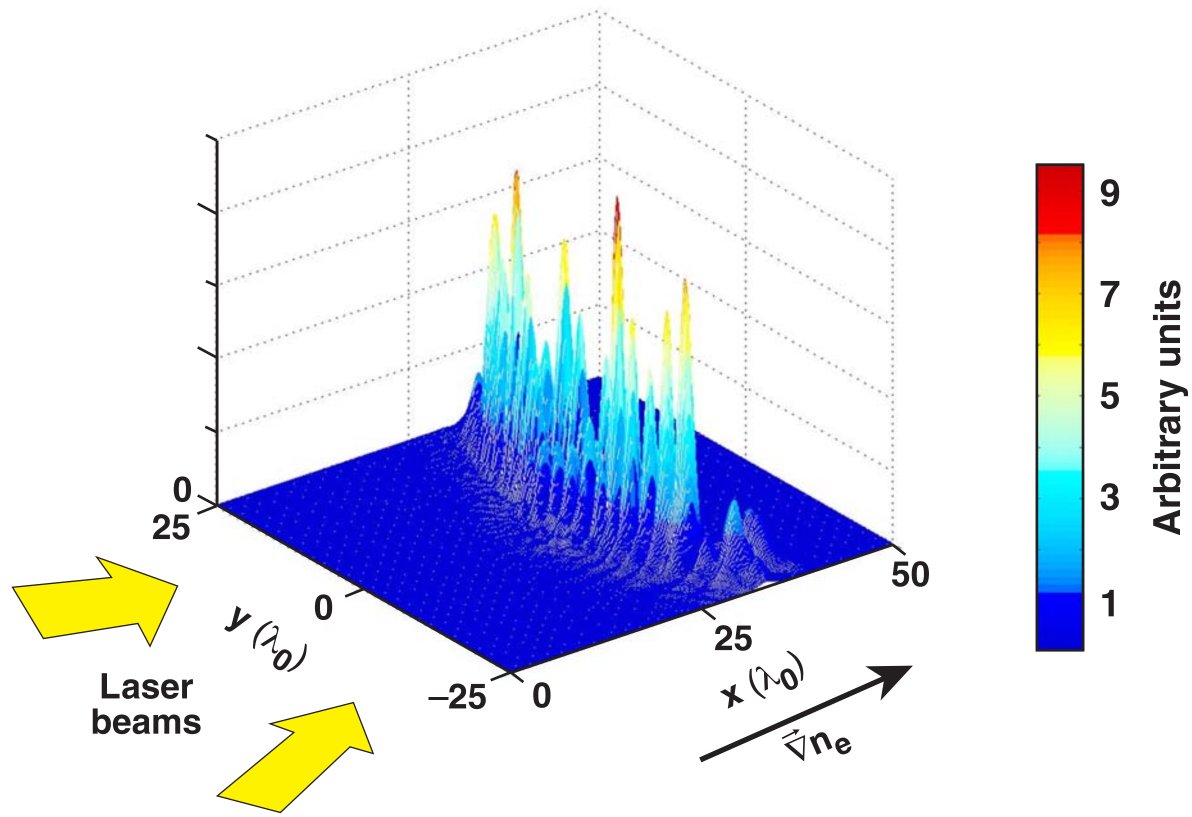
Two-Plasmon-Decay Instability in Plasmas Irradiated by Incoherent Laser Beams



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Summary

The increase in the angular spread of the incoherent laser beams detunes the two-plasmon-decay (TPD) resonance and reduces the TPD growth

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- TPD instability driven by incoherent laser beams has been studied with a non-paraxial model.
- The TPD driven by incoherent laser beams has a regime where the growth rate is proportional to overlapped laser-beam intensity, consistent with OMEGA experimental results.
- When the density scale length is large enough, the low-frequency density perturbations can reduce the TPD growth.

