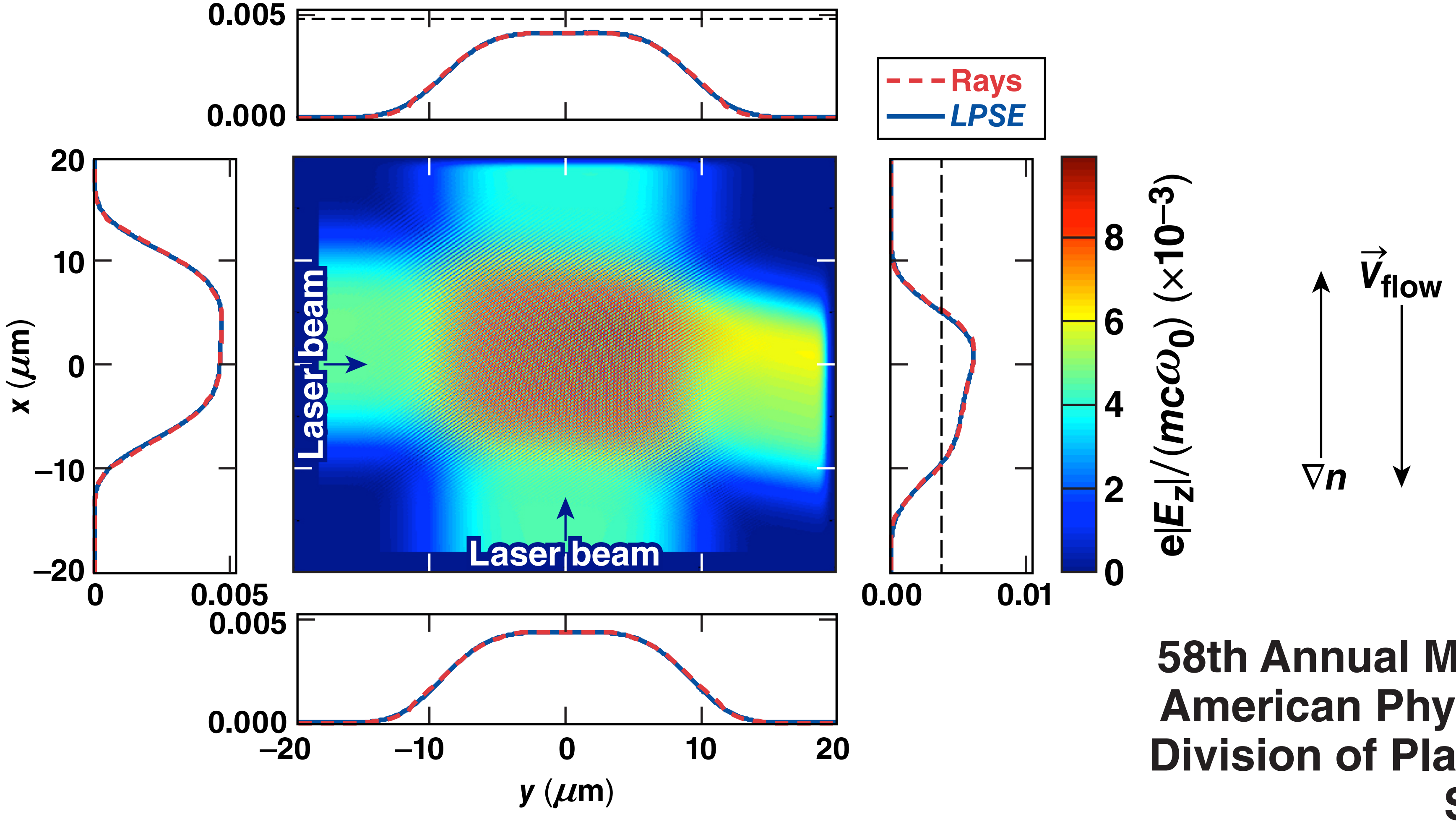
Comparing Ray-Based and Wave-Based Models of Cross-Beam Energy Transfer

LPSE **simulation of two crossing beams in a density and flow gradient**



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Summary

A wave-based cross-beam energy transfer (CBET) model (*LPSE*-CBET) is used as a platform to test the accuracy of ray-based CBET models

- Ray-based and wave-based CBET show good agreement when the assumptions made in the ray-based model are satisfied
- Laser speckle can amplify CBET gains when the angle between the interacting beams is small
- The CBET interaction between speckled beams generates larger density perturbations than the interaction between plane waves

