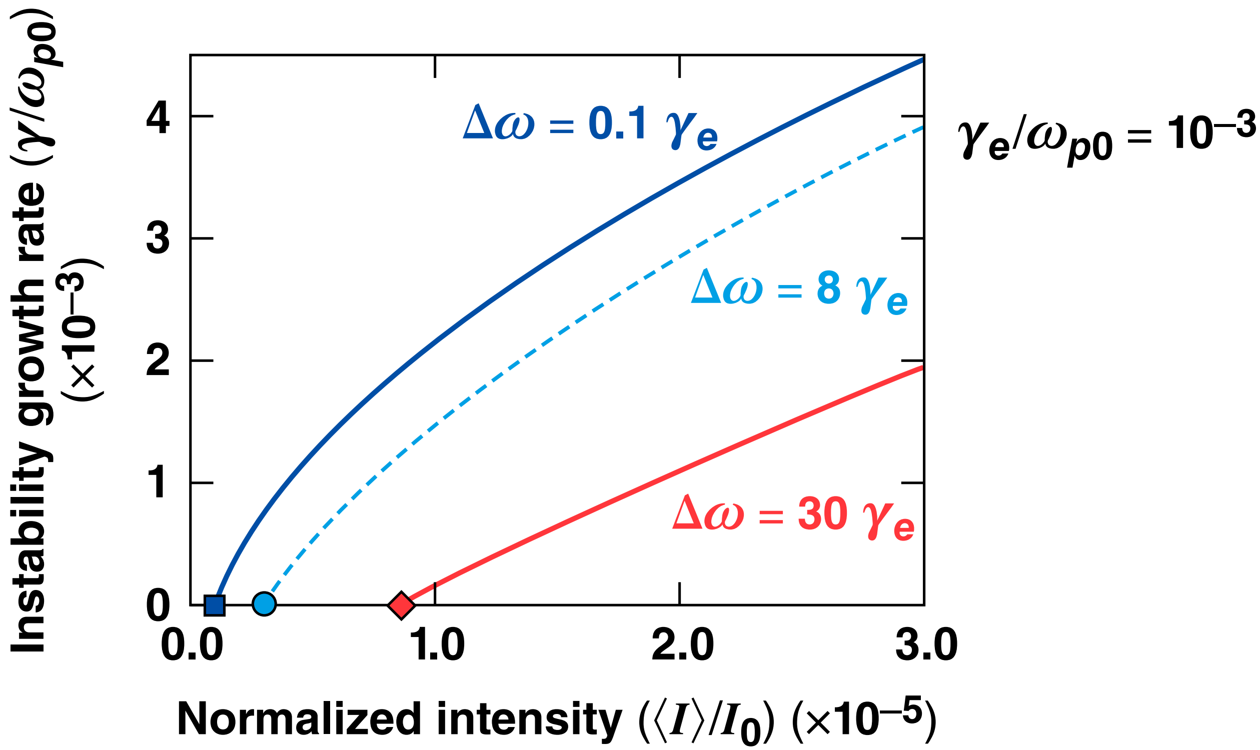
Two-Plasmon-Decay Instability Driven by Incoherent Laser Irradiation