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

Equation for the instability growth rate γ:

$$\frac{2(\gamma+\gamma_e)}{\omega_{p0}} = -\mathrm{Im}\int \frac{d\vec{k}_0}{k_0\Delta\theta}\,\frac{\left\langle |v_0|^2 \right\rangle F(\vec{k}_0,\vec{k})}{2i(\gamma+\gamma_e)\omega_{p0} - 3v_{Te}^2\left[\left(\vec{k}_0-\vec{k}\right)^2-\left(\vec{k}_{0C}-\vec{k}\right)^2\right]}$$

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

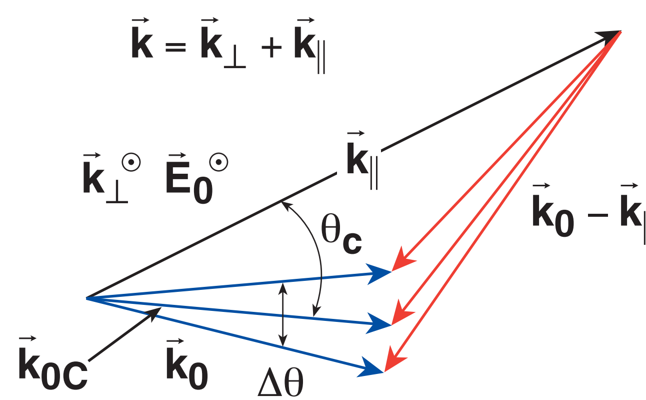
γ_e – damping coefficient,

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

$\int d\vec{k}_0 \rightarrow \int d\theta$: to integrate over the resonant denominator in the integrand

Large angular width $\Delta\theta$: $(\gamma+\gamma_e) << \Delta\omega$

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



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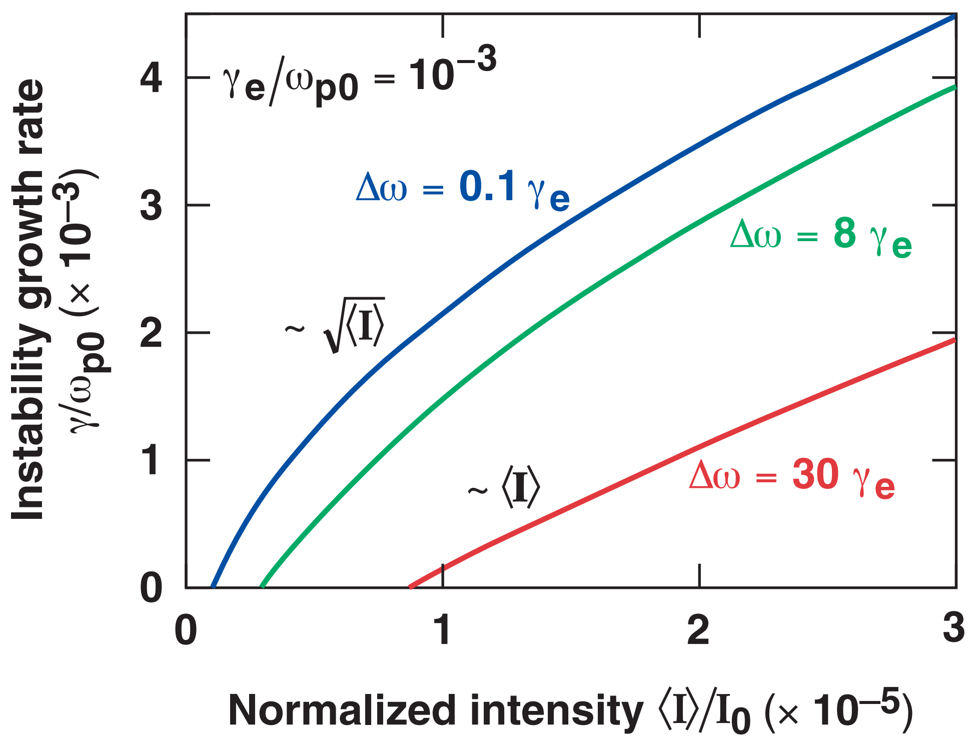
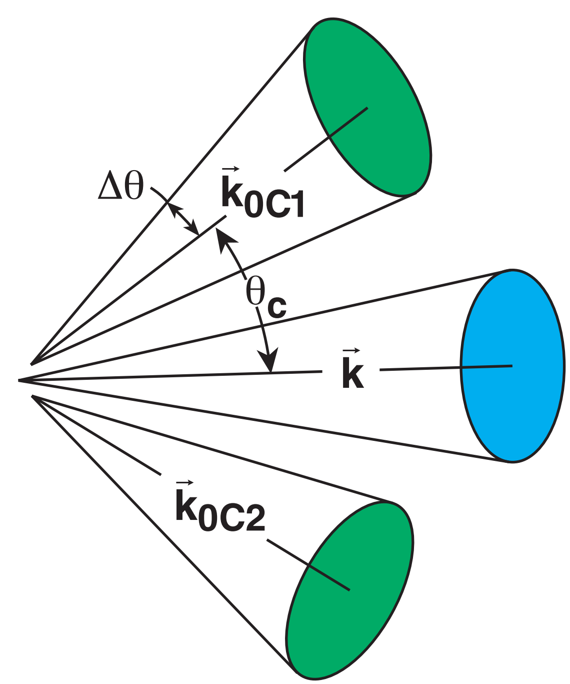
The increase of the angular width of an incoherent laser beam leads to the decrease of TPD growth rate and an increase of the threshold





