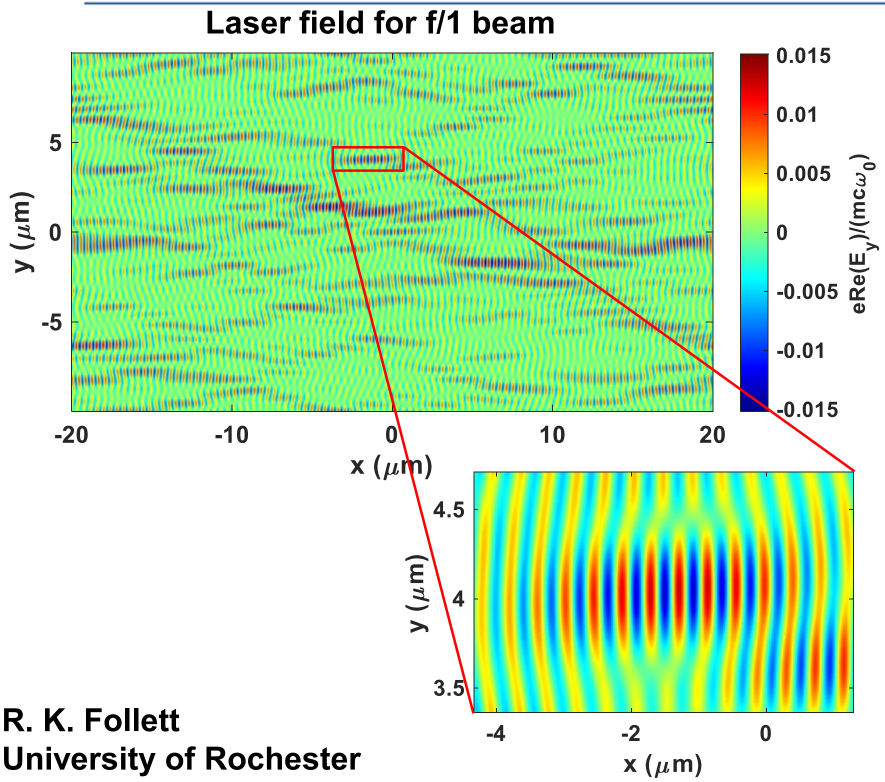
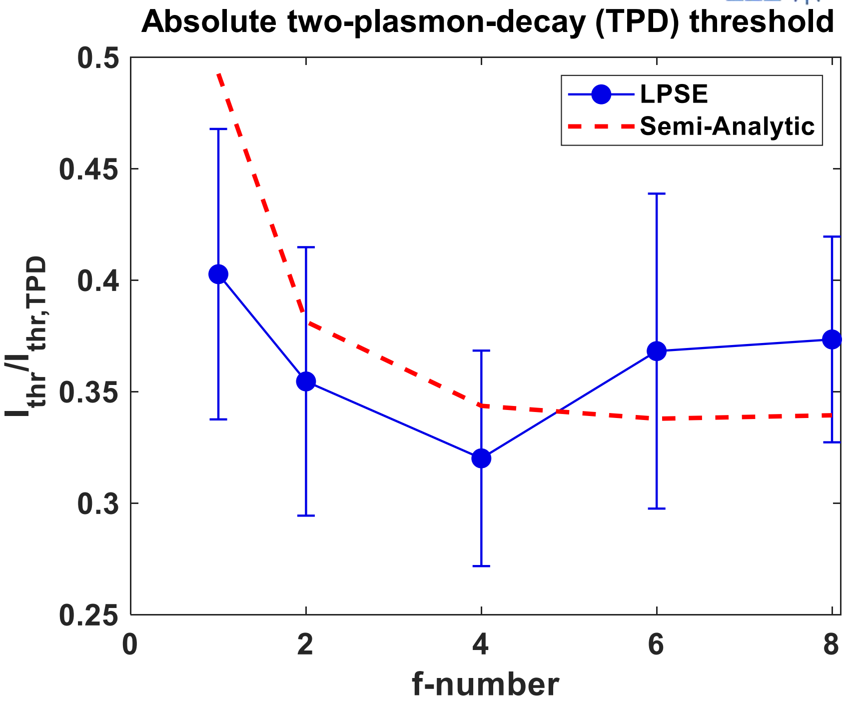
# A local-field approach to understanding multibeam laser-plasma instabilities