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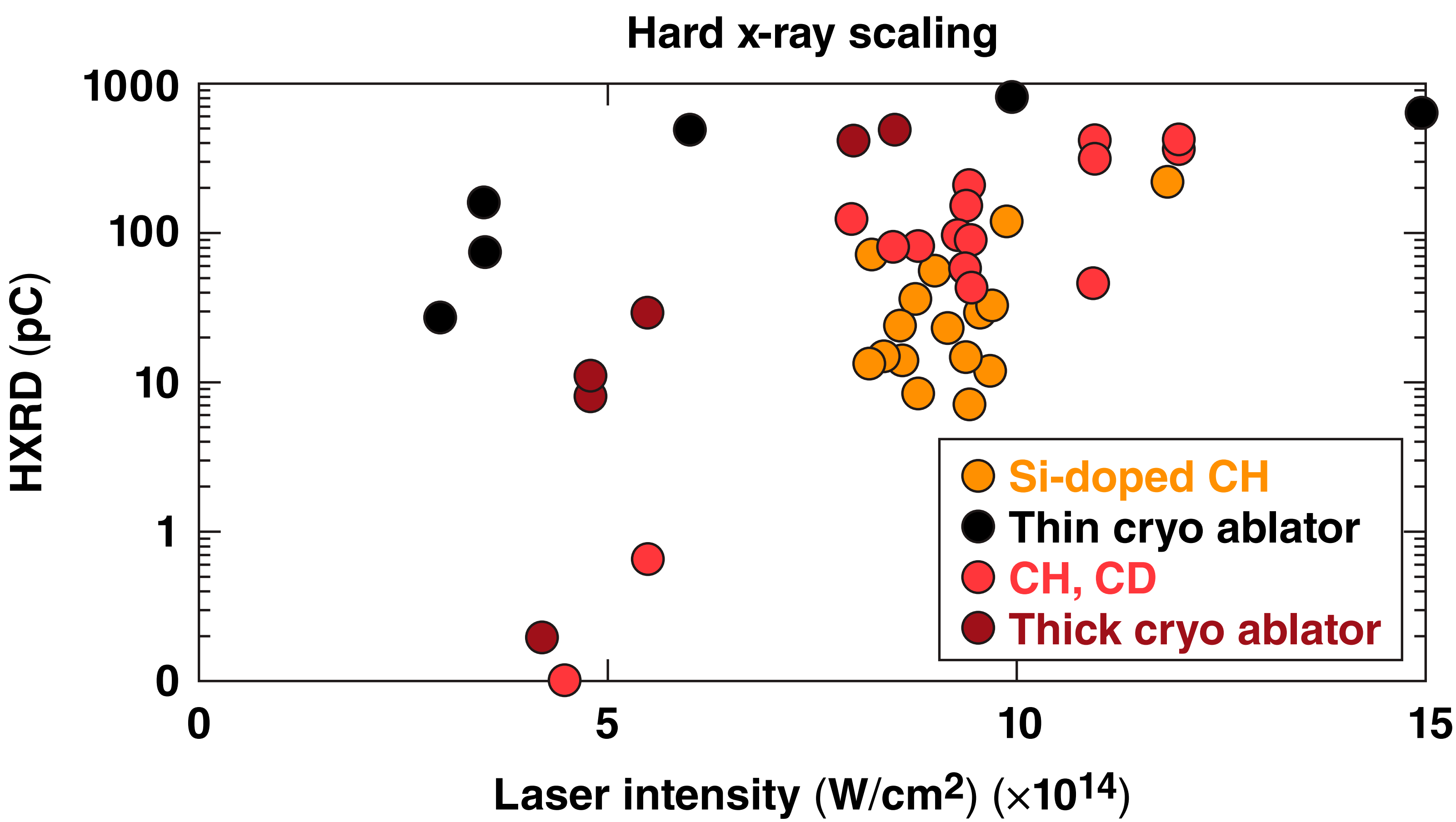
Summary

The onset of TPD instability and preheat in direct-drive plasmas is strongly influenced by laser-beam incoherence

- The TPD driven by incoherent laser beams has a regime where the growth rate is determined by the overlapped laser-beam intensity.
- For parameters of laser–plasma interaction in OMEGA plasmas, the threshold of TPD depends on the interplay between
  - plasma inhomogeneity
  - wave damping
  - resonance detuning due to beam incoherence
- When the density scale length is large enough, the low-frequency density perturbations can reduce the TPD growth.

