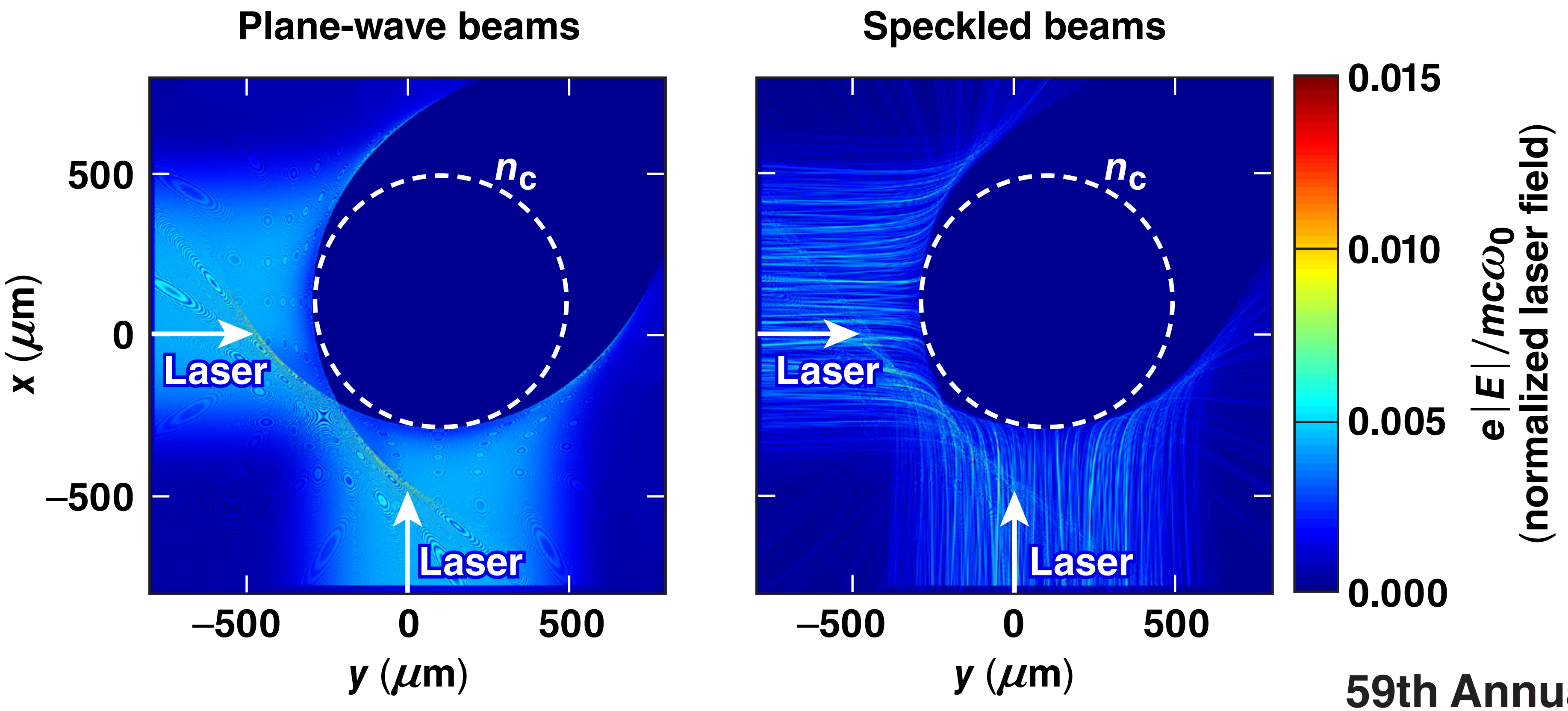
Wave-Based Cross-Beam Energy Transfer Simulations with Laser Speckle and Polarization Smoothing

Full-scale *LPSE* simulations



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A 3-D wave-based model has been developed to understand the physics of cross-beam energy transfer (CBET) in an inhomogeneous plasma

- Detailed CBET calculations are used to study ray-based CBET models that are implemented in hydrodynamics codes
- The comparisons highlight the accuracy of ray-based models
- Discrepancies between the models are found related to beam speckle and polarization smoothing when the speckle length is longer than the interaction region