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# The local-field approach is a procedure for developing simple models of laser-plasma instabilities in complex laser configurations



- Simple models for laser-plasma instabilities are often limited to plane-wave thresholds, but speckled laser beams introduce local field structure
- Global instability behavior can be understood by convolving the local instability behavior with the statistical properties of the laser field
- A semi-analytic model for the absolute two-plasmon-decay (TPD) instability was developed that accurately predicts the instability threshold for a speckled beam

**This approach can be applied to other instabilities or expanded to include effects like polarization smoothing or speckle motion**

# Collaborators

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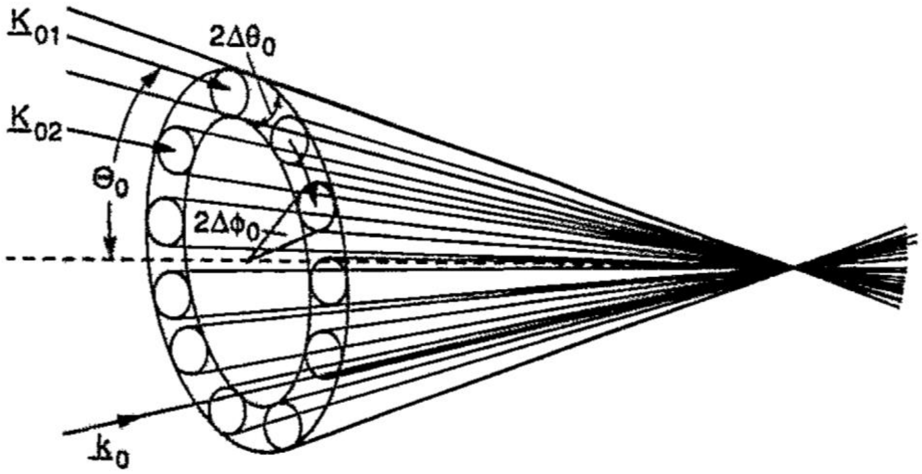
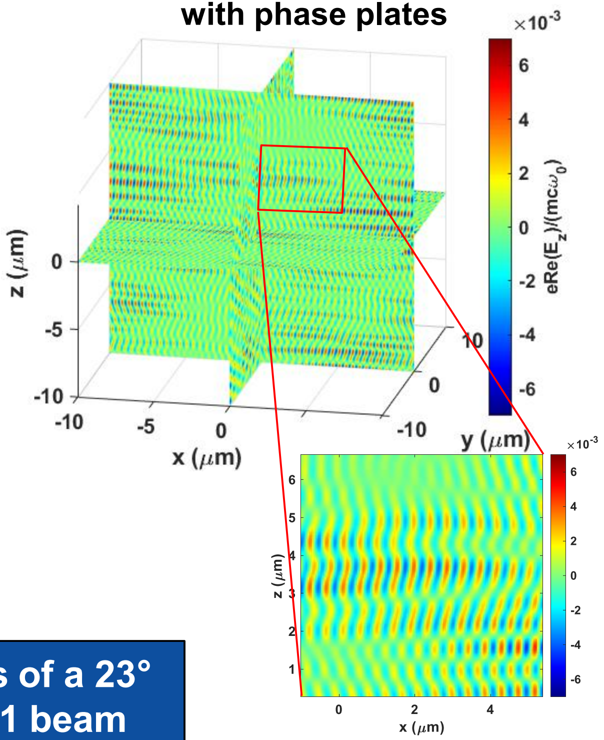
# The prevailing picture of multibeam laser-plasma interactions does not account for the local structure of a speckled laser field

