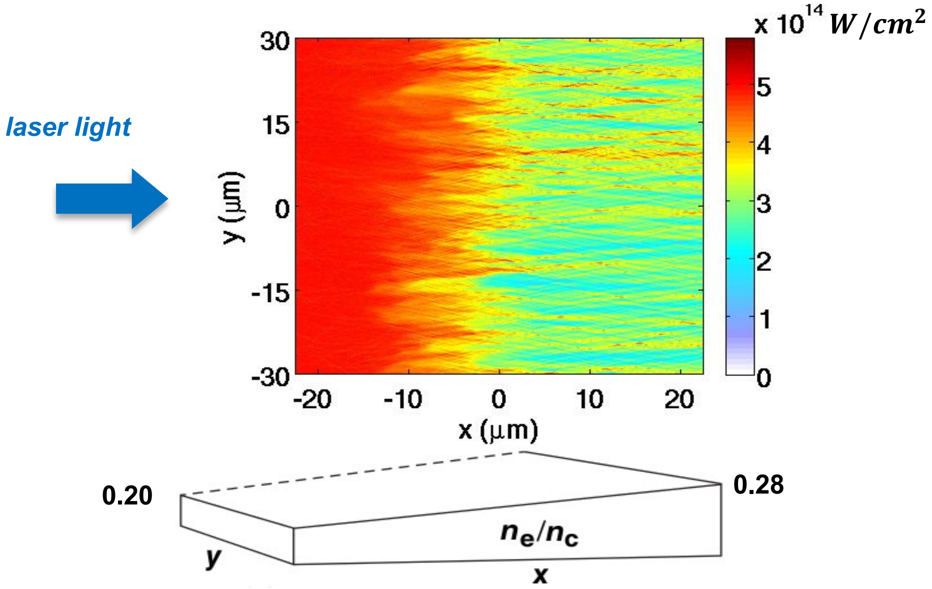
Effect of multi-beam two-plasmon decay instability on cross-beam energy transfer in plasmas



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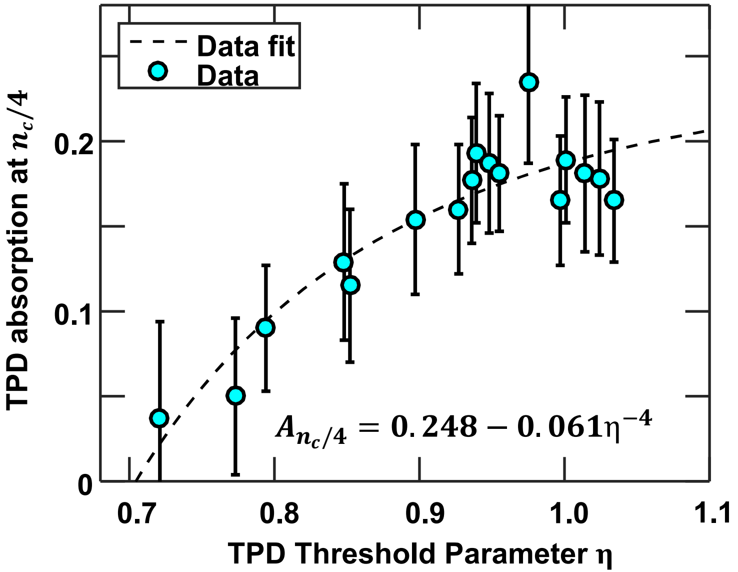
Summary

In direct-drive OMEGA plasmas, the balance of absorption and scattering near the quarter-critical density is determined by the interplay of two-plasmon decay (TPD) and cross-beam energy transfer (CBET)

- **The scaling with intensity of absorption due to TPD pump depletion has been obtained for the conditions of OMEGA experiments using LPSE *.**
- **The absorption of laser light due to TPD driven by two laser beams is smaller than for a single beam for the same averaged intensity.**
- **When plasma conditions favor CBET, the low-frequency density perturbations can be shared between CBET and TPD, reducing TPD and the absorption of laser light due to TPD.**

* Laser Plasma Simulation Environment
J. F. Myatt et al., Phys. Plasmas 24, 056308 (2017)

Recently the data from OMEGA experiments has been analyzed*, and laser absorption due to TPD has been shown to scale with $\eta = I_{14} L(\mu m)/(233\, T_e(keV))$**



in experiments
$\eta_{min} = (0.7 - 0.8)$

Average absorption over the duration of the TPD activity was compared to average η extracted from LILAC simulations over a comparable duration, for a series of shots

*D. Turnbull, this conference, NO5.00005.