Collaborators

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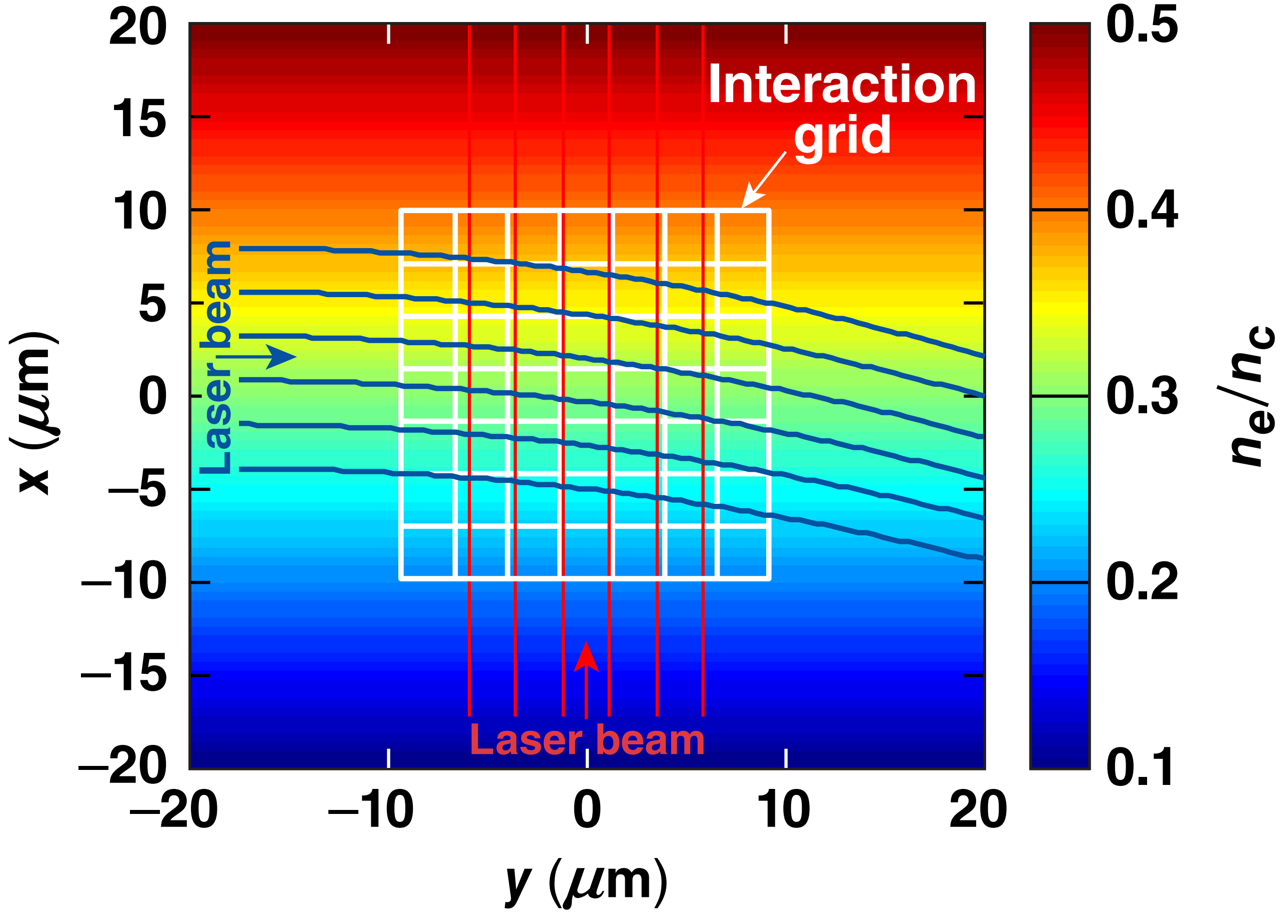
Ray-based CBET models calculate CBET by considering pairwise interactions between rays

Schematic of ray-interaction calculation



$$\frac{dI_i}{d\ell} = -\sum_j I_i \times L_{ij}^{-1}$$

$$L_{ij}^{-1} = 5.88 \times 10^{-2} \frac{I_j \lambda}{T_e\left(1 + 3T_i/ZT_e\right)} \frac{n_e}{n_c} \frac{\omega_s}{\nu_i} P(\eta_{ij})$$

$$P(\eta) = \frac{\nu_i^2 \eta}{\left(\eta^2 - 1\right)^2 + \nu_i^2 \eta^2} \qquad \eta_{ij} = \frac{\omega_j - \omega_i - \left(k_j - k_i\right) \cdot u}{\omega_s}$$

Assumptions

- Small ion-acoustic waves (IAW's) ($\delta n/n \ll 1$)
- Plane-wave approximation
- Strong-damping limit (IAW's do not propagate)
- Wentzel–Kramers Brillouin (WKB) approximation

