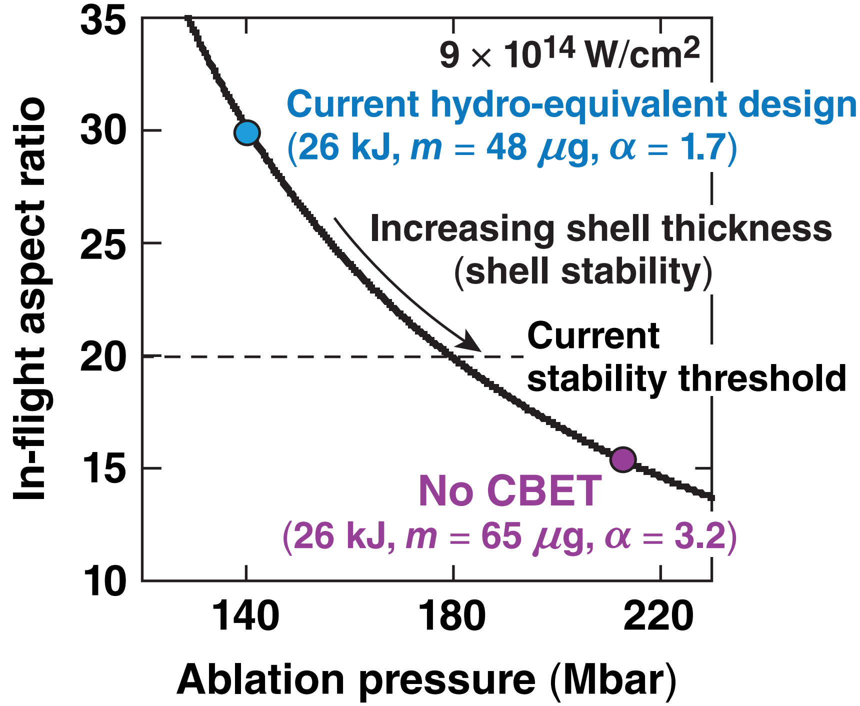
Mitigation of Cross-Beam Energy Transfer in Direct-Drive–Implosions on OMEGA

OMEGA constant hot-spot pressure (180 Gbar 1-D), areal density (ρR = 300 mg/cm^2) implosion velocity, V_{imp} = 3.7 × 10^7 cm/s)



D. H. Froula
University of Rochester
Laboratory for Laser Energetics

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Summary

Hydrodynamic equivalence on OMEGA will require reducing cross-beam energy transfer (CBET) and/or improving the stability threshold

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- **CBET reduces the ablation pressure by over 50% in hydro-equivalent designs**
- **Experiments have demonstrated increased hydroefficiency with reduced focal-spot size**
- **Calculations suggest that zooming can recover all of the ablation pressure lost to CBET without negatively impacting the hydro stability**
- **A full-aperture zooming scheme is being developed that uses bandwidth to control the focal-spot size and could provide more on-target energy with full laser-beam smoothing**

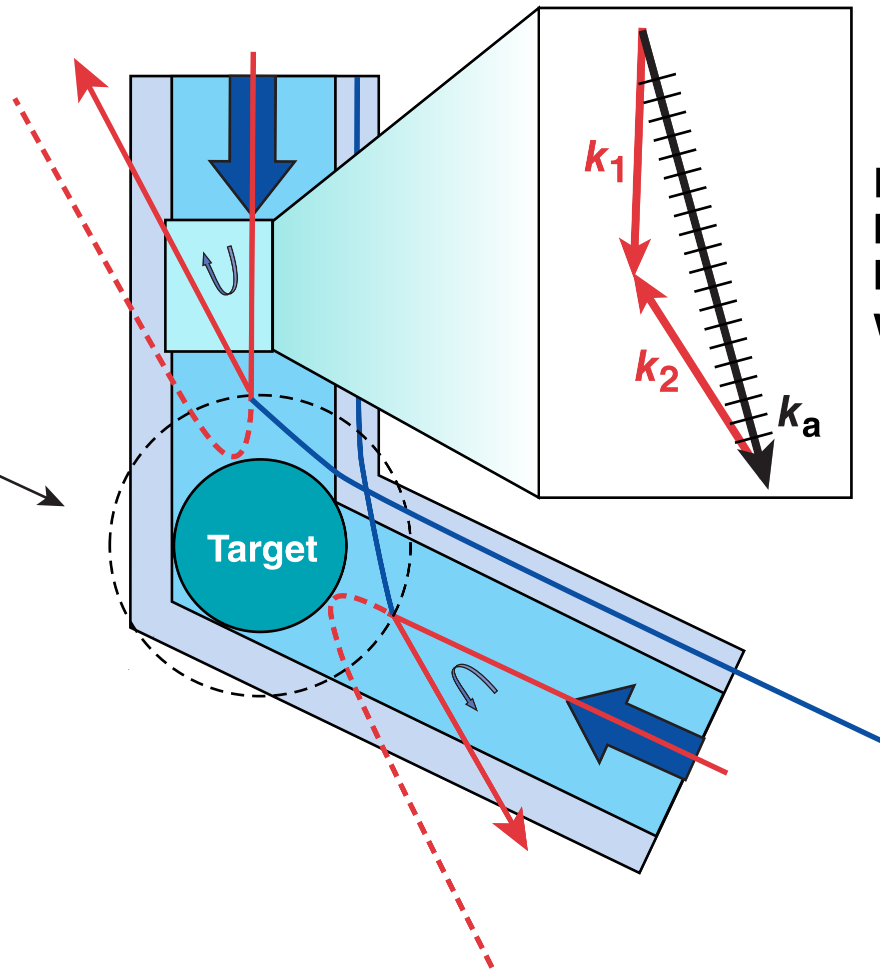
Collaborators

T. J. Kessler, A. K. Davis, G. Fiksel, R. K. Follette, D. H. Edgell, I. V. Igumenshchev, V. N. Goncharov, R. J. Henchen, H. Huang, S. X. Hu, J. H. Kelly, D. T. Michel, T. C. Sangster, A. Shvydky, W. Seka, C. Stoeckl, and B. Yaakobi

University of Rochester
Laboratory for Laser Energetics

CBET reduces the energy coupled to the fusion capsule