**Idealized picture of multibeam interactions with a shared daughter wave along the axis of symmetry***




**Electric field for a 23° cone of beams with phase plates**

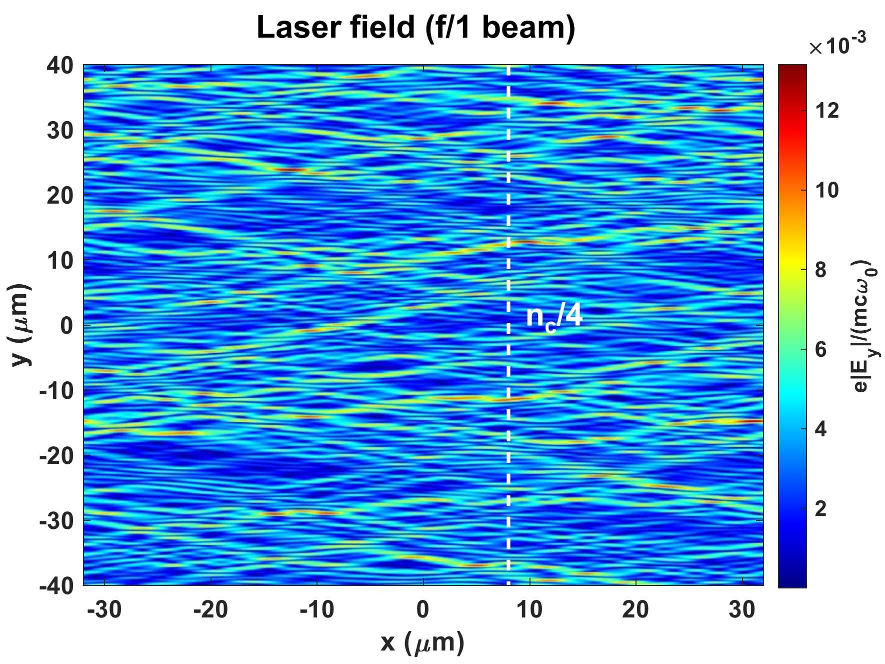


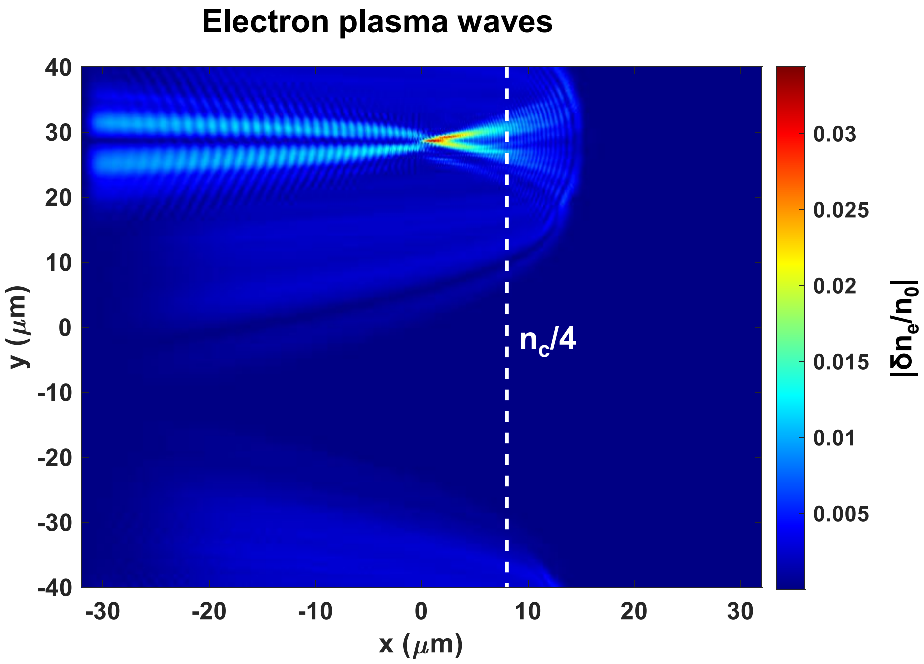

**The local fields and statistical properties of a 23° cone of beams are similar to a single f/1 beam**



*Dubois et al., Phys. Fluids B **4**, 241 (1992).