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

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

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The effect of density inhomogeneity on TPD are limited in OMEGA plasmas

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

$$(\gamma/\omega_{p0})_{inhom} = (\gamma/\omega_{p0})_{hom} - \Delta_{inhom}$$
$$\Delta_{inhom} \sim 1/k_0 L_N$$

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

$$L_N = 200 - 400\ \mu m,$$

$$\text{and}\ \boxed{\Delta_{inhom} \sim 10^{-4}}$$

* Liu and Rosenbluth, Phys. Fluids 19, 967 (1976).
Lasinski and Langdon, UCRL-50021-77, 4–49 (1977).
Simon, Short *et al.*, Phys. Fluids 26, 3107 (1983).

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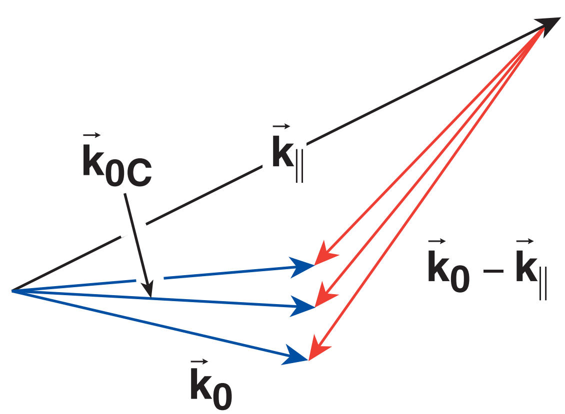
A new code has been developed to model the TPD instability driven by incoherent laser beams

- The code is based on fluid-type description.
- It runs in two spatial dimensions.
- Equations for plasma waves are enveloped around $\omega_0/2$.
- The solver for plasma waves is nonparaxial.
- The grid allows to resolve scales few times smaller than the laser wavelength.
- The code has been tested in a linear instability regime.