Collaborators

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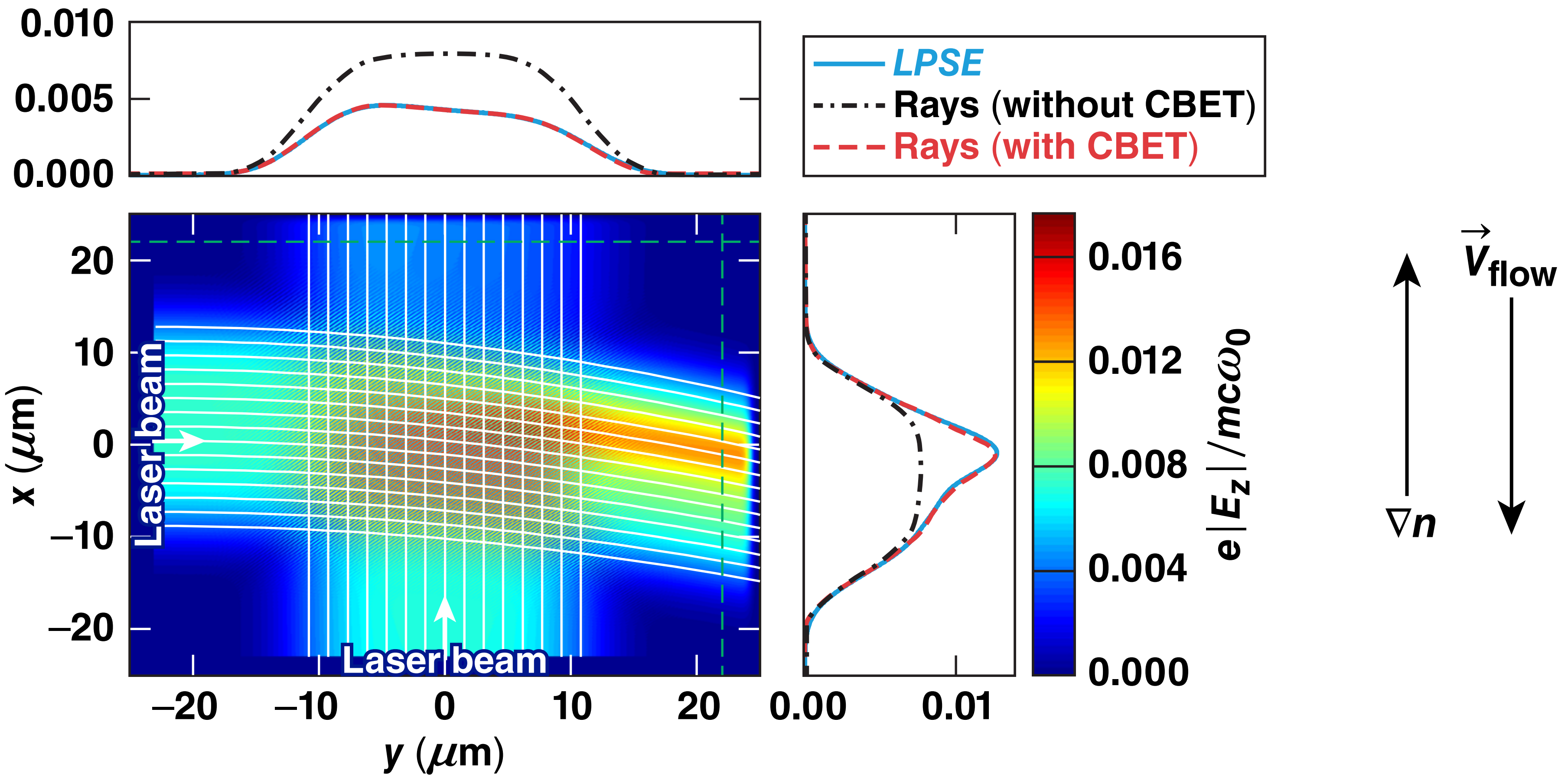
Ray- and wave-based CBET models give the same result in simple interaction geometries (plane-wave beams, no caustics)



All of the approximations made in the ray model are satisfied in this configuration.

