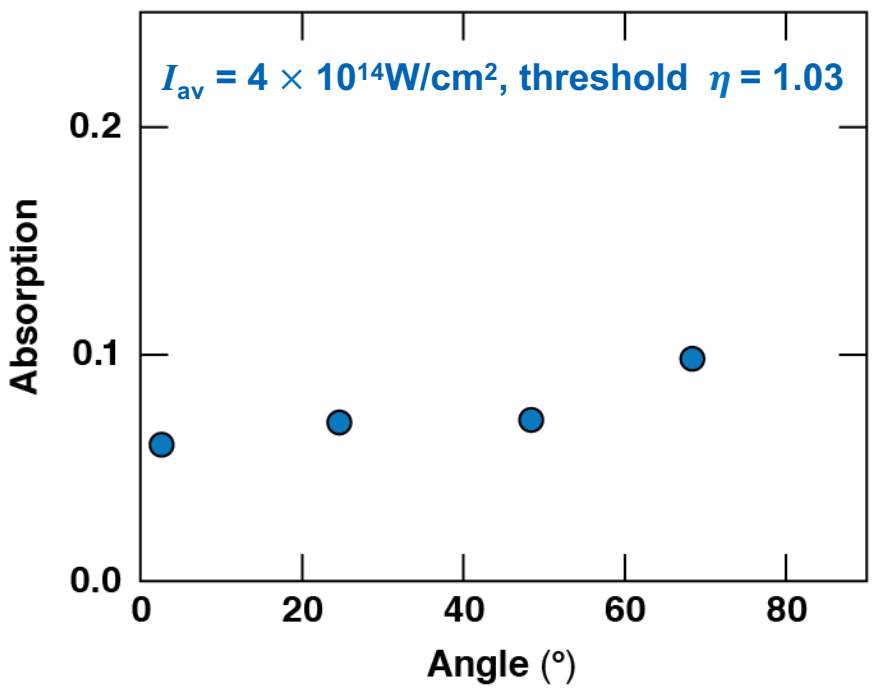
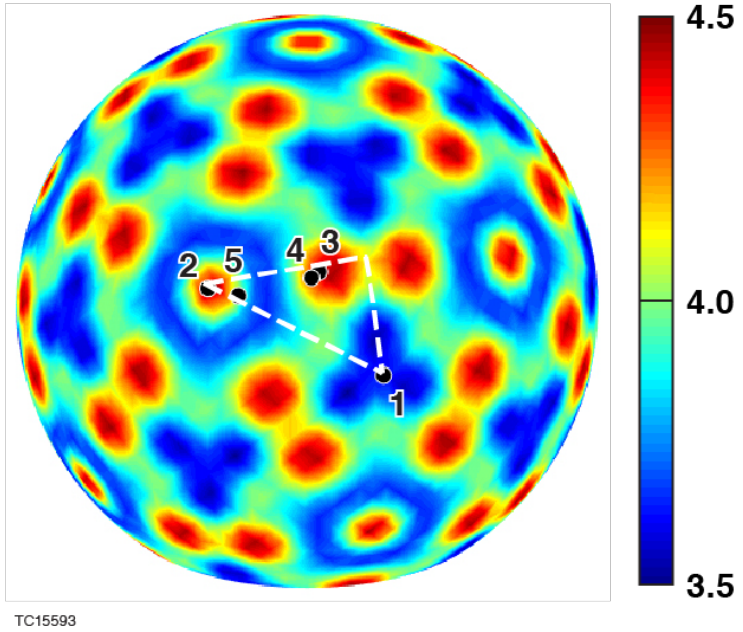
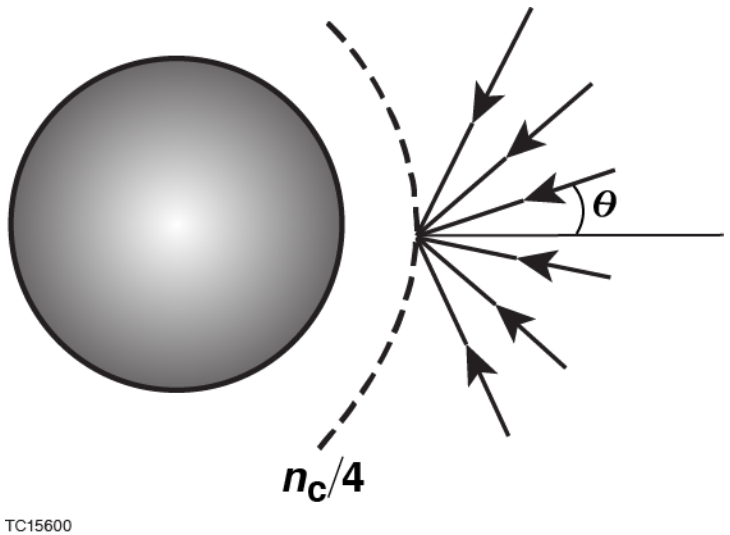
Nonlinear Absorption of Multiple Laser Beams due to the Two-Plasmon–Decay Instability