C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

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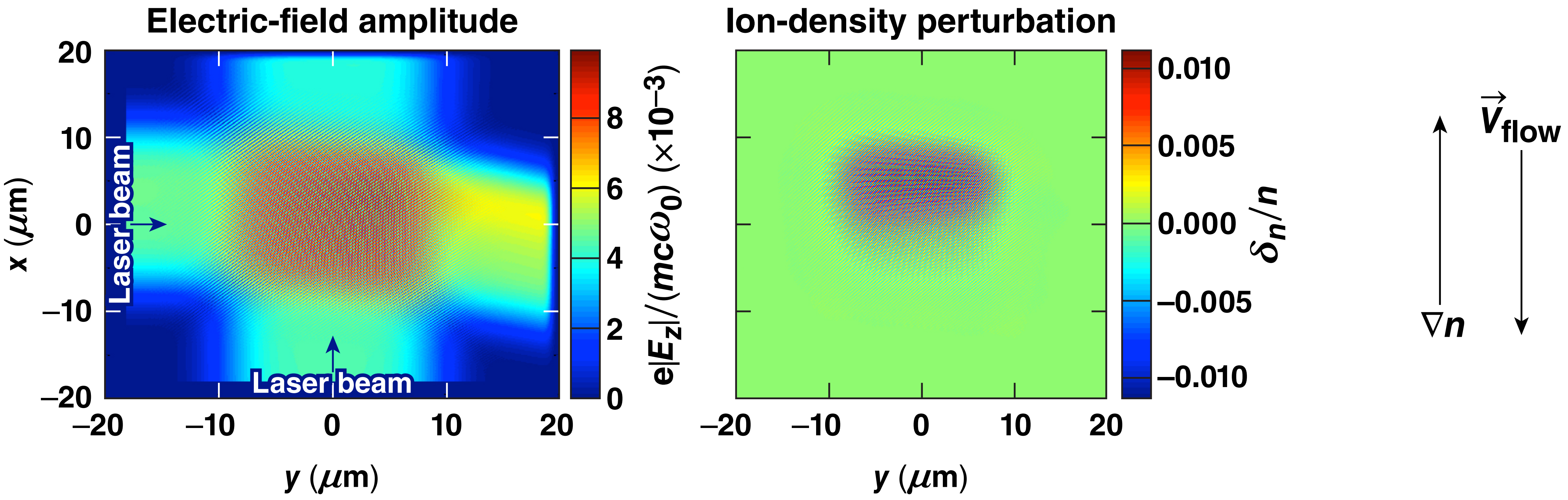
LPSE solves for the enveloped electric-field vector and the ponderomotively driven ion-density perturbations using fewer approximations than ray-based CBET models



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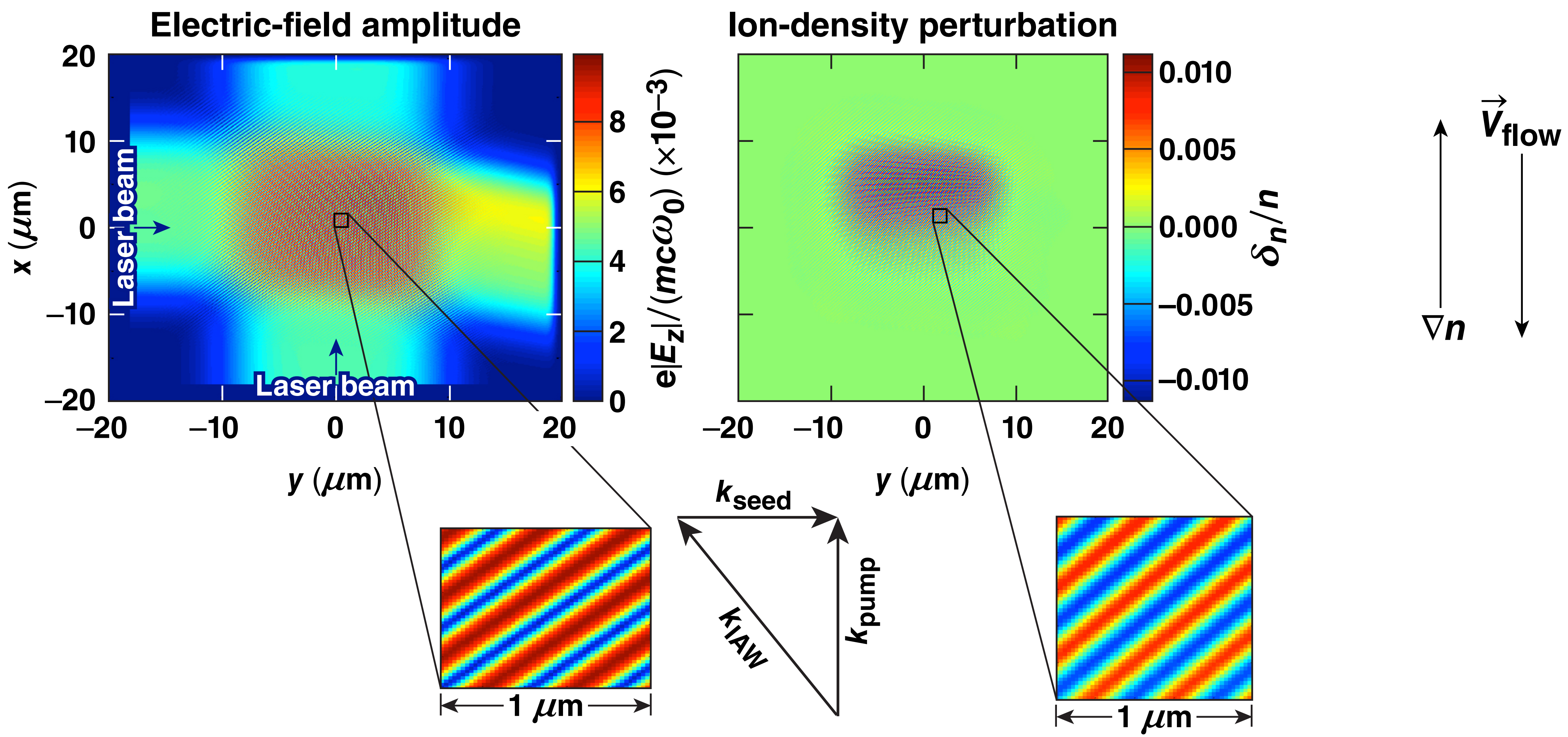