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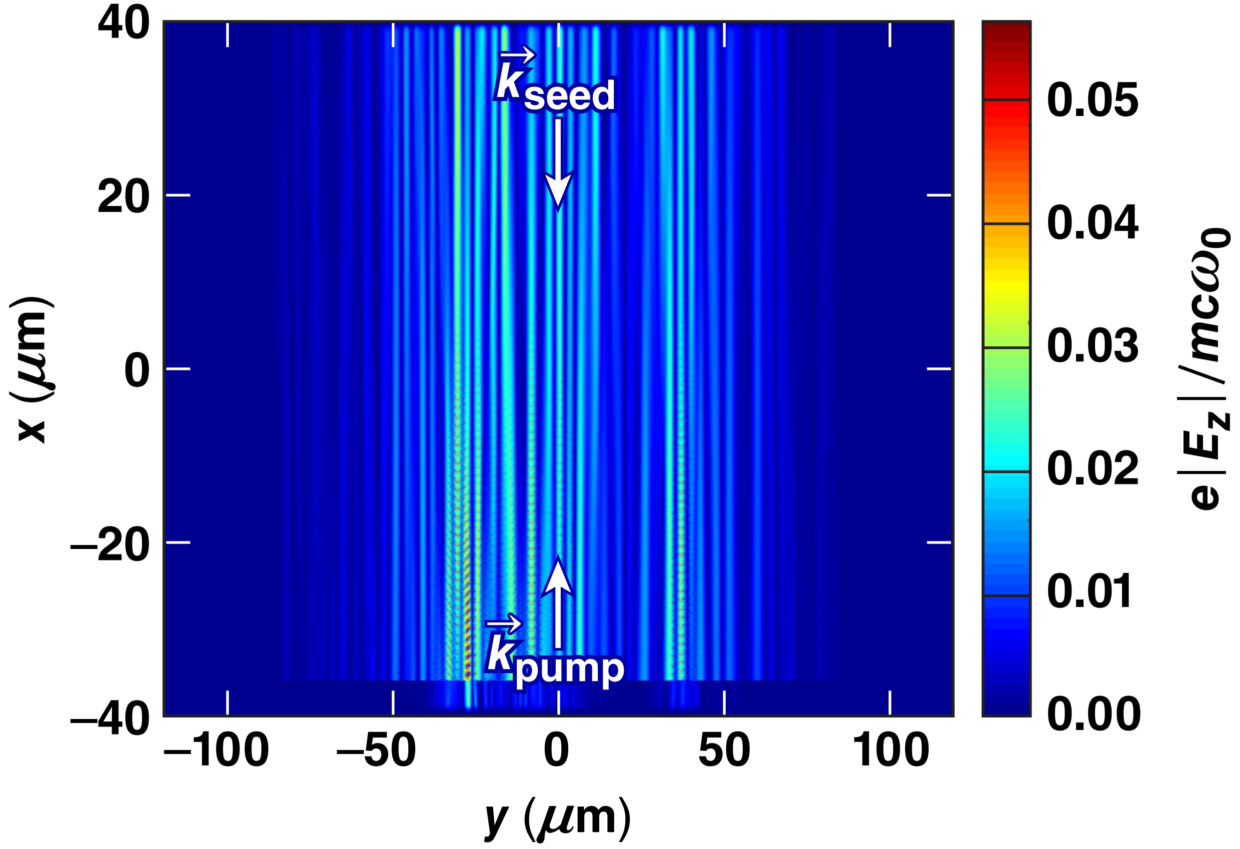
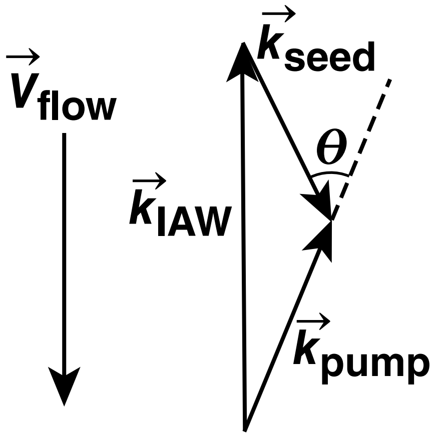
Speckled beams can transfer more energy than plane-wave beams with the same average intensity

LPSE simulation of counter-propagating speckled beams
($I_{pump} = 2 \times 10^{15}$ W/cm^2, $I_{seed} = 10^{12}$ W/cm^2)