$\vec{k} = \vec{k}_\perp + \vec{k}_\parallel$

$\vec{k}_\perp^{\odot}$ $\vec{E}_0^{\odot}$



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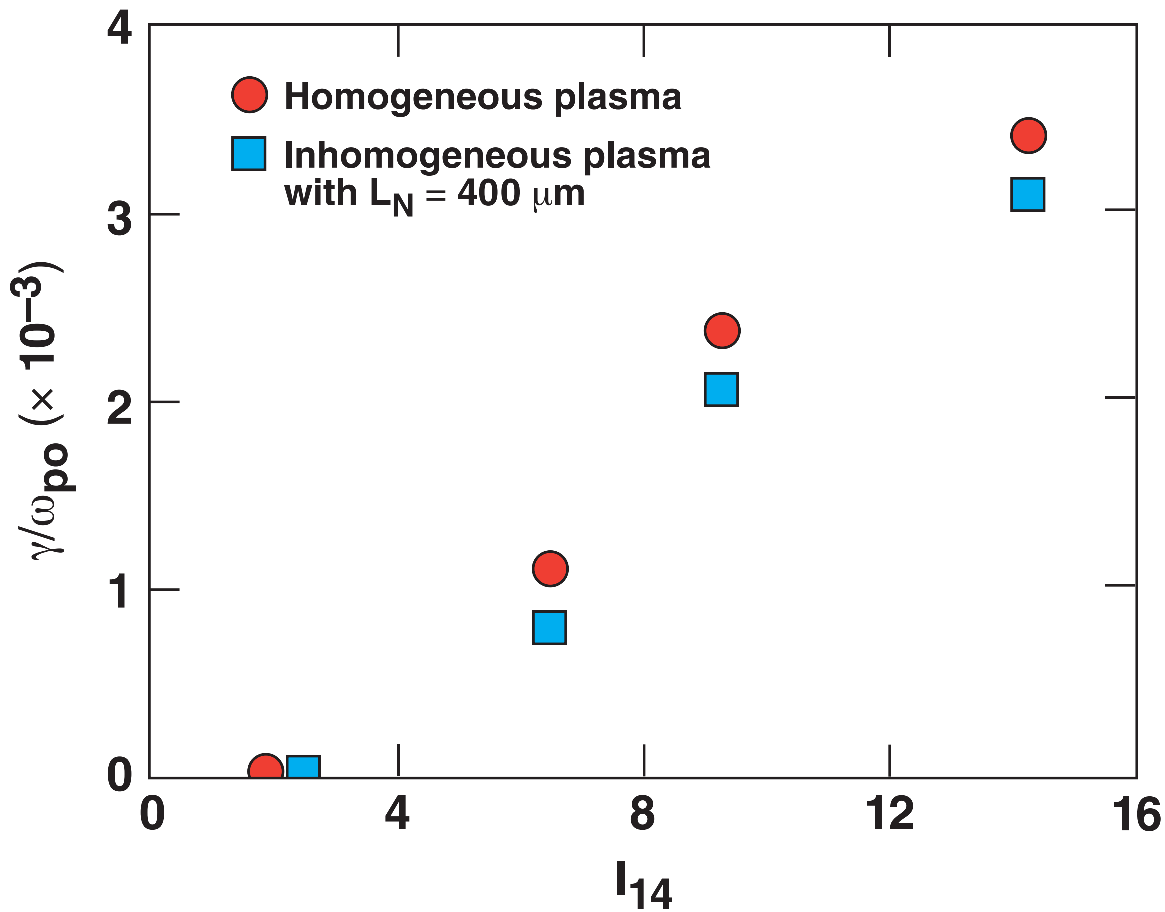
For the parameters of OMEGA plasmas, the plasma inhomogeneity moderately decreases the absolute growth rate of TPD