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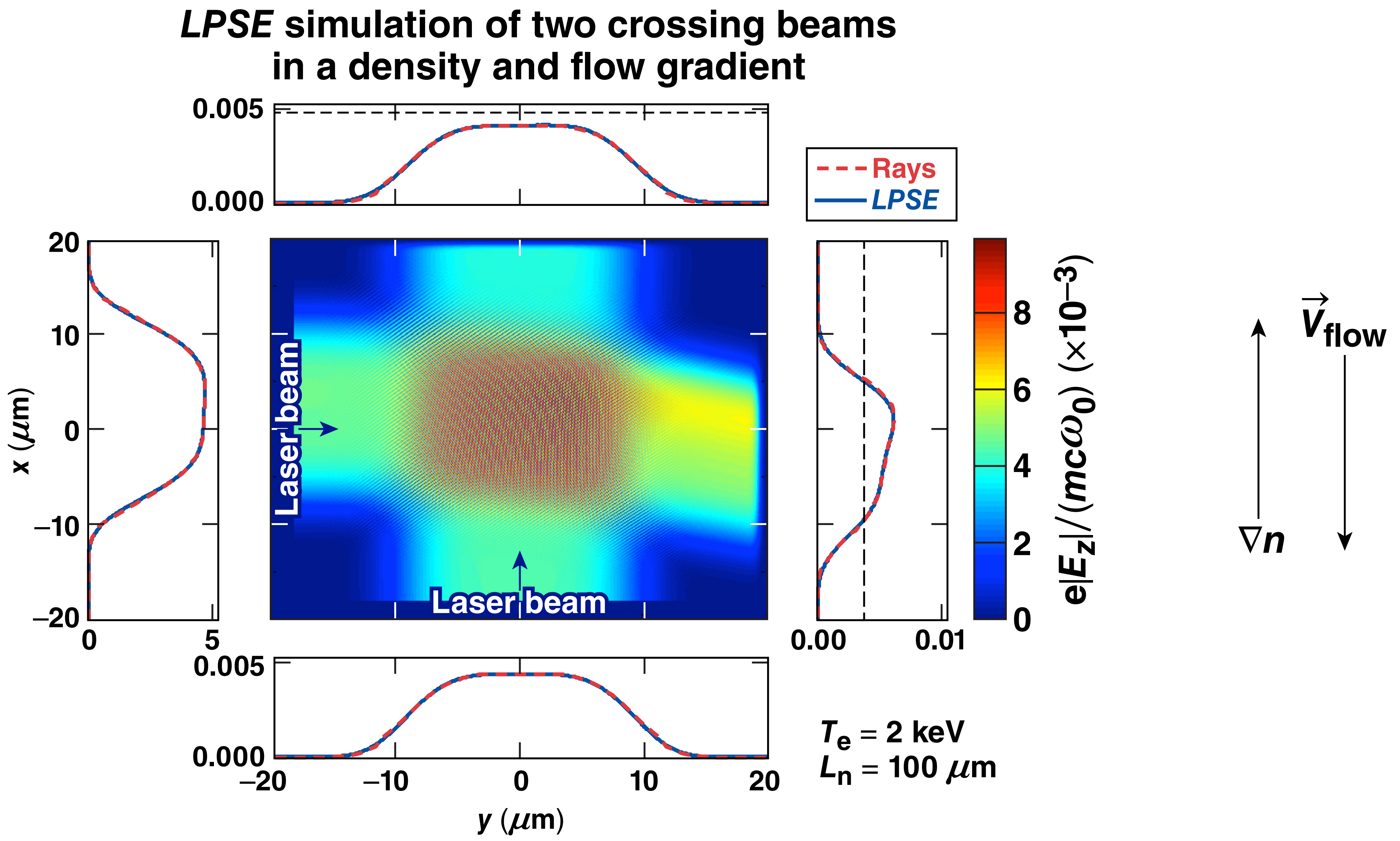
Ray- and wave-based CBET models show excellent agreement when the assumptions made in the ray-based model are satisfied