# As an example, consider the absolute TPD instability in a speckled beam



# The local-field approach uses the instability behavior in a single speckle to construct a semi-analytic theory of the global behavior

$$I_{thr} = (\text{function of speckle statistics}) \times (\text{function of single-speckle instability properties})$$

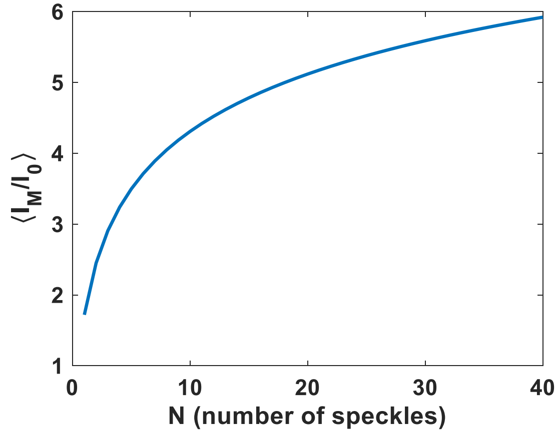
$$= \frac{1}{\langle I_M / I_0 \rangle} \times I_{thr,speckle}(L_n, T_e, \lambda_0, w_s, l_s)$$

**expected ratio of max speckle intensity to average intensity**

$\langle I_M / I_0 \rangle$ **can be determined analytically using the probability distribution of speckle intensities***

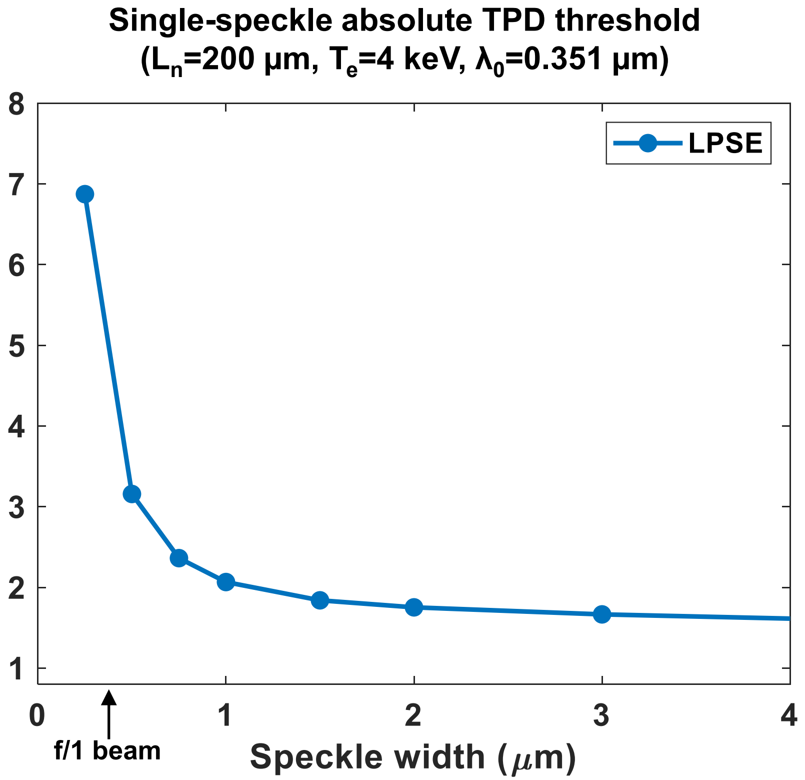
$$\left\langle \frac{I_M}{I_0} \right\rangle = -\sum_{a=1}^{N} \binom{N}{a} a^{-1-a} \left( \frac{-2-\pi}{4+\pi} \right)^a e^{\frac{a(4+\pi)}{2+\pi}} \Gamma\left[1+a, \frac{a(4+\pi)}{2+\pi}\right]$$

$$N = \frac{P_L}{\langle P_s \rangle} \approx \frac{w_g}{f_\# \lambda_0} \frac{4+\pi}{3+\pi} \sqrt{\frac{\log 2}{\pi}}$$




*Garnier et al., Phys. Plasmas **6**, 1601 (1999).