** A. Simon *et al.*, Phys. Fluids 26, 3107 (1983);
C. Stoeckl *et al.*, Phys. Rev. Lett. 90, 235002 (2003);
W. Seka *et al.*, Phys. Plasmas 16, 052701 (2009);
D.T. Michel *et al.*, Phys. Plasmas 20, 055703 (2013);
J. Delettrez *et al.*, Phys. Plasmas 26, 062705 (2019).

The experimental data have motivated the addition of laser pump depletion due to TPD into *LPSE*

- **The model describes the evolution of laser light (enveloped near frequency ω_0), plasma-wave field (near ω_p), and ion-acoustic perturbation *N***

Laser light

$$i\frac{\partial \mathbf{V}_0}{\partial t} + i\gamma_0 \circ \mathbf{V}_0 + \frac{c^2}{2\omega_0}\nabla^2\mathbf{V}_0 + \frac{\omega_0^2 - \omega_p^2(1+N_0+\delta N)}{2\omega_0}\mathbf{V}_0 = \frac{i\omega_p}{4\omega_0}\left[(\nabla\cdot\mathbf{V}_\mathrm{p})\mathbf{V}_\mathrm{p}\right]_\mathrm{T}\cdot e^{-i\,\delta\omega\,t}$$

Plasma wave

$$i\frac{\partial \mathbf{V}_p}{\partial t} + i\gamma_p \circ \mathbf{V}_p + \frac{3\mathrm{v}_\mathrm{Te}^2}{2\omega_1}\nabla^2\mathbf{V}_p - \frac{\omega_p(N_0+\delta N)}{2}\mathbf{V}_p = \frac{1}{\omega_p}\left[\nabla(\mathbf{V}_\mathrm{p}^*\cdot\mathbf{V}_0) - \left(\nabla\cdot\mathbf{V}_\mathrm{p}^*\right)\mathbf{V}_0\right]\cdot e^{i\,\delta\omega\,t}$$

Ion-acoustic

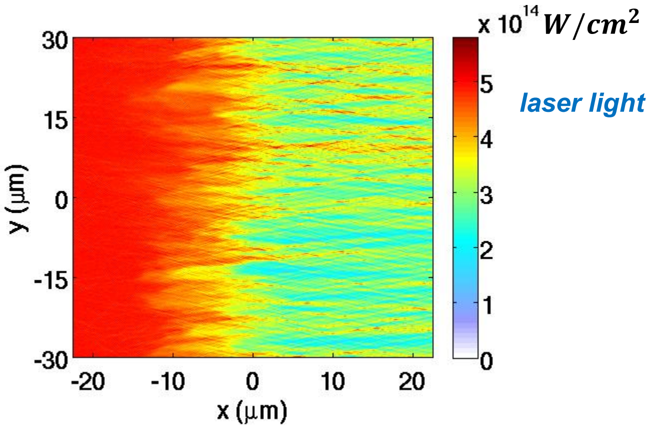
$$\frac{\partial^2\delta\mathrm{N}}{\partial\tau^2} + 2\gamma_{ia}\circ\frac{\partial\delta\mathrm{N}}{\partial\tau} - \mathrm{c}_\mathrm{s}^2\nabla^2\delta\mathrm{N} = \frac{1}{16\pi n_0 m_i}\nabla^2\left[\left|\mathbf{E}_p\right|^2 + \frac{n_0}{n_c}\left|\mathbf{E}_0\right|^2\right]$$