In OMEGA experiments, the hard x-ray production depends on the overlapped intensity of multiple incoherent laser beams



TC8036

The growth rate of the TPD instability can be proportional to the average laser intensity

- Equation for the growth rate γ (in random phase approximation):

$$\frac{2(\gamma+\gamma_e)}{\omega_{p_0}} = -\mathrm{Im}\int \frac{d\vec{k}_0}{k_0 \Delta\theta} \frac{\left\langle |v_0|^2 \right\rangle F(\vec{k}_0,\vec{k})}{2i(\gamma+\gamma_e)\omega_{p_0} - 3v_{Te}^2\left[(\vec{k}_0-\vec{k})^2-(\vec{k}_{0C}-\vec{k})^2\right]}$$

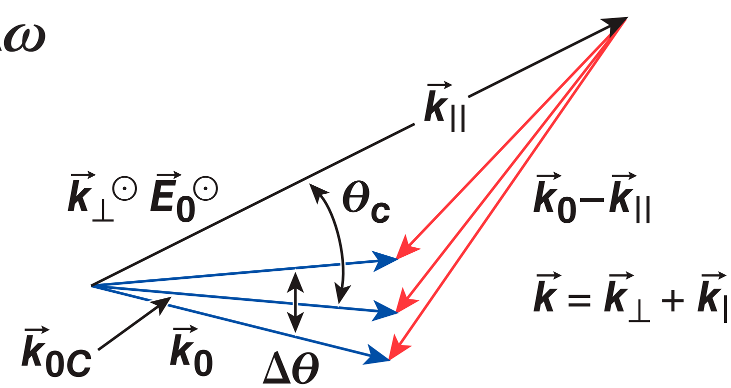
where $F(\vec{k}_0,\vec{k}) = \dfrac{\left(k_0^2 - 2\vec{k}_0\vec{k}\right)^2}{4\left[(\vec{k}_0-\vec{k})^2 k^2\right]} k_\perp^2$

γ_e – damping coefficient,

$\Delta\omega = 3k_{||}k_0\lambda^2_{De}|\sin\theta_c|\Delta\theta\omega_{p0}$

- Large resonance width: $(\gamma + \gamma_e) << \Delta\omega$

$$\boxed{\gamma+\gamma_e = \frac{\pi}{4}\frac{\left\langle |v_0|^2 \right\rangle F(\vec{k}_{0C},\vec{k})}{\Delta\omega}}$$