# Single-speckle simulations can be used to find $I_{thr,speckle}(L_n,T_e,\lambda_0,w_s,I_s)$



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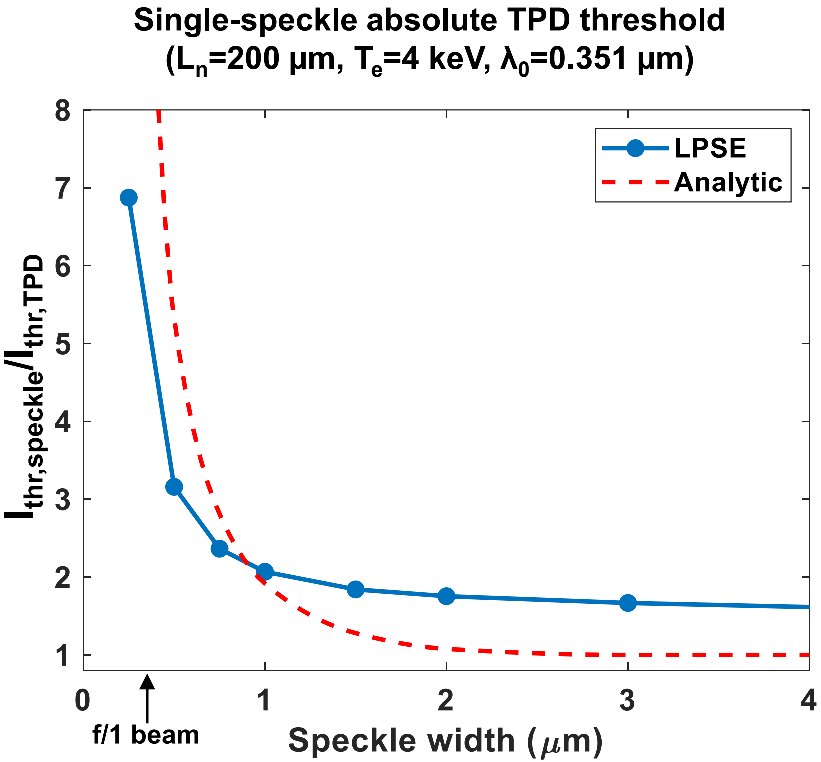
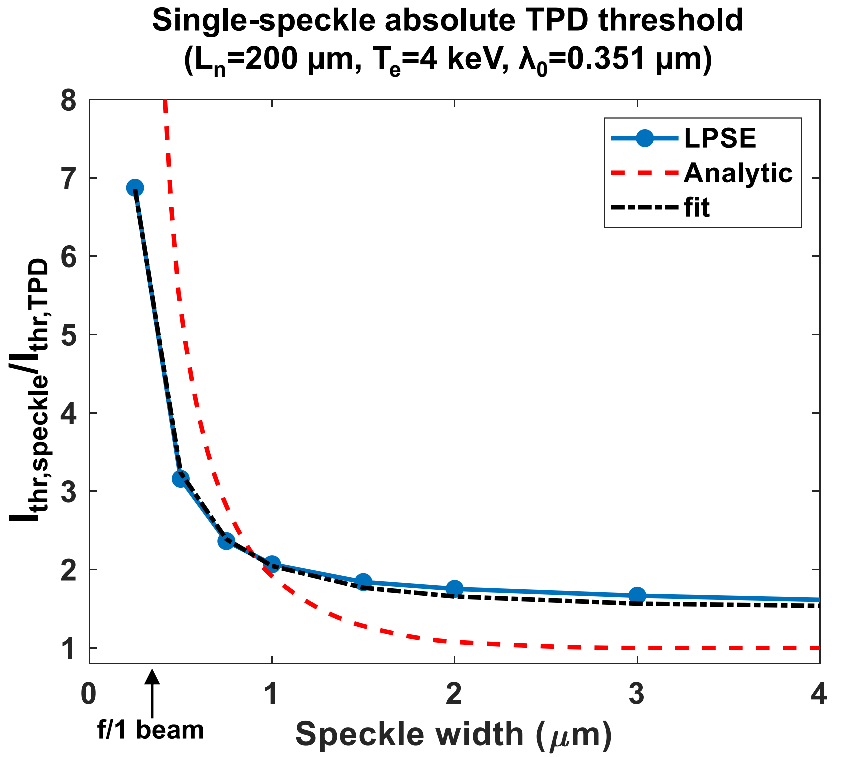