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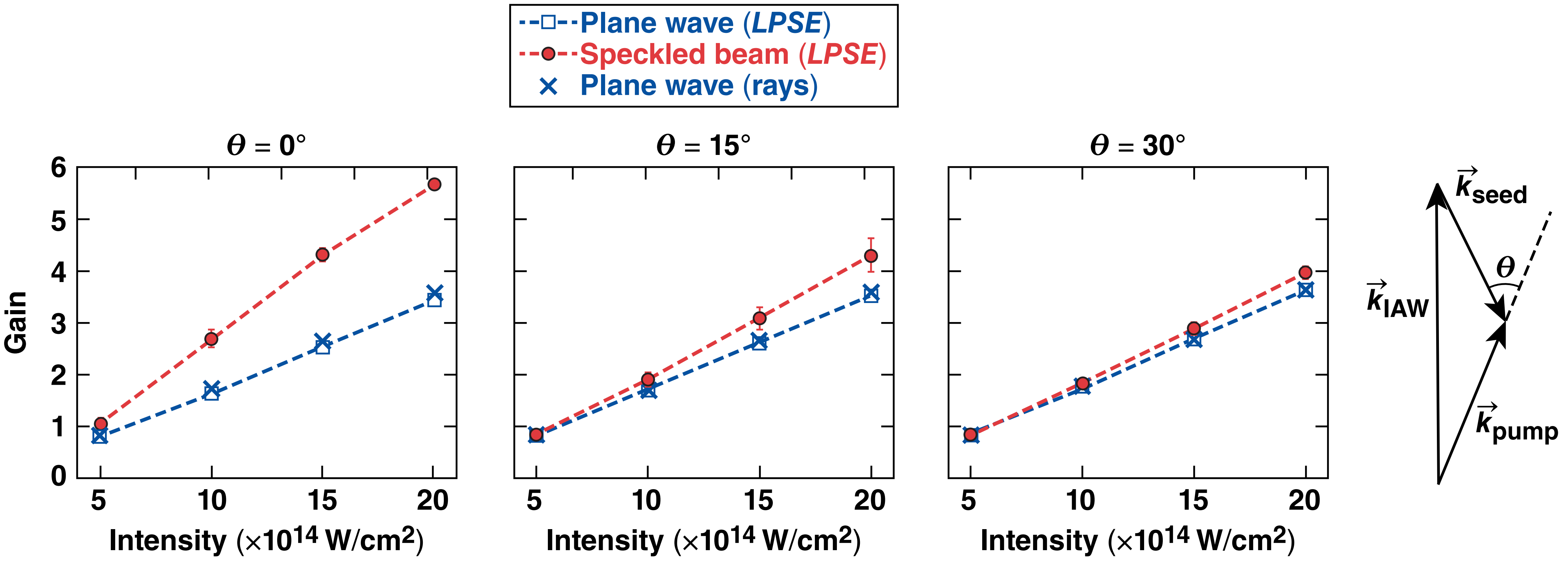
The CBET gain is sensitive to beam speckle for gains greater than ~1 and relative beam angles of less than ~30°