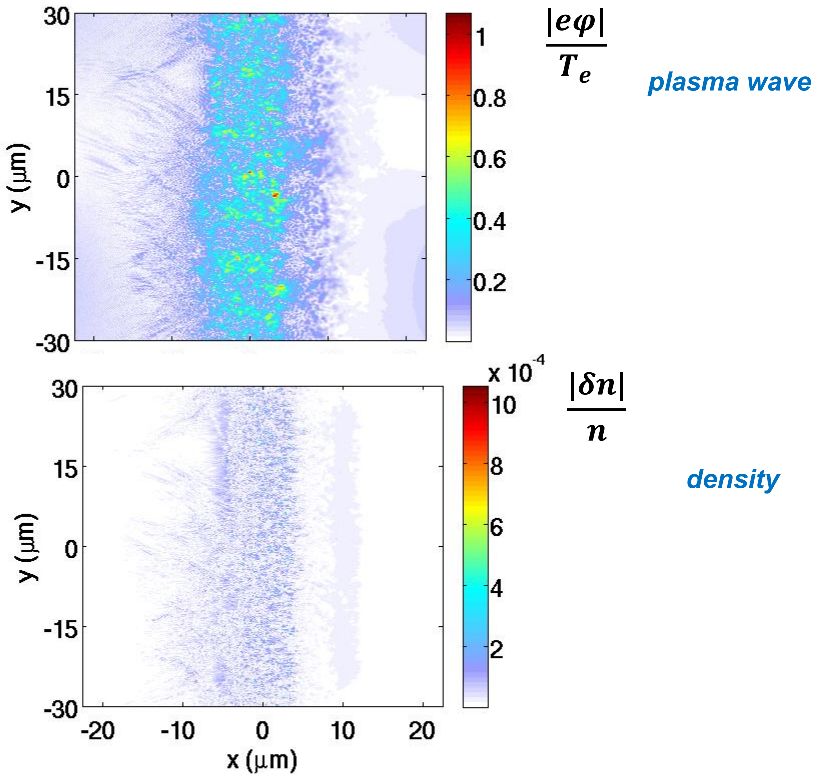
where $\mathbf{V}_\mathrm{j} = \frac{\mathrm{i}e\mathbf{E}_\mathrm{j}}{\mathrm{m}_\mathrm{e}\omega_\mathrm{j}}(\mathrm{j}=0,\mathrm{p})$ $\frac{\partial}{\partial\tau} = \frac{\partial}{\partial \mathrm{t}} + \mathbf{U}_0\cdot\nabla$, $\mathbf{U}_0$-flow; N_0 - background density profile;

$\delta\omega = \omega_0 - 2\omega_\mathrm{p}$ - frequency mismatch

It is possible to study the relative importance of different wave-coupling processes.

Modeling of TPD influence on laser light has been performed for parameters relevant to OMEGA experiments





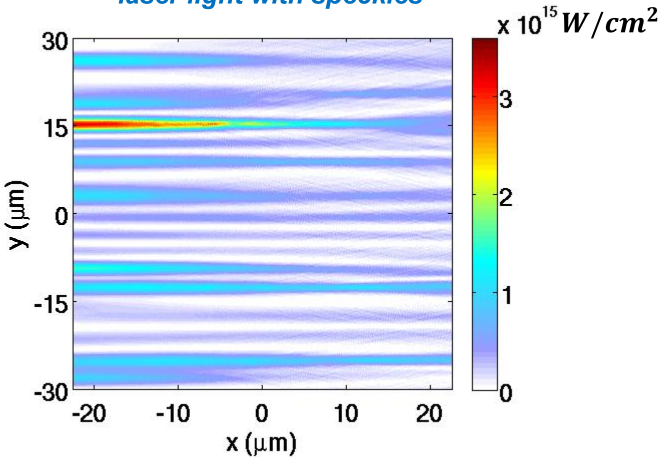
$I_0 = 5 \cdot 10^{14}\ W/cm^2$;

T_e = 2.5 keV; $L_n = 150\ \mu m$;
T_i = 1.25 keV; CH

time: t = 20 ps

When TPD is driven by speckled beams, the instability growth and pump depletion are determined by the high-intensity speckles

laser light with speckles



$I_0 = 5 \cdot 10^{14}\ W/cm^2$;