Simulation region

$200\ \lambda_0 \times 200\ \lambda_0$

$\Delta\theta = 0.15$

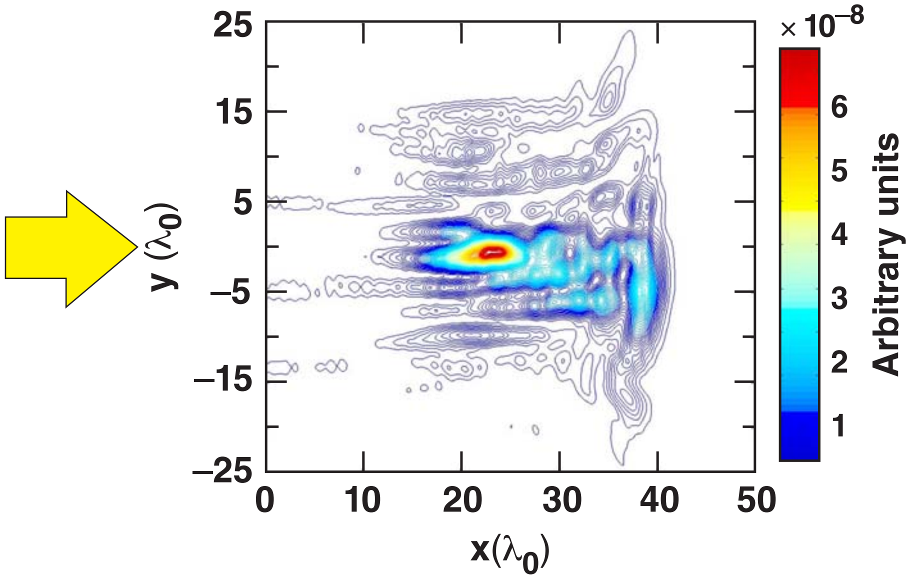
$\Delta\omega > \gamma_e$

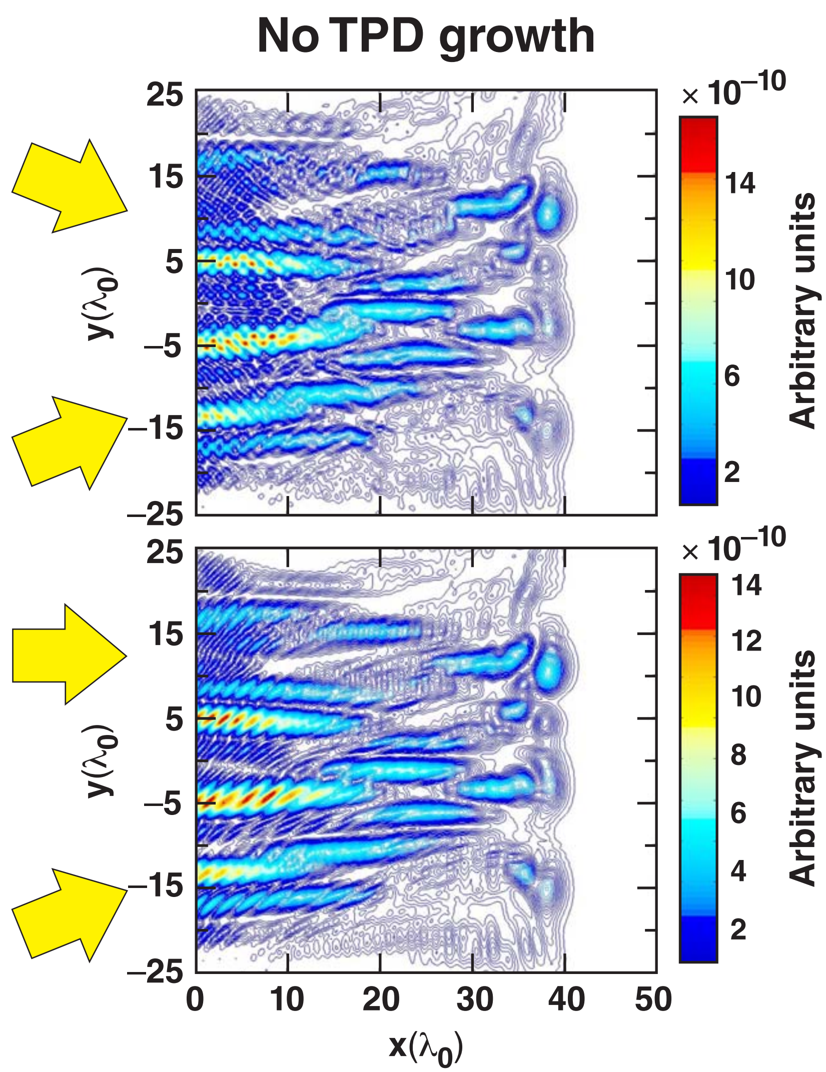
$k_0 \lambda_{De} = 0.15$,

$k_\perp = k_0$,

$\gamma_e/\omega_{p0} = 10^{-3}$

The increase in the angular spread of the driving laser beam reduces the TPD growth