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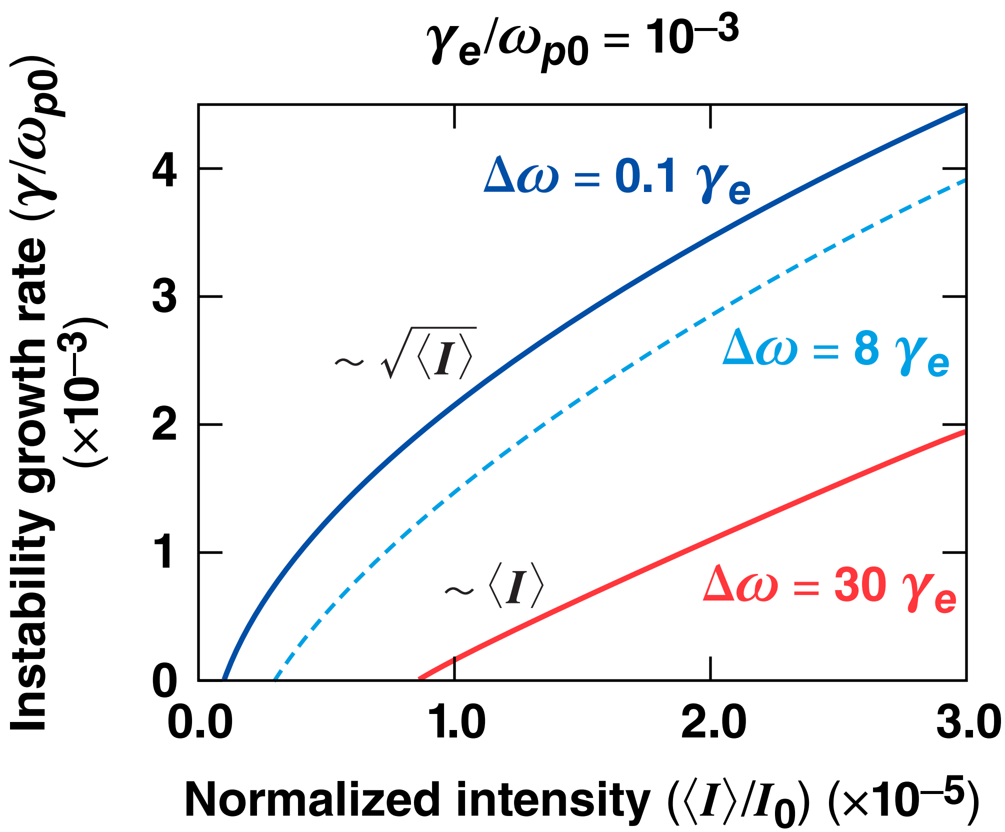
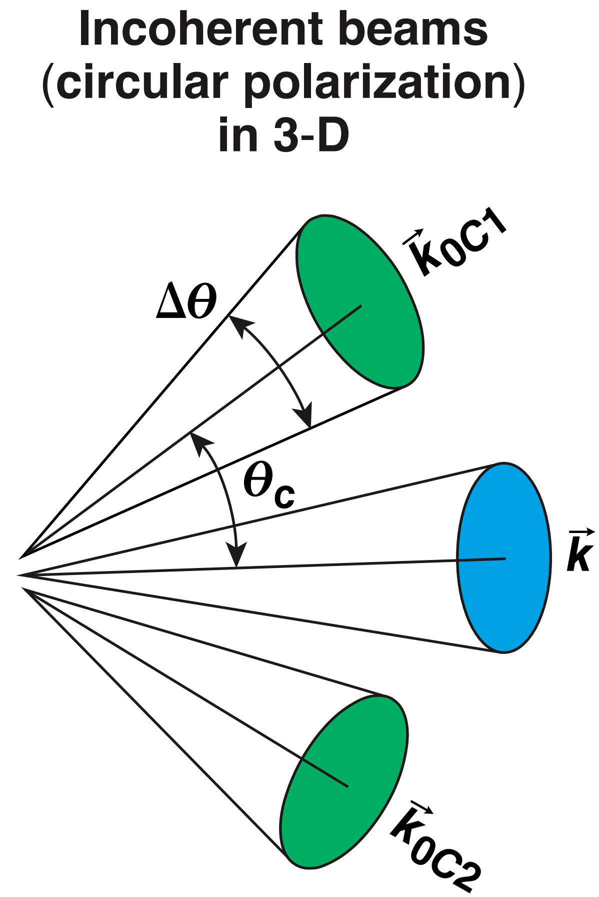
The increase of the angular width of an incoherent laser beam leads to the decrease of TPD growth rate and to the increase of the threshold





$$(\gamma + \gamma_e)/\omega_{p0} \equiv \sqrt{\langle I\rangle/I_0} \text{ at } \Delta\omega = 0$$

Resonance width $\Delta\omega/\omega_{p0} = 3\,k\,k_0\lambda_{De}^2|\sin\theta_c|\Delta\theta$

TC7798

Thresholds of TPD in OMEGA plasmas are influenced by the density inhomogeneity scale

- Different studies* have shown that for TPD in inhomogeneous plasmas the absolute growth rate

$$\left(\gamma/\omega_{p0}\right)_{\text{inhom}} = \left(\gamma/\omega_{p0}\right)_{\text{hom}} - \Delta_{\text{inhom}} - \left(\gamma_e/\omega_{p0}\right)$$

$$\Delta_{\text{inhom}} \sim 1/k_0 L_N$$

- For OMEGA plasmas the density scale length near quarter-critical density

$$L_N = (150-400)\mu\text{m}$$

- Low-frequency density perturbations can increase the effective damping

$$\gamma_e \sim \sqrt{(\delta N)^2} \sim 1/\gamma_{ia}$$

*C. S. Liu and M. N. Rosenbluth, Phys. Fluids 19, 967 (1976).
B. F. Lasinski and A. B. Langdon, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50021-77, 4-49 (1978).
A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

TC7799

For parameters of OMEGA plasmas, the TPD instability threshold is influenced by the interplay of several parameters

- **Homogeneous three-wave growth rate** $\gamma^0 = \dfrac{k_0 |V_0|}{\omega_{p0}} = 8.2 \times 10^{-3} \sqrt{I_{15}}$