An analytic approximation can be obtained by assuming the transverse spectrum of absolutely unstable modes be broad enough for absolute growth to occur within a speckle:

$$\Delta k_\perp = 2\pi \,/\, (\text{speckle width}) = 2\pi \,/\, f_\# \lambda_0$$

$$\longrightarrow \frac{\Delta k_\perp}{k_0} = \frac{1}{f_\#}$$

# Single-speckle simulations can be used to find $I_{thr,speckle}(L_n,T_e,\lambda_0,w_s,I_s)$



# The analytic approximations show good agreement with speckled-field thresholds calculated using LPSE

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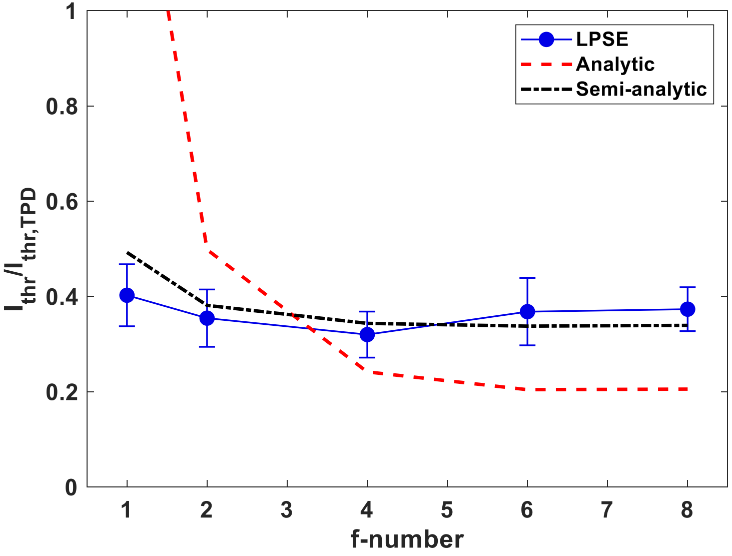
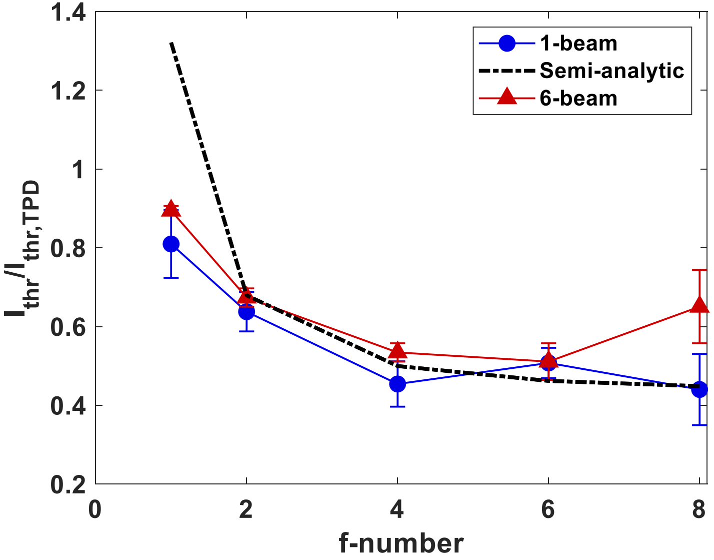
**2-D absolute TPD threshold**
**($L_n$=200 μm, $T_e$=4 keV)**




**3-D absolute TPD threshold**
**($L_n$=400 μm, $T_e$=4 keV)**



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