A. V. Maximov, D. Turnbull, D. H. Edgell, J. G. Shaw, R. K. Follett, H. Wen, D. H. Froula, and J. P. Palastro
University of Rochester
Laboratory for Laser Energetics

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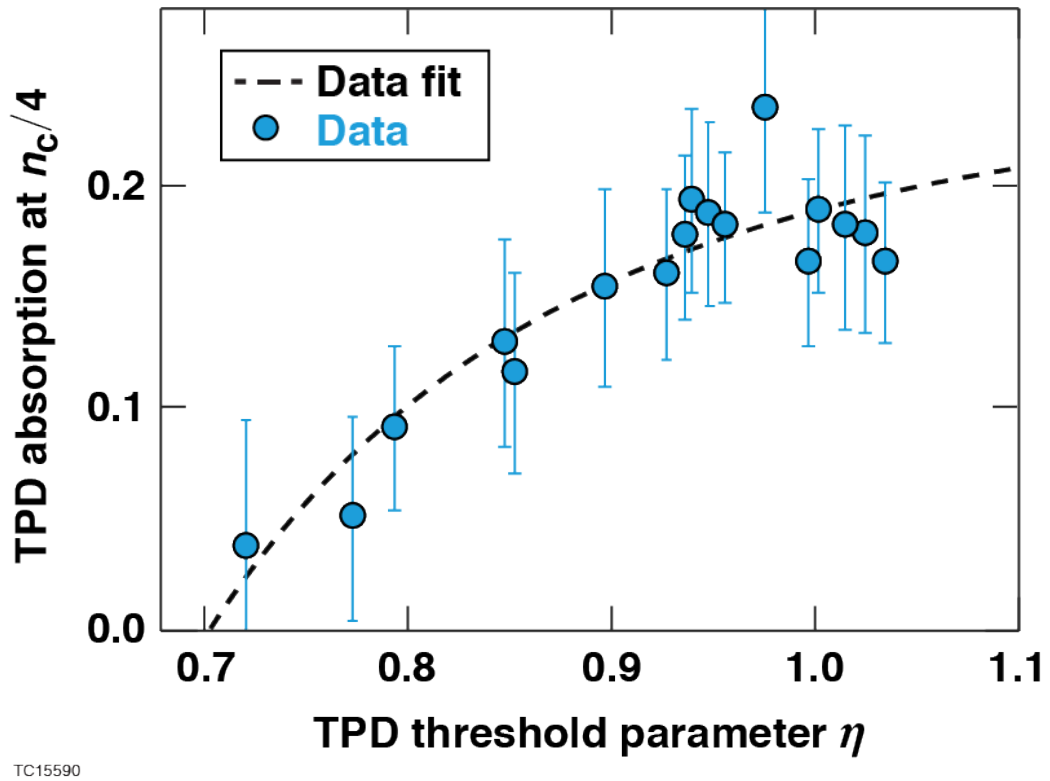
Summary

The scaling of laser absorption due to two-plasmon decay (TPD) has been obtained for direct-drive inertial confinement fusion (ICF) plasmas on the OMEGA laser

- *LPSE*[*] simulations with realistic beams (geometry, speckles, polarizations, incidence angles, and intensities) were used to determine the absorption of each laser beam in multibeam TPD
- Laser absorption due to TPD is not sensitive to the location on the target sphere
- Absorption is weakly dependent on the beam incidence angle, increasing moderately at larger angles for higher intensities

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

Recent analysis of OMEGA experimental data* demonstrated that laser absorption due to TPD scales with the threshold parameter $\eta = I_{14}L(\mu\mathrm{m})/[233\,T_e(\mathrm{keV})]$**



Absorption due to TPD can reach ~15% for OMEGA conditions

Radiation-hydrodynamics codes do not include absorption due to TPD.