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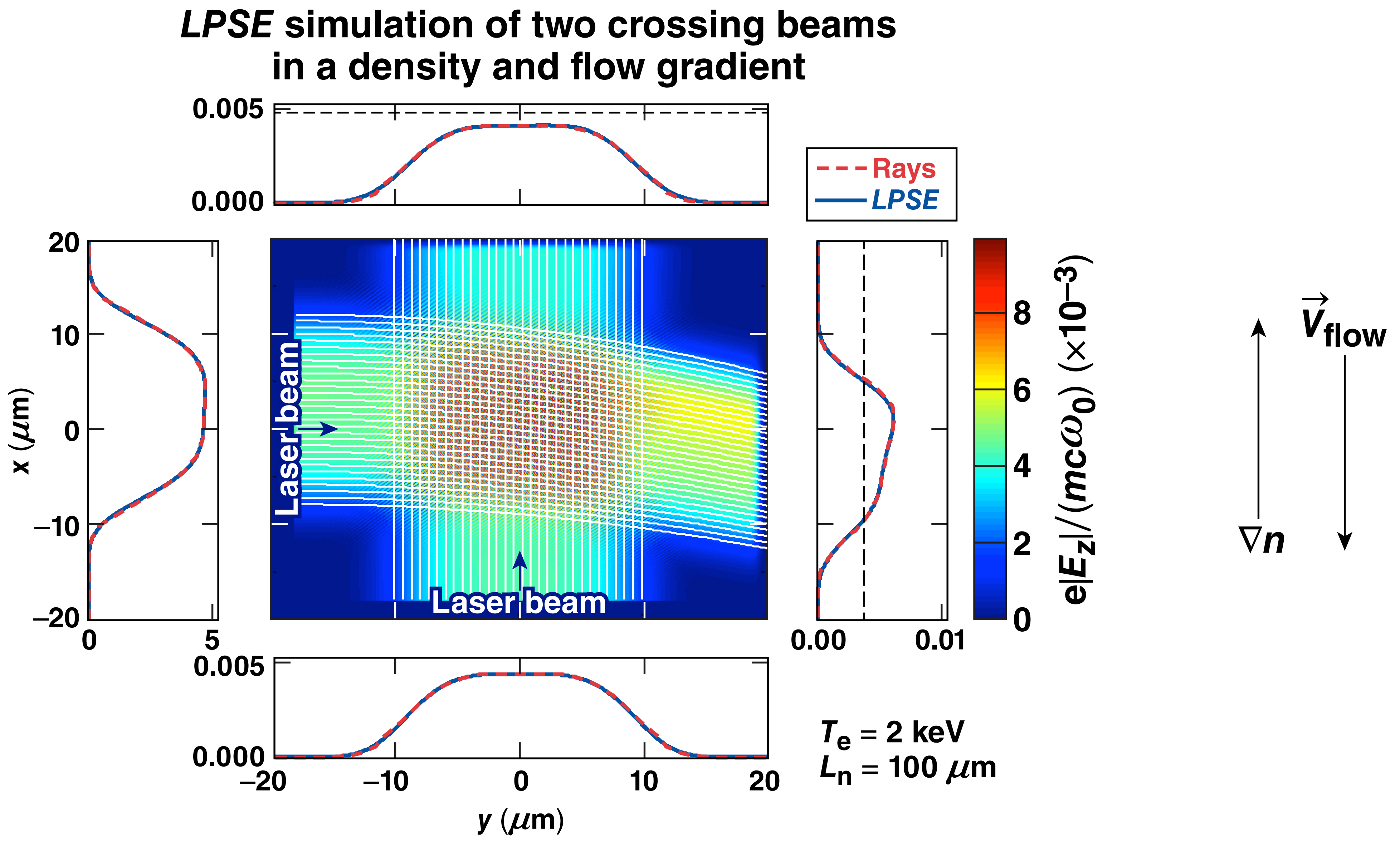

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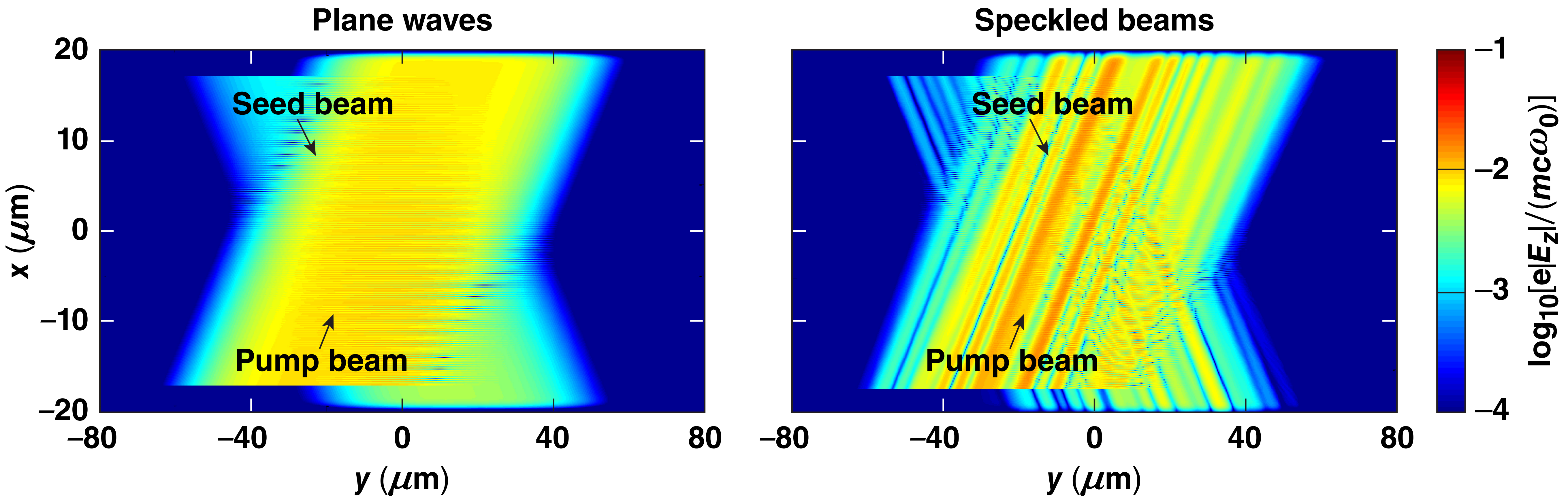
Laser-beam speckle can cause CBET gains to differ from predictions based on the plane-wave approximation