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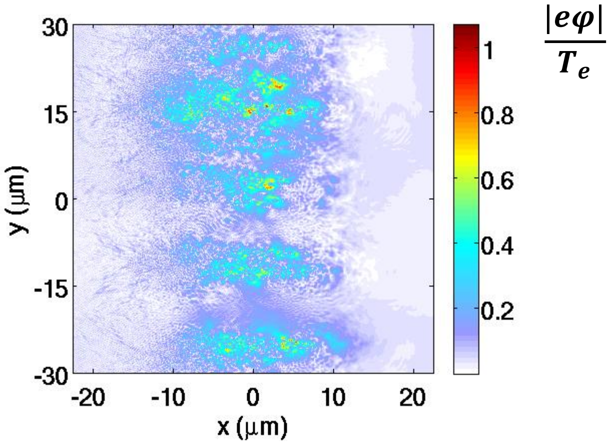
plasma wave



A scaling of TPD influence on the laser light depletion has been obtained in LPSE simulations

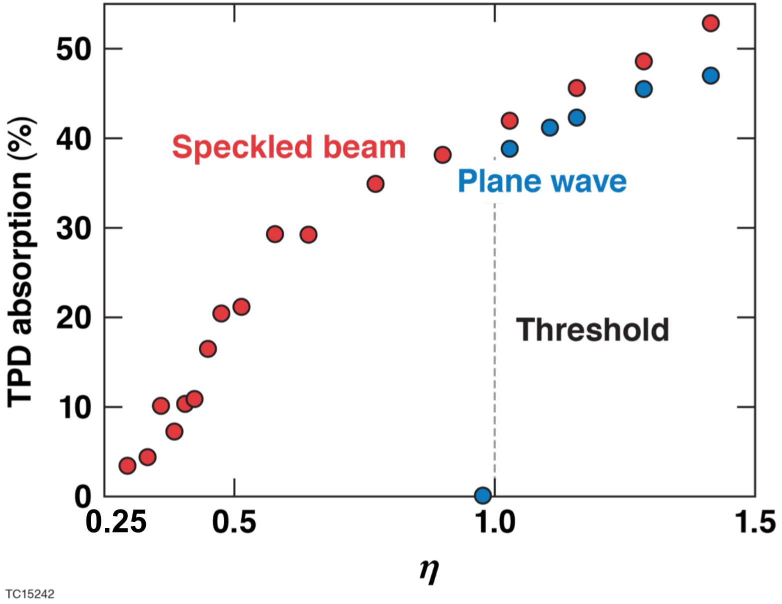
$I_0 = (1.2 - 5.5) \cdot 10^{14}\ W/cm^2$;

T_e = 2.5 keV; $L_n = 150\ \mu m$;
T_i = 1.25 keV; CH

$\eta = (0.3 - 1.42)$

in experiments
$\eta_{min} = (0.7 - 0.8)$

Due to polarization smoothing (PS)
η in experiment corresponds to a value
2 times smaller in 2D modeling without PS



In the case of two crossing beams driving the TPD instability, the wave spectra are broader, and the saturation mechanism is similar to a single beam case

2 beams - same overlapped intensity as 1 beam before:

$I_0 = 2.5 \cdot 10^{14}\ W/cm^2$ *each*;