* D. Turnbull *et al.*, Phys. Rev. Lett. 124, 185001 (2020).
** A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

LPSE was upgraded to model laser depletion due to TPD

- **Model solves for laser light (near frequency ω_0) and plasma-wave field (near ω_p) in terms of velocities $V_{0,p} = ieE_{0,p}/m_e\omega_0$ and for ion-acoustic perturbation δN, and includes background density profile N_0**

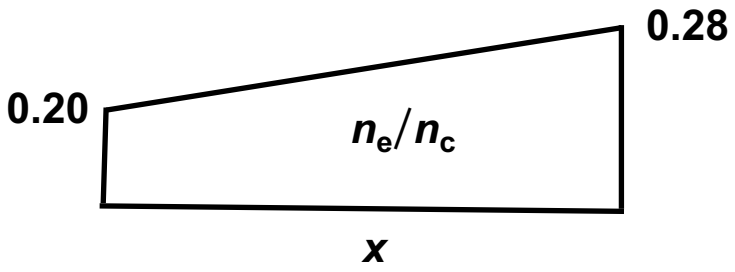
Laser light

$$i\frac{\partial V_0}{\partial t} + i\gamma_0 \circ V_0 + \frac{c^2}{2\omega_0}\nabla^2 V_0 + \frac{\omega_0^2 - \omega_p^2(1+N_0+\delta N)}{2\omega_0}V_0 = \frac{i\omega_p}{4\omega_0}\left[(\nabla\cdot V_p)V_p\right]_{\text{Transverse}}\cdot e^{-i\delta\omega t}$$

Plasma wave

$$i\frac{\partial V_p}{\partial t} + i\gamma_p \circ V_p + \frac{3V_{Te}^2}{2\omega_l}\nabla^2 V_p - \frac{\omega_p(N_0+\delta N)}{2}V_p = \frac{1}{\omega_p}\left[\nabla(V_p^*\cdot V_0) - (\nabla\cdot V_p^*)V_0\right]\cdot e^{i\delta\omega t}$$

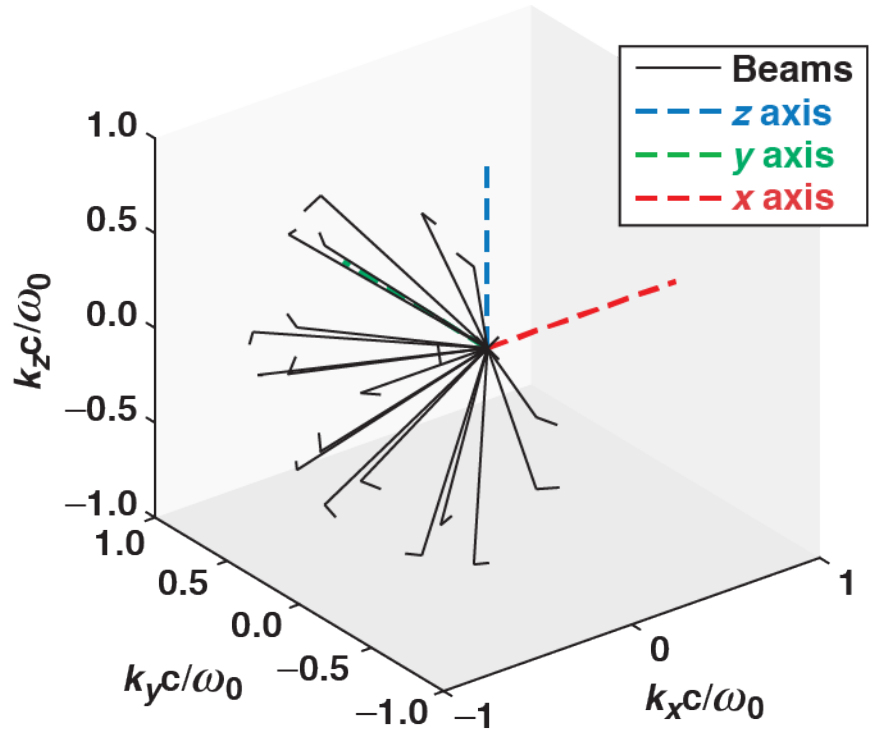
where $\delta\omega = \omega_0 - 2\omega_p$ – frequency mismatch



L_n = 150 μm; T_e = 2.5 keV; T_i = 1.25 keV; CH

LPSE simulations used realistic beams with incidence angles and intensities from a ray trace in plasma profiles extracted from the radiation-hydrodynamics code *LILAC*