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

CBET gain versus pump intensity for various relative beam angles



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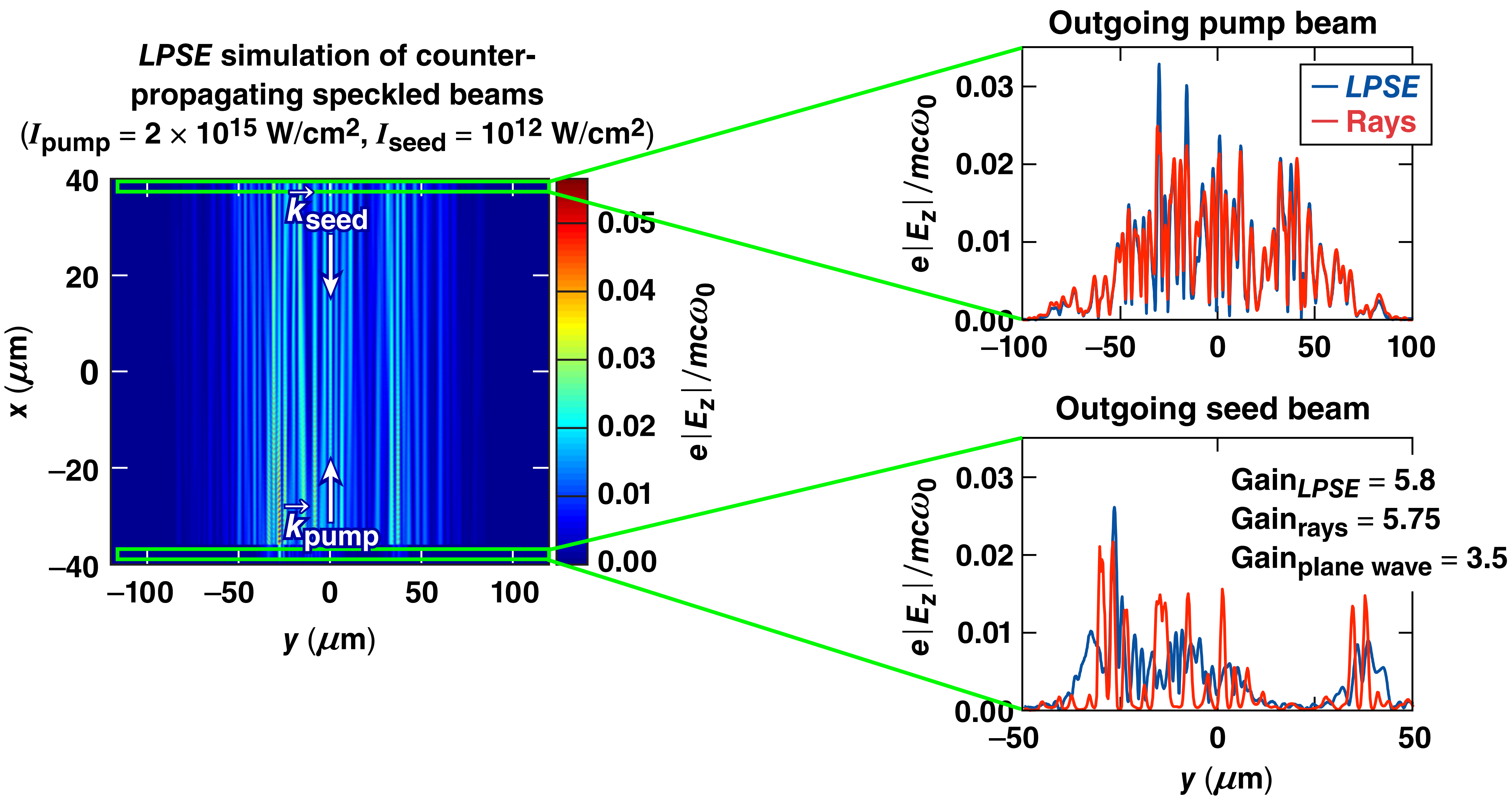
A good approximation to the CBET between speckled beams can be obtained by using the linearity of Maxwell's equations



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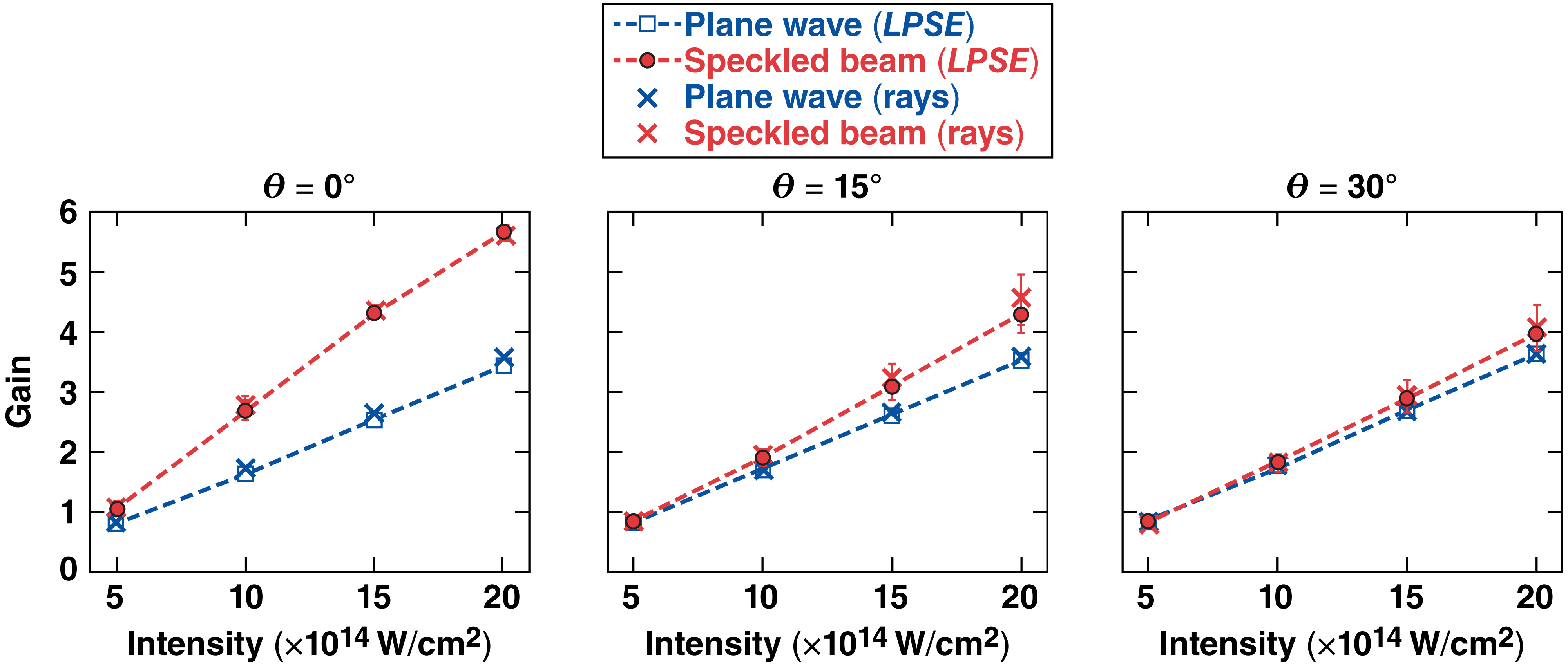
The ray-based speckled field calculations show good agreement with the wave-based results