$\langle I \rangle = 6 \times 10^{14}$ W/cm^2

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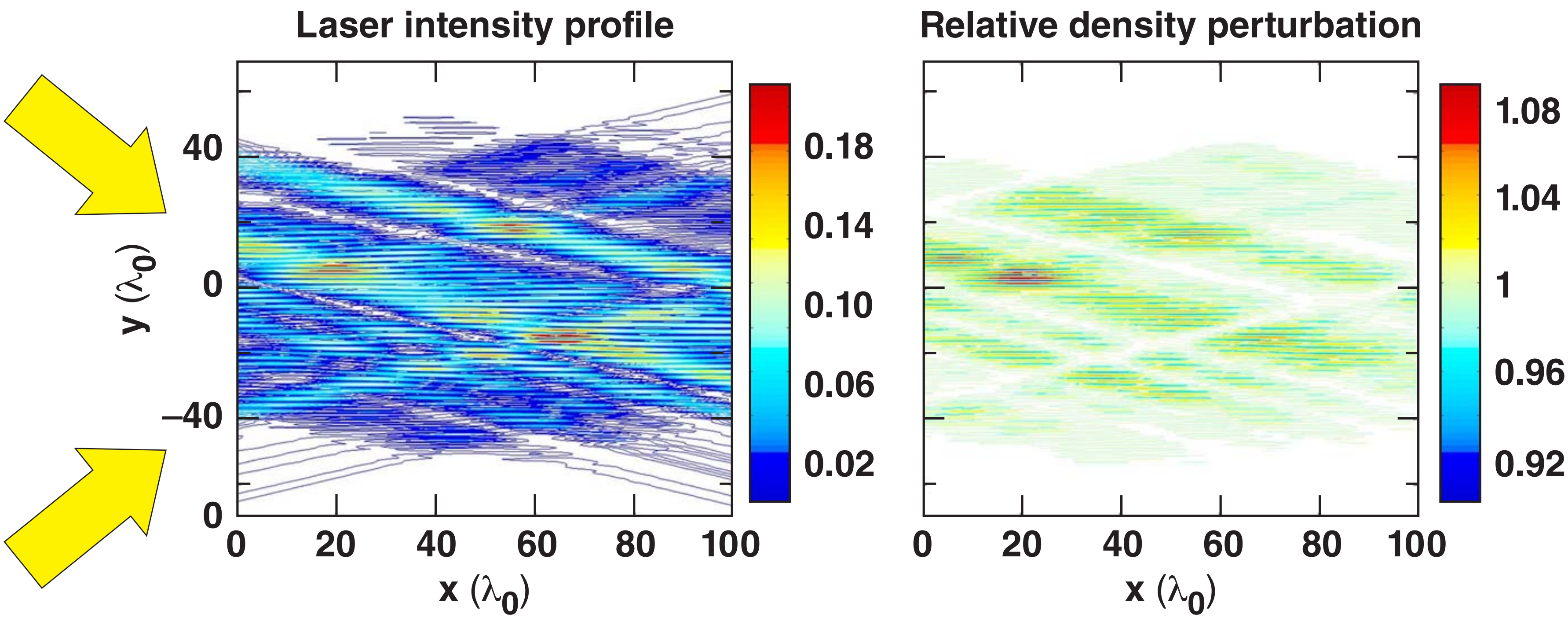
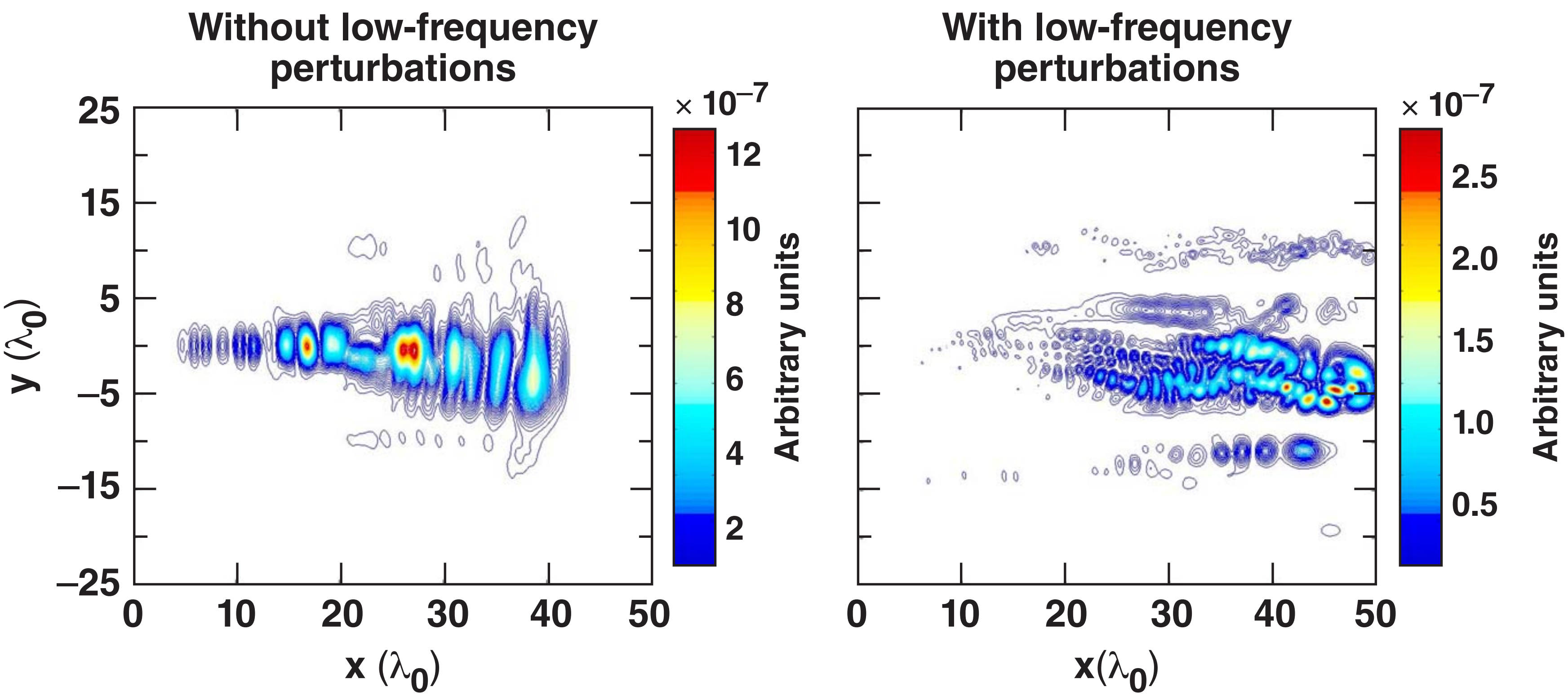
Interaction of incoherent laser beams with plasmas produces low-frequency perturbations in electron density



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

$$\frac{n_e}{n_o} - 1 \sim -\frac{I}{\langle I \rangle}$$

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

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Summary/Conclusions

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