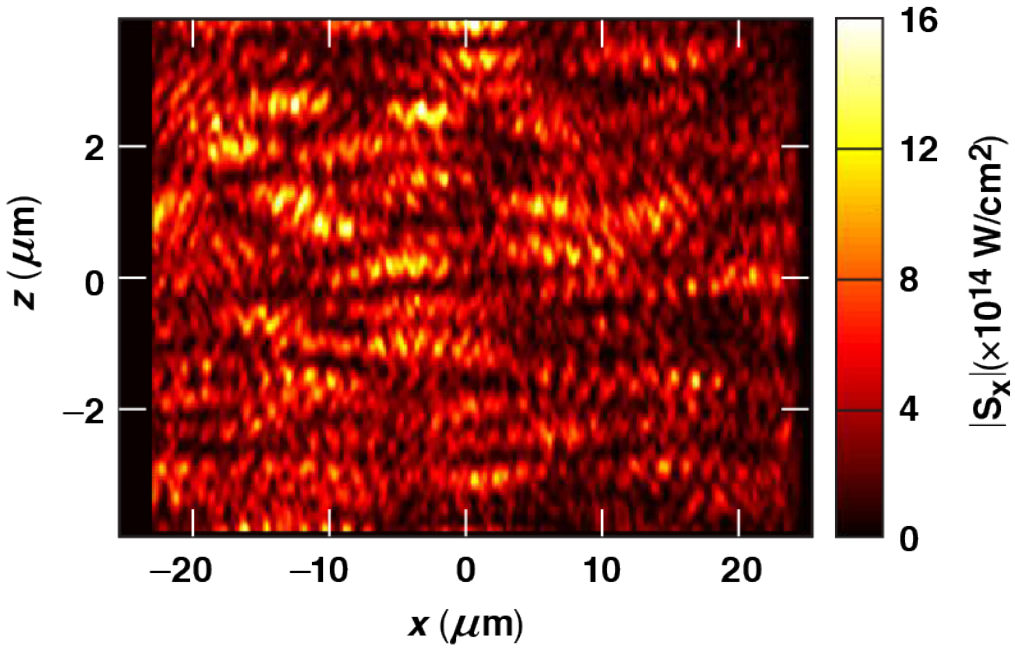
Beam wave vectors



TC15595

Far-field Poynting flux

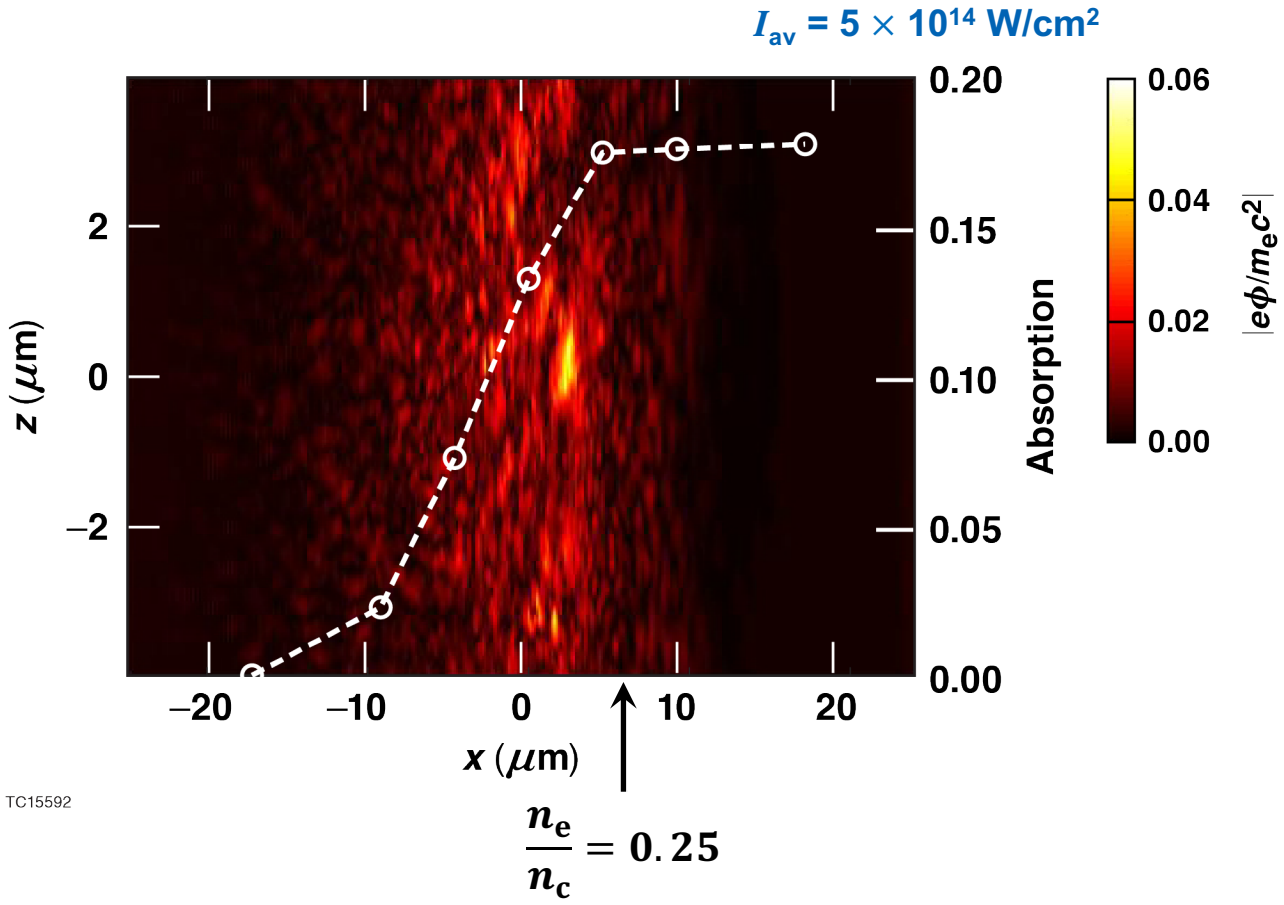
$I_{av} = 5 \times 10^{14}$ W/cm^2