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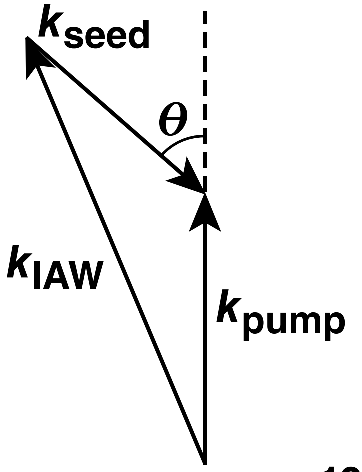
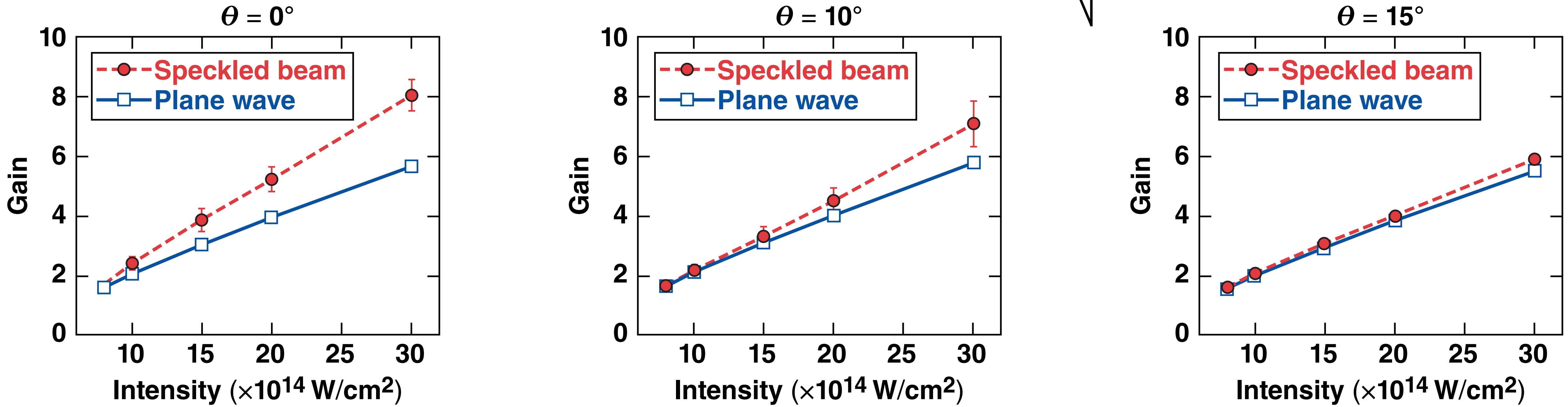
The CBET gain is sensitive to beam speckle for gains $\gtrsim$1 and relative beam angles of $\lesssim$15°