- **Detuning due to beam incoherence** $\dfrac{\Delta\omega}{\omega_{p0}} = 2 \times 10^{-3} \left(T_e / 2\ \text{keV}\right) \left(\dfrac{\Delta\theta}{0.2}\right) \sin\theta_c$

- **Plasma-wave damping** $\left(\dfrac{\gamma_e}{\omega_{p0}}\right)_{\text{coll}} = 0.5 \times 10^{-3} \dfrac{(Z/5.3)}{\left(T_e / 2\ \text{keV}\right)^{3/2}}$

- **Detuning due to inhomogeneity** $\dfrac{1}{k_0 L} = \dfrac{4.2 \times 10^{-4}}{(L / 150\ \mu m)}$

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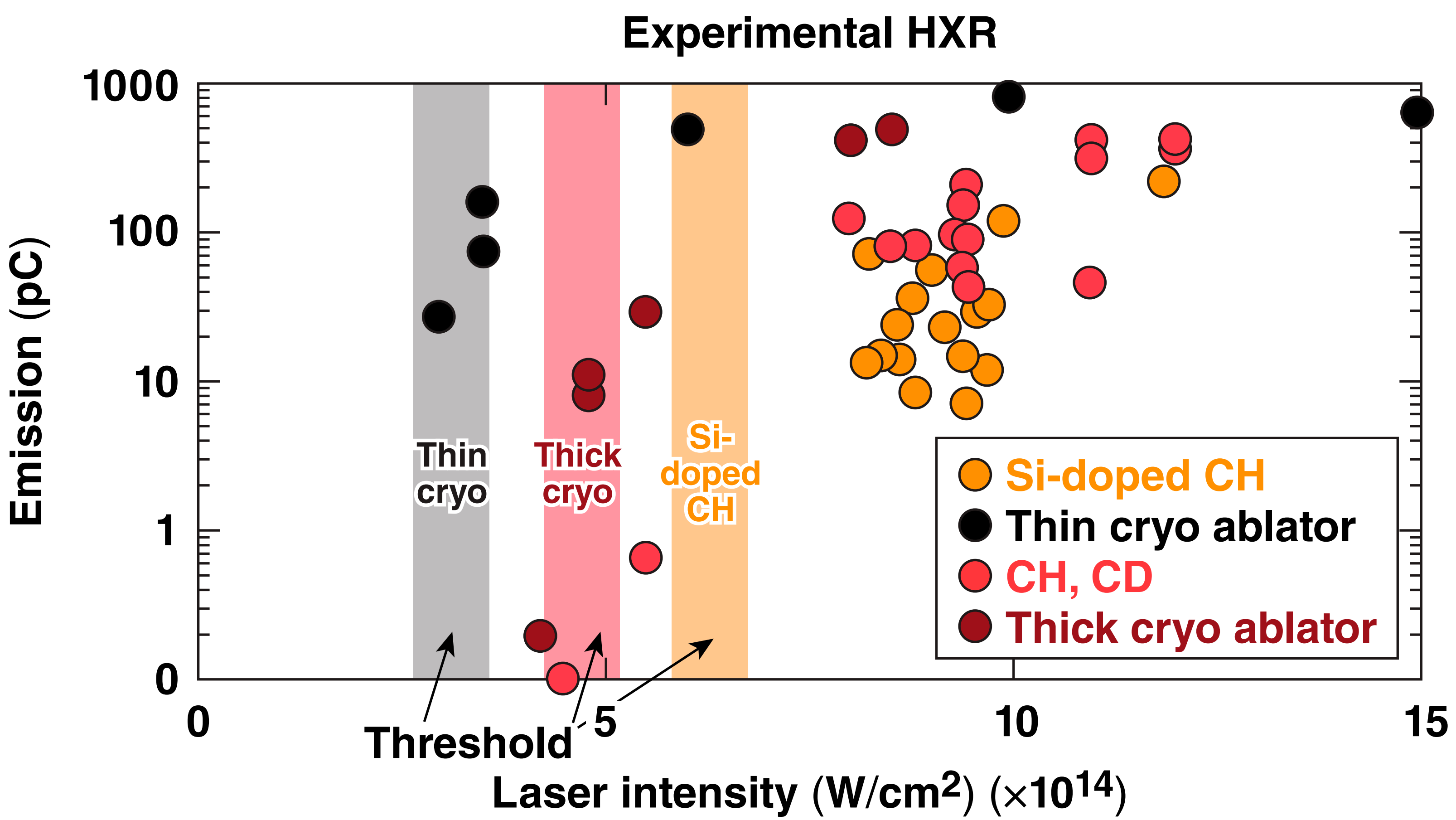
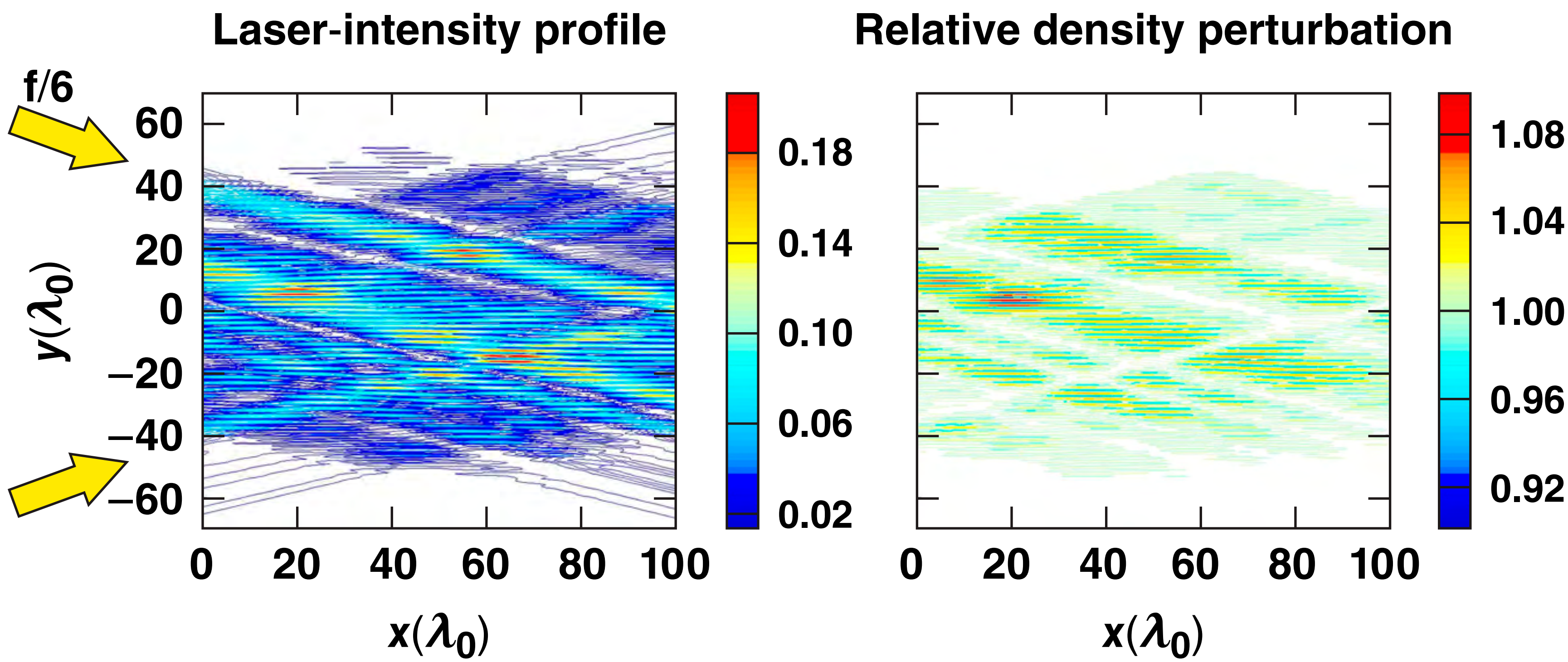