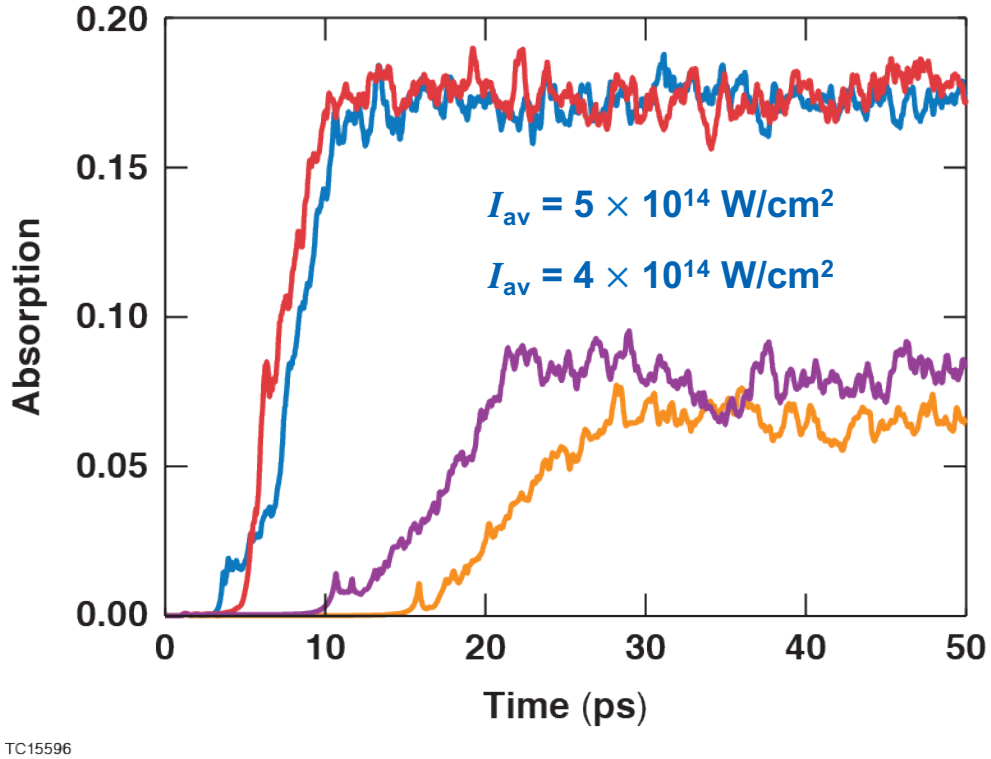
TC15591

Additional laser absorption (up to ~15%) occurs in a narrow layer near the TPD instability region and saturates on a time scale ~10 ps