CBET gain versus pump intensity for various relative beam angles



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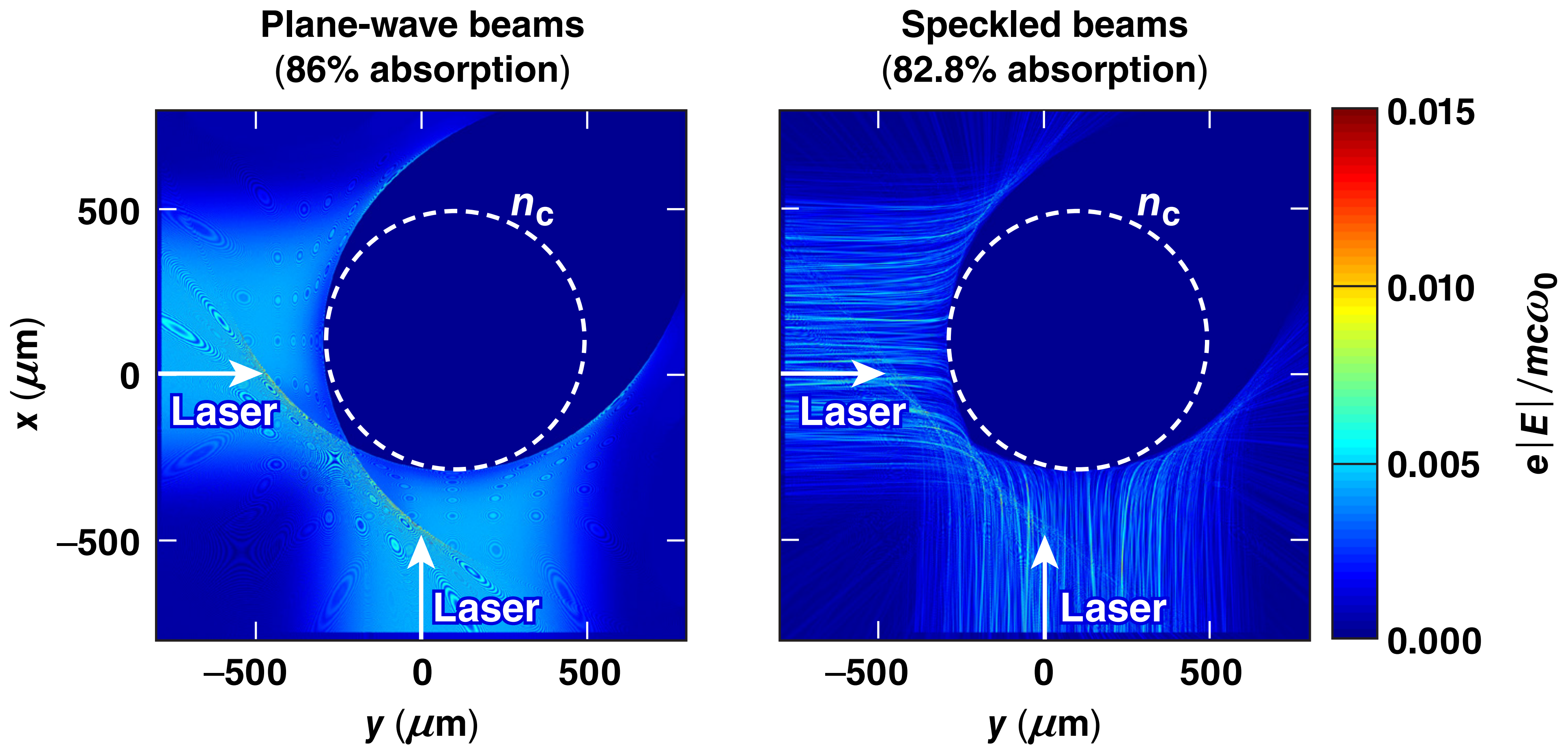
Speckled beams result in a modest decrease in laser absorption in full-scale two-beam *LPSE* simulations at ICF-relevant plasma conditions