T_e = 2.5 keV; $L_n = 150\ \mu m$;
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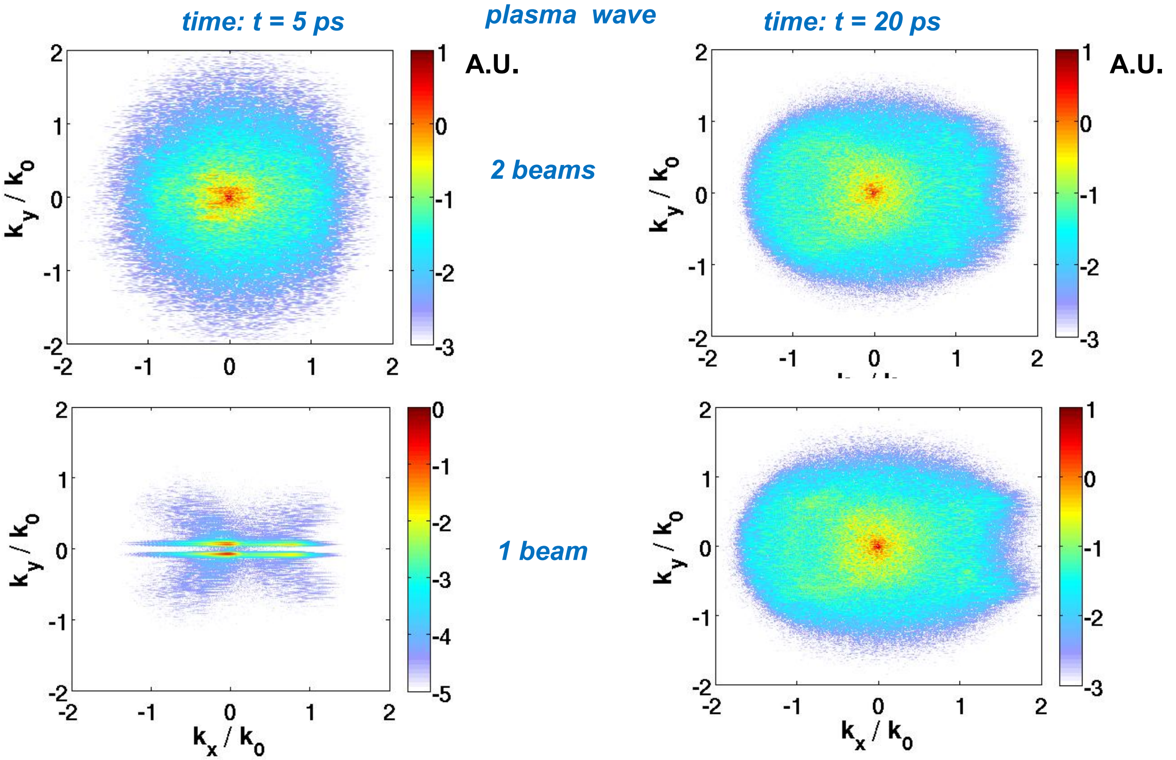
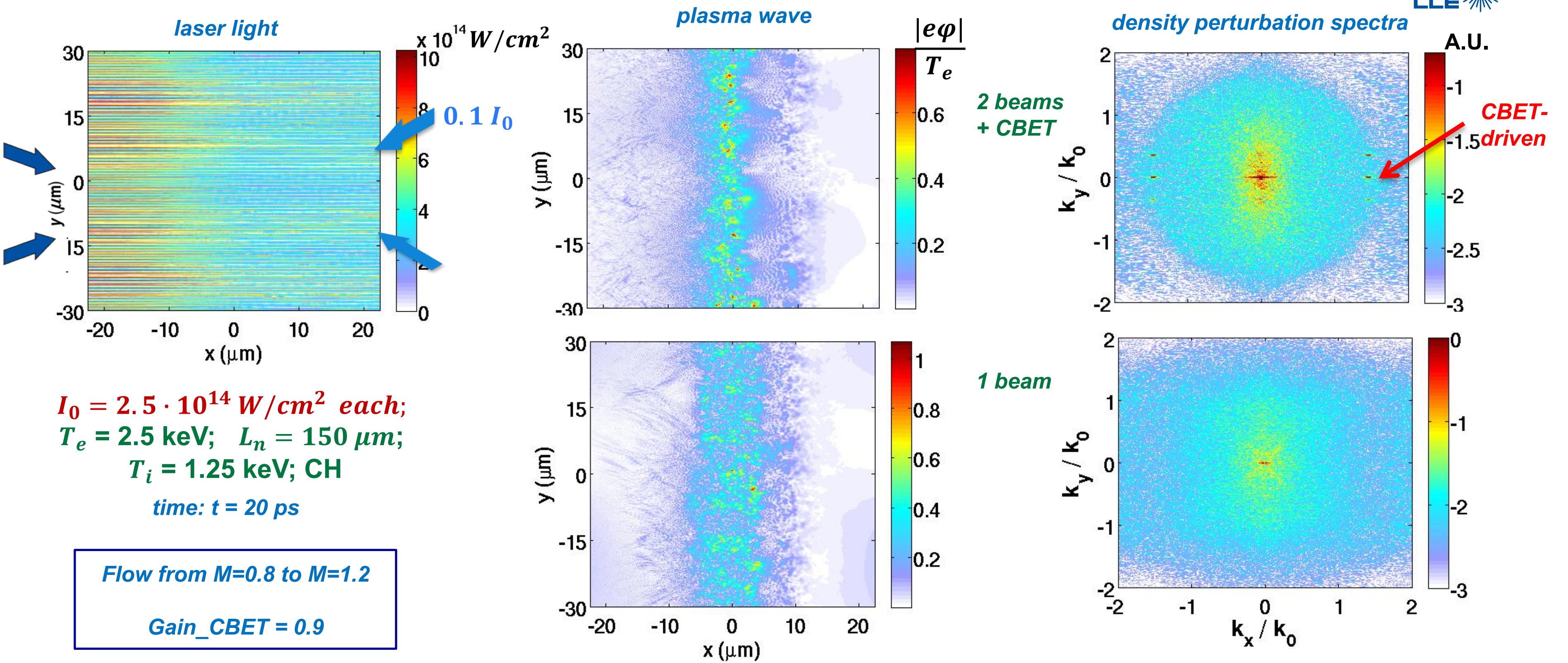