Plasma-wave potential

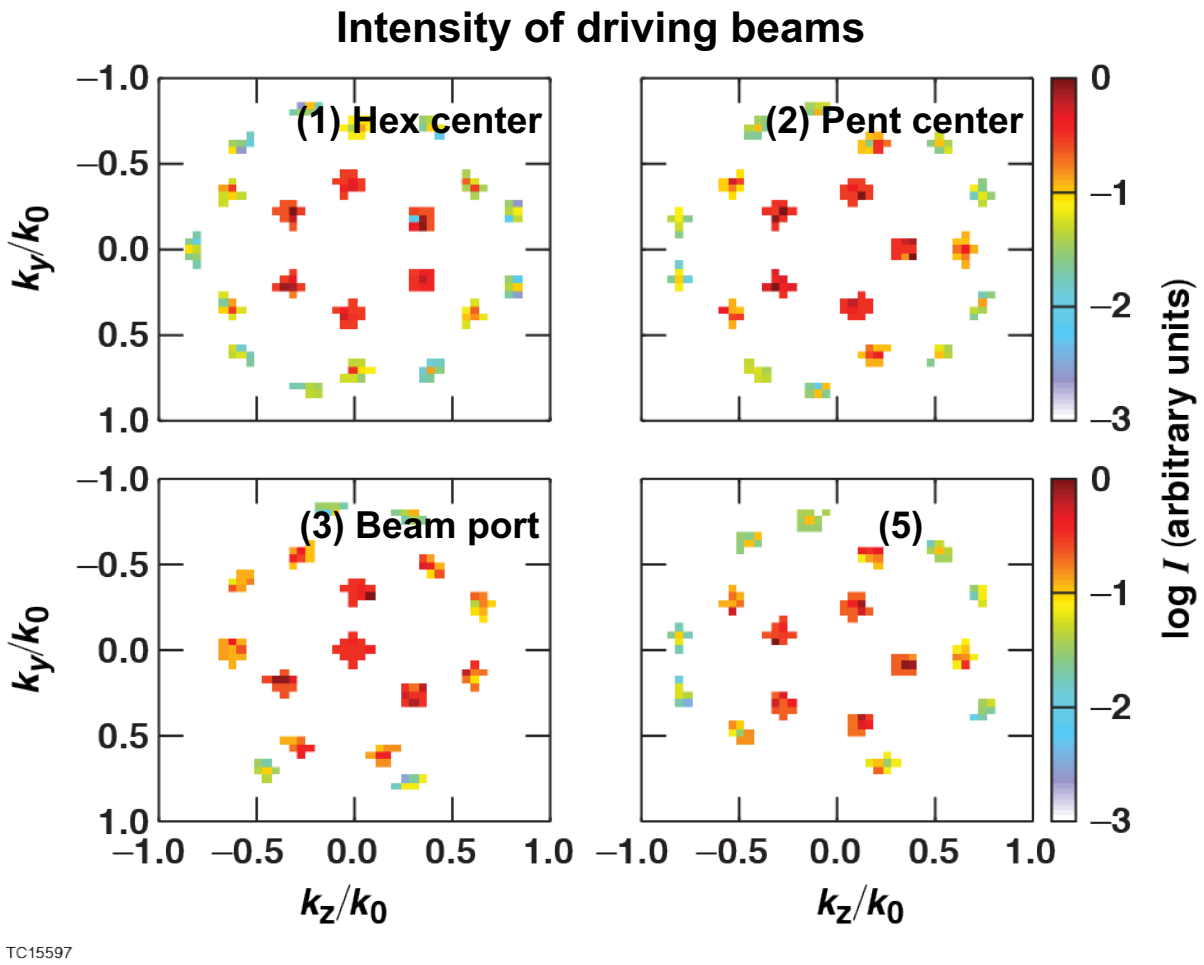


Laser absorption

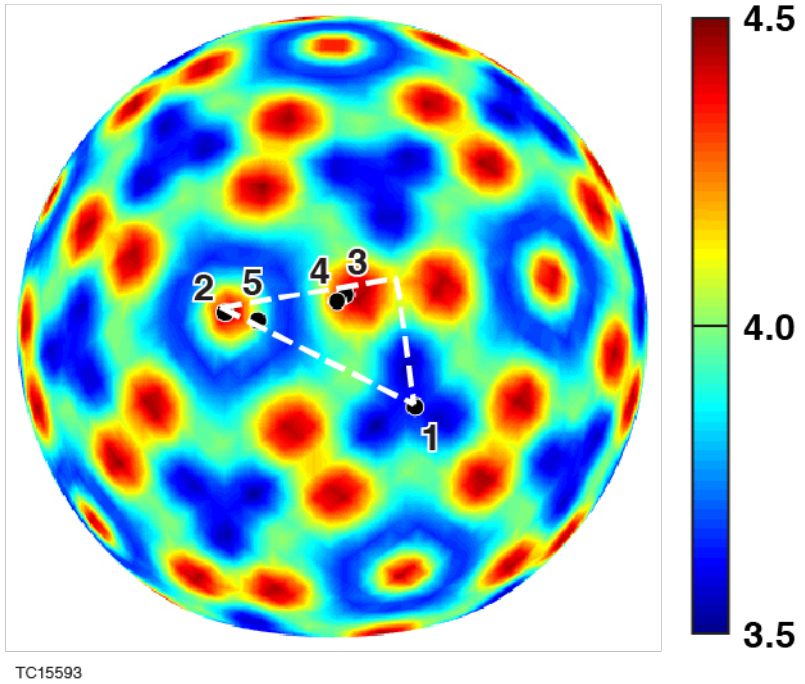


Absorption reaches nonlinear saturation, and saturated absorption is used in further analysis