TC8036a

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

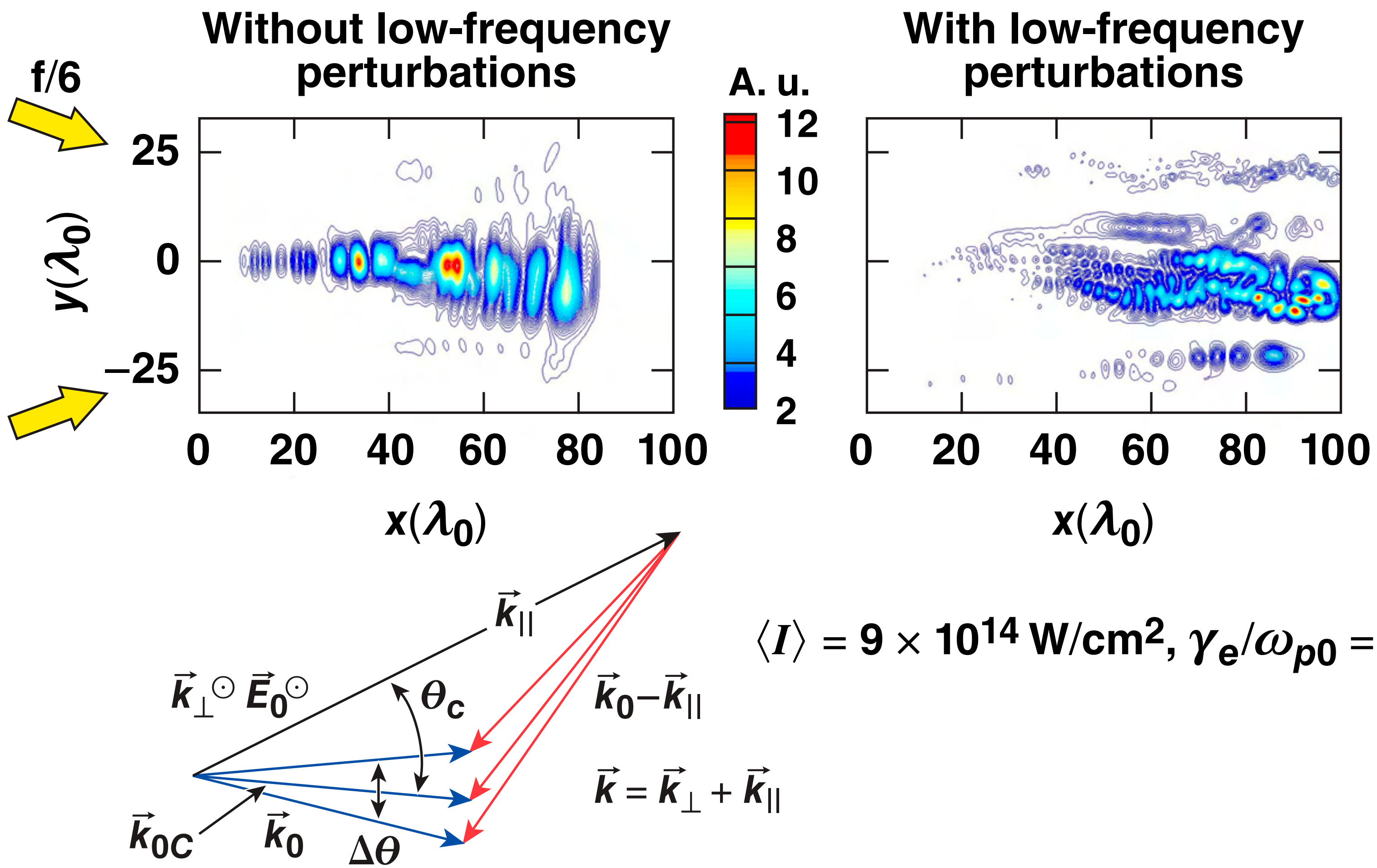


$\langle I \rangle = 9 \times 10^{14}$ W/cm^2, $T_e = 2$ keV, $n_e = \dfrac{n_c}{4}$

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

TC7801

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

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