When CBET is favored by the plasma flow profile and laser seeding beams, the plasma wave intensity is lower



$I_0 = 2.5 \cdot 10^{14}\ W/cm^2\ \ each;$

T_e = 2.5 keV; $L_n = 150\ \mu m;$

T_i = 1.25 keV; CH

time: t = 20 ps

Flow from M=0.8 to M=1.2

Gain_CBET = 0.9

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T_e = 2.5 keV; $L_n = 150\ \mu m$;
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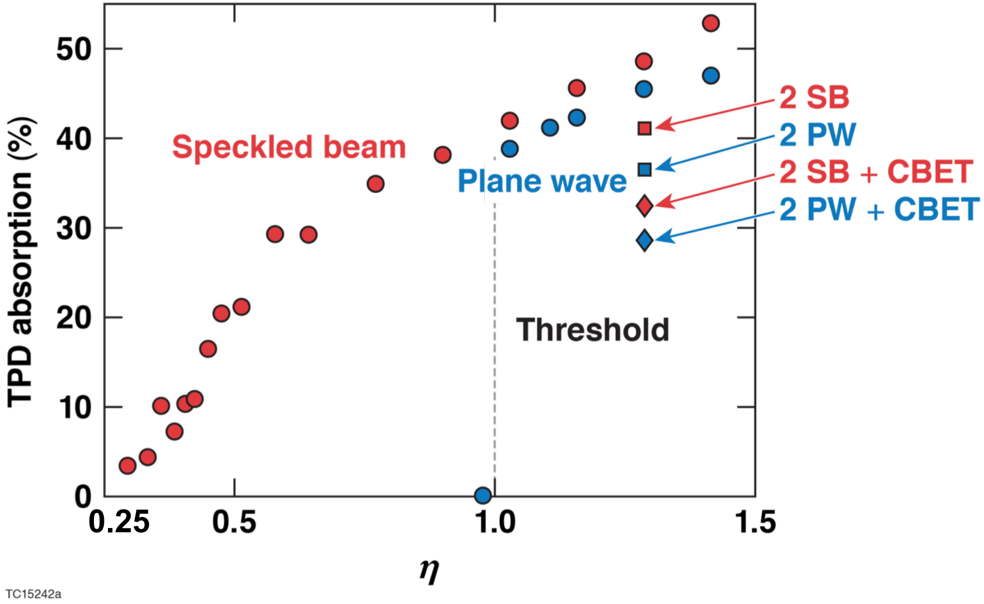
$\eta \quad = (0.3 - 1.42)$



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