Laser absorption due to TPD was modeled near the quarter-critical surface for five beam configurations corresponding to different locations on the target sphere



$I_{av} = 4 \times 10^{14}$ W/cm^2, threshold $\eta = 1.03$



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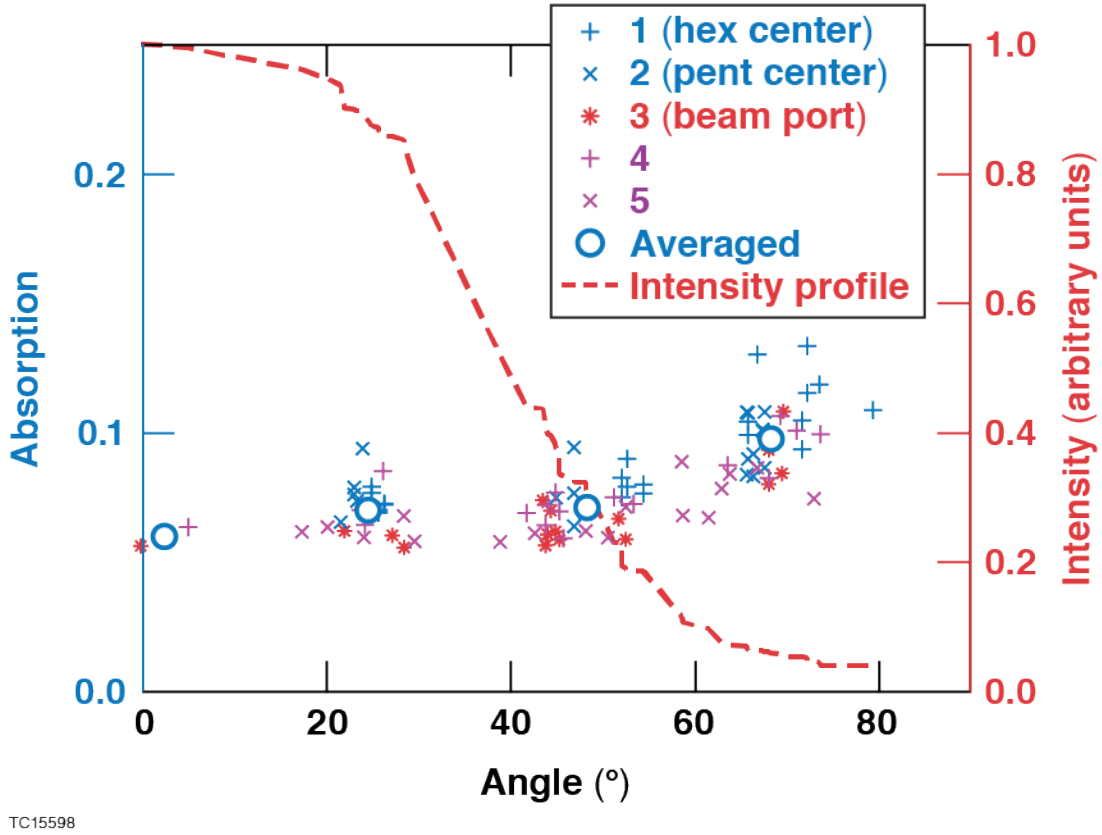