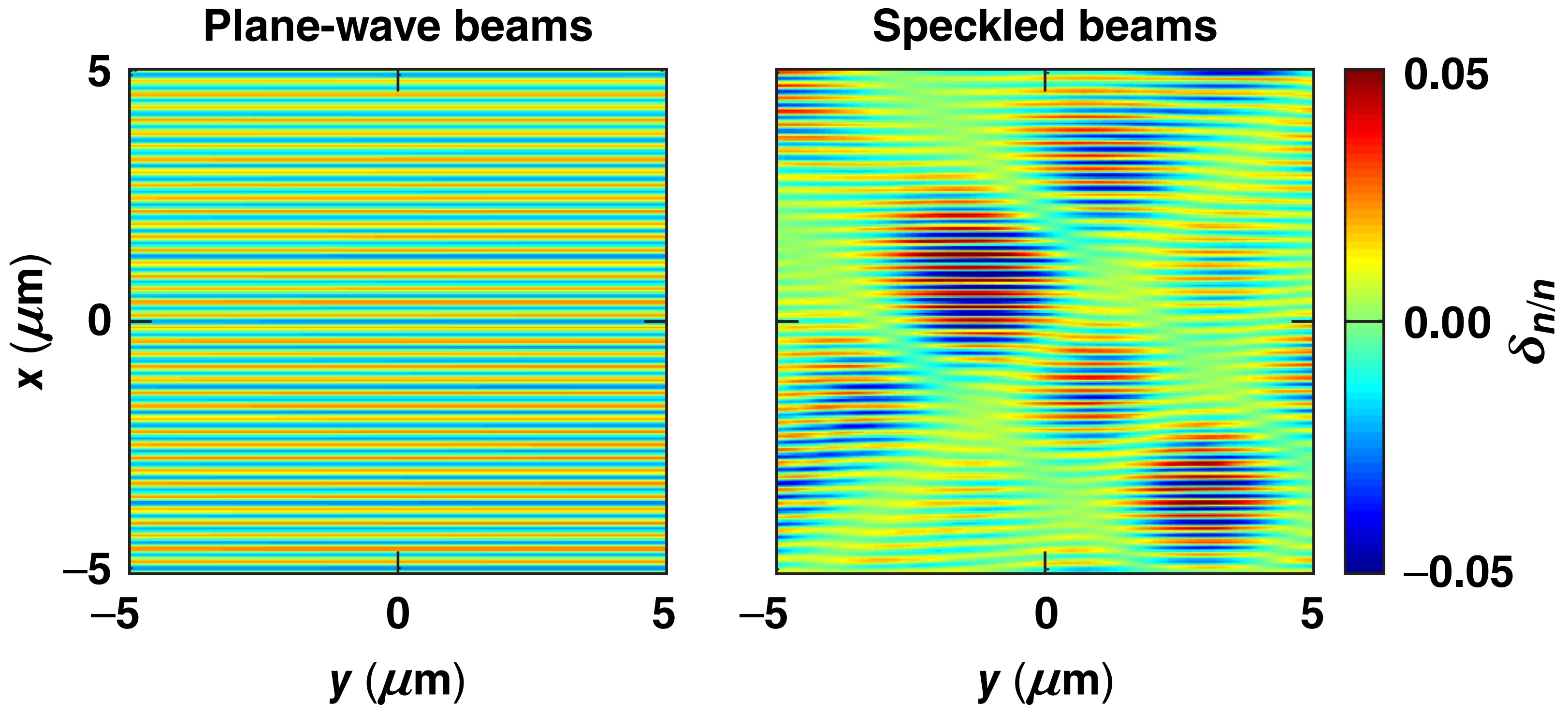
CBET gain for various two-beam interaction angles

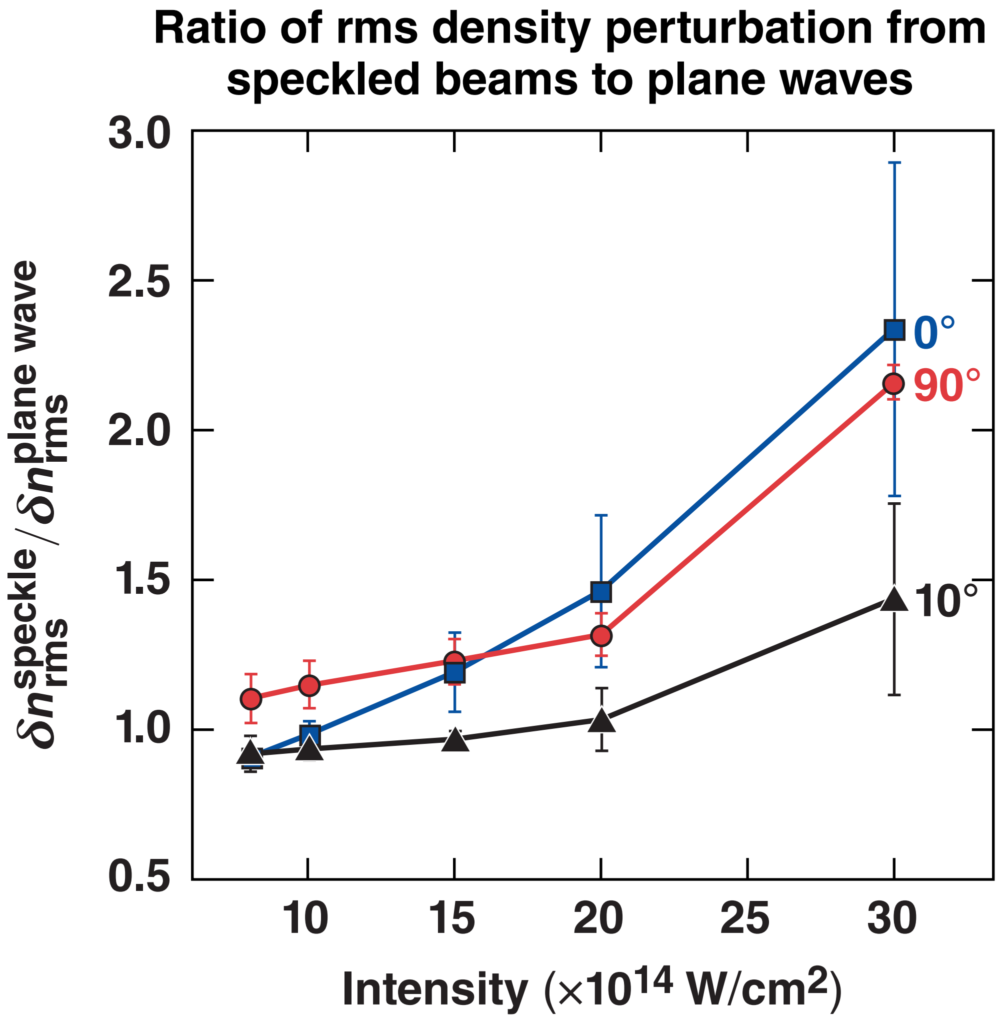
$$\text{Gain} = \log\left(\frac{\text{Seed energy out}}{\text{Seed energy in}}\right)$$