- **Full-scale *LPSE* simulations ($I = 2 \times 10^{14}$ W/cm^2)**



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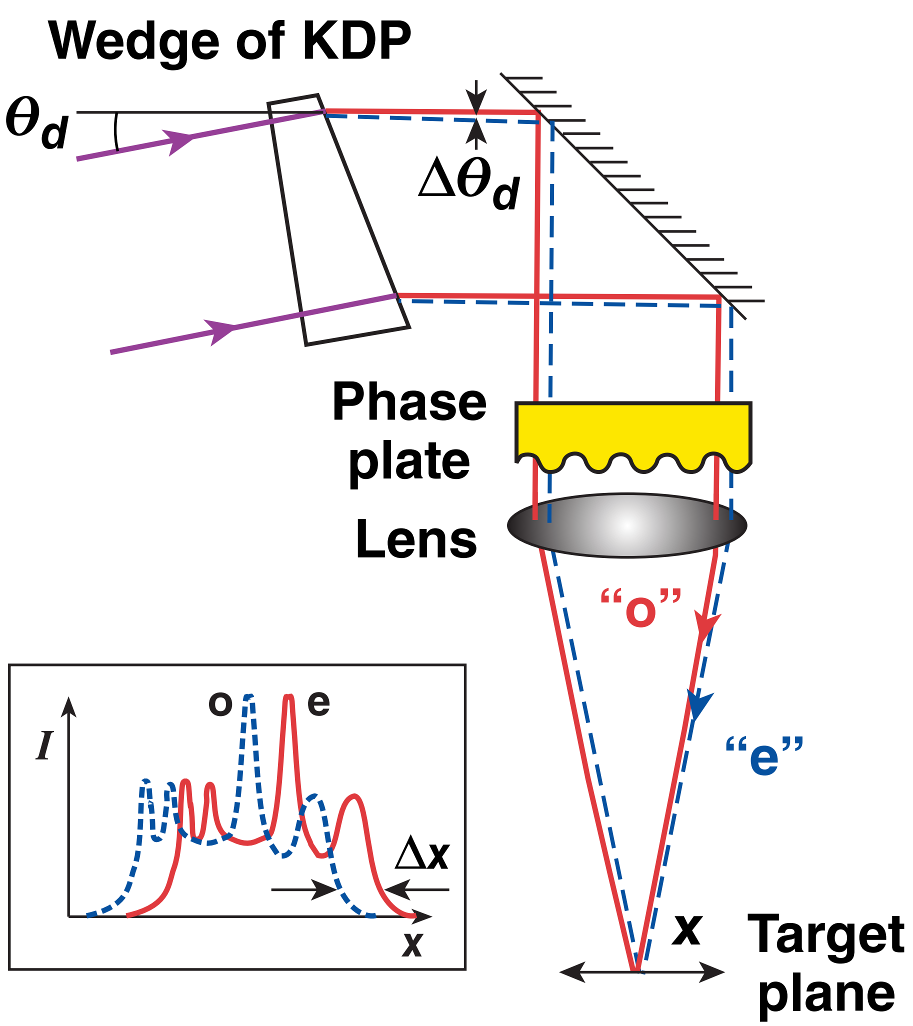
Polarization smoothing is accounted for in ray-based CBET models by multiplying the gain coefficient by a factor of $(1 + \cos^2\theta)/4$*

Polarization smoothing on OMEGA



- The factor of $(1 + \cos^2\theta)/4$ comes from assuming that the interacting beams have random relative polarizations with uncorrelated speckle patterns

$$\left\langle |\phi|^2 \right\rangle_{PS} = \frac{1}{4}\left(1 + \cos^2\theta\right)|\phi|_{\parallel}^2$$

*P. Michel *et al.*, Phys. Plasmas 20, 056308 (2013).