Absorption is averaged over time and two statistical realizations

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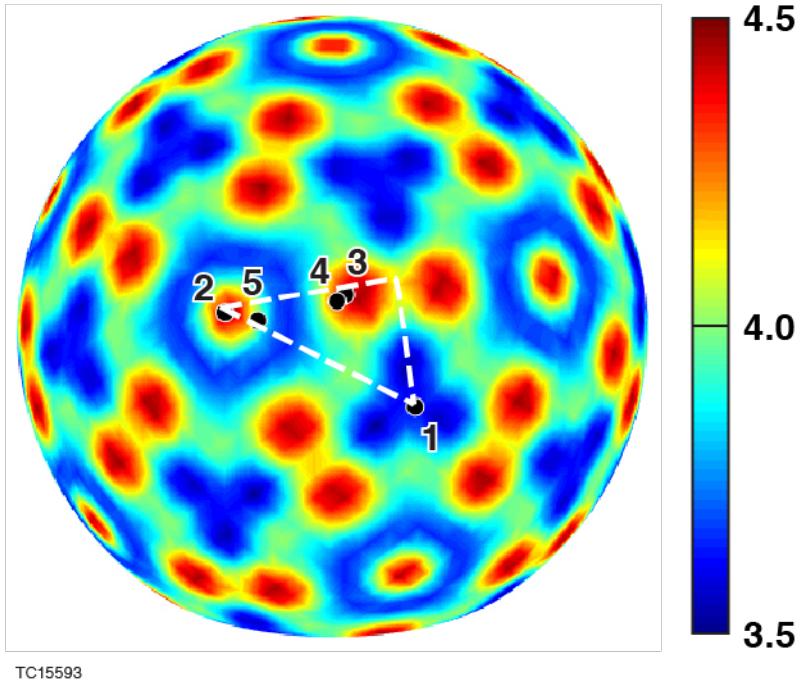
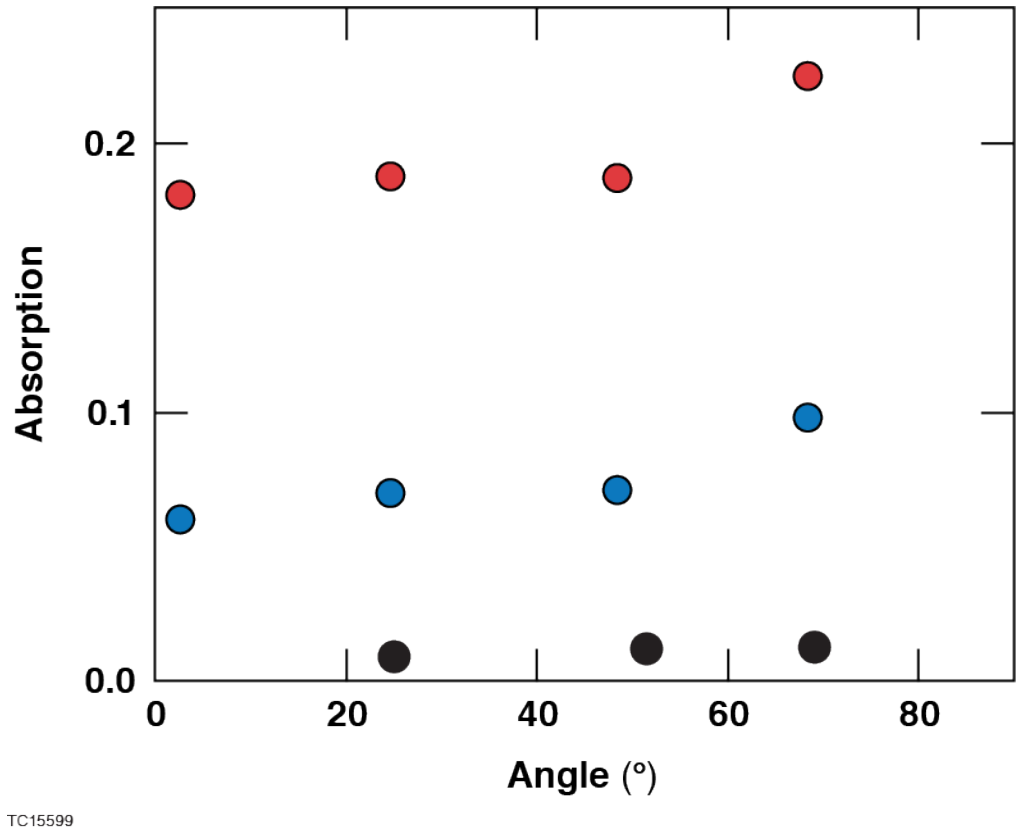


Absorption increases moderately with incidence angle but is not sensitive to location.

The scaling of absorption with beam incidence angle has been obtained for three average laser intensities



Absorption is averaged over angular range

$I_{av} = 5 \times 10^{14}\ \mathrm{W/cm^2}, \eta = 1.29, A_{av} = 18.7\ \%$

$I_{av} = 4 \times 10^{14}\ \mathrm{W/cm^2}, \eta = 1.03, A_{av} = 7.1\ \%$

$I_{av} = 3.6 \times 10^{14}\ \mathrm{W/cm^2}, \eta = 0.93, A_{av} = 1.2\ \%$

Absorption increases moderately with incidence angle for larger intensities.

Summary/Conclusions

The scaling of laser absorption due to two-plasmon decay (TPD) has been obtained for direct-drive inertial confinement fusion (ICF) plasmas on the OMEGA laser

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- LPSE* simulations with realistic beams (geometry, speckles, polarizations, incidence angles and intensities) were used to determine the absorption of each laser beam in multi-beam TPD
- Laser absorption due to TPD is not sensitive to the location on the target sphere
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The absorption scaling can be readily included in stand-alone ray-trace or radiation hydrodynamics codes.

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