Speckled beams can generate larger density perturbations than plane-wave beams even when the CBET gain is not modified





Enhanced density perturbations could lead to earlier saturation of CBET than would be predicted using a plane-wave approximation.

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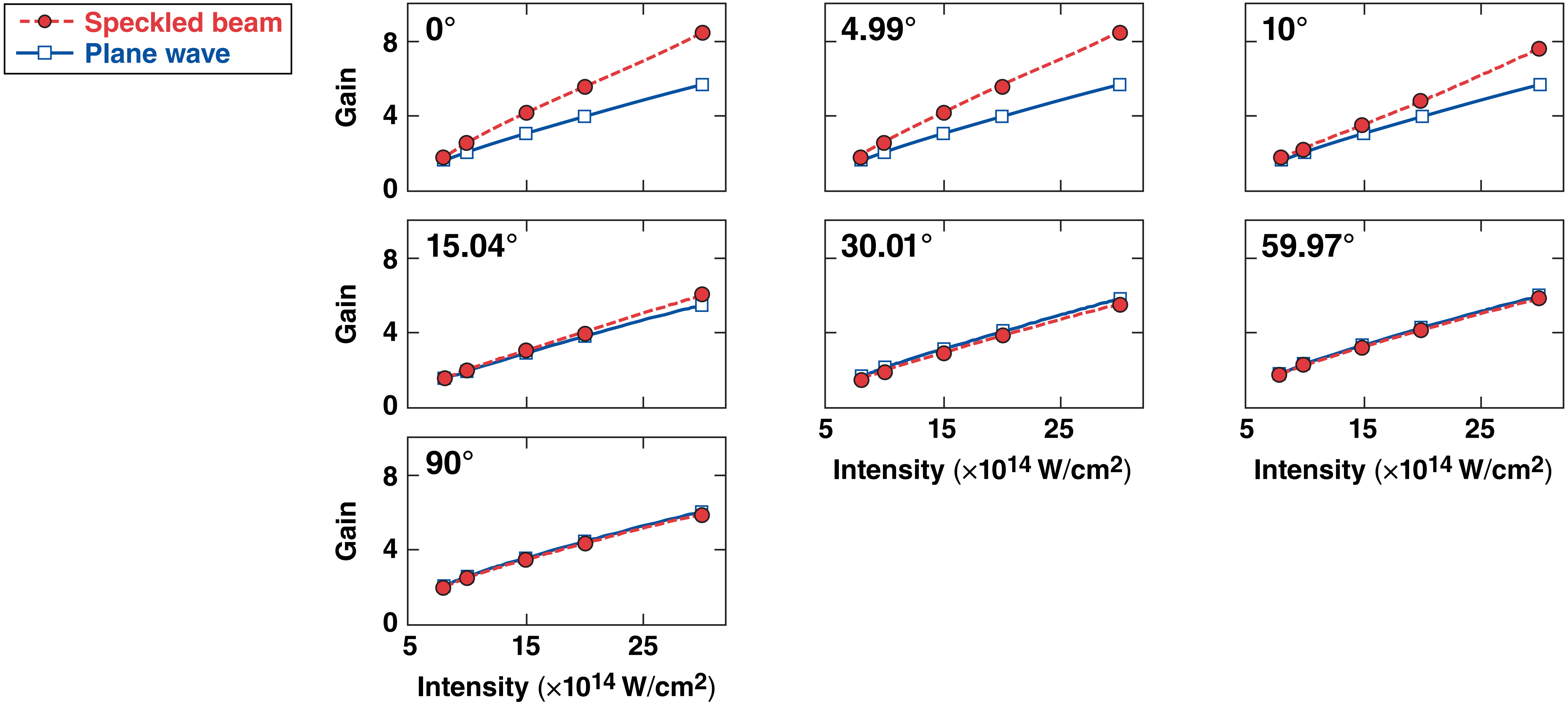
Campaign SBS6, SBS21:SBS90, homogeneous at $n_e/n_e = 0.1$, nui = 0.01



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