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The factor of $(1 + \cos^2\theta)/4$ used to account for the modification of the CBET gain between beams with polarization smoothing is valid only when the speckle length is shorter than the interaction region*

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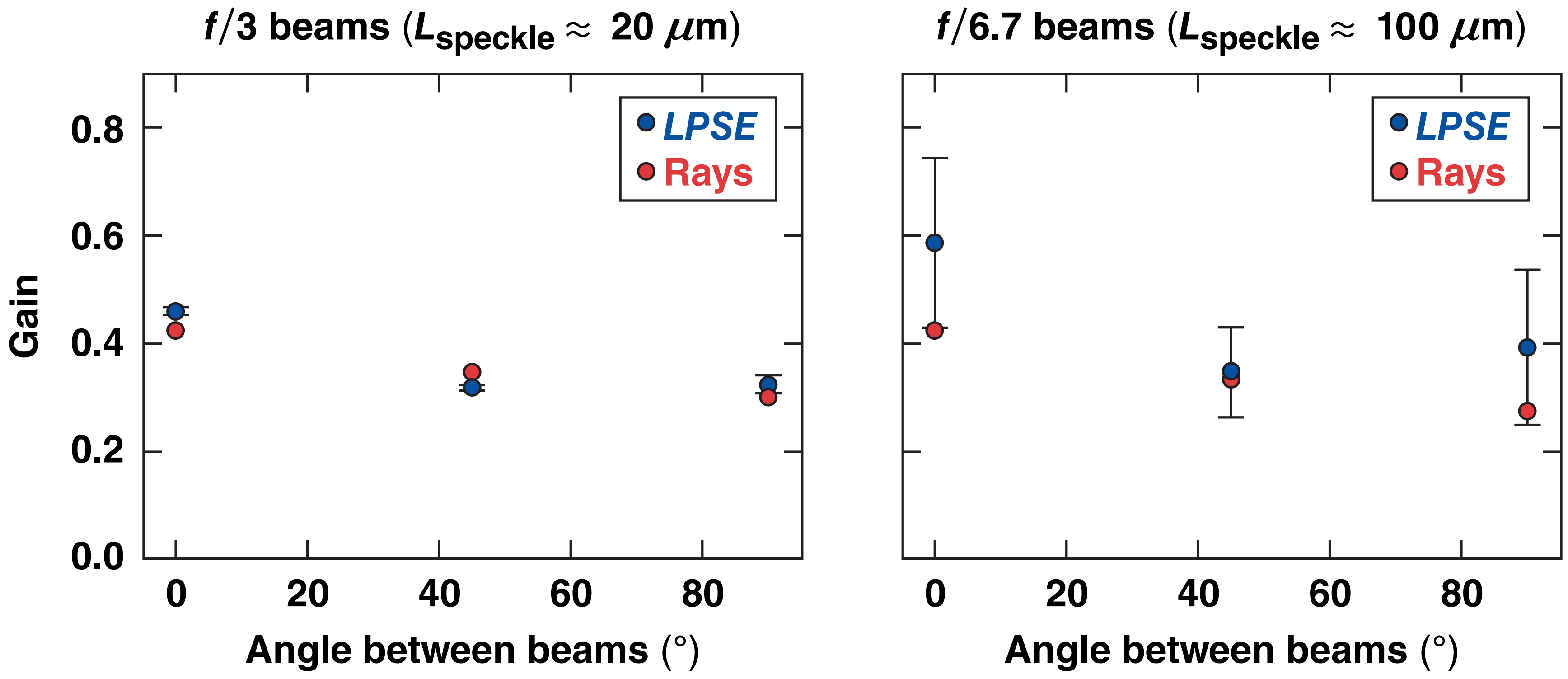
CBET gain versus relative beam angle for beams with polarization smoothing averaged over 12 realizations of polarization/phase
($I_{pump} = 5 \times 10^{14}$ W/cm^2, $I_{seed} = 2 \times 10^{13}$ W/cm^2)



Speckle length = $2\pi f_{\#}^2 \lambda_0$

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*P. Michel *et al.*, Phys. Plasmas 20, 056308 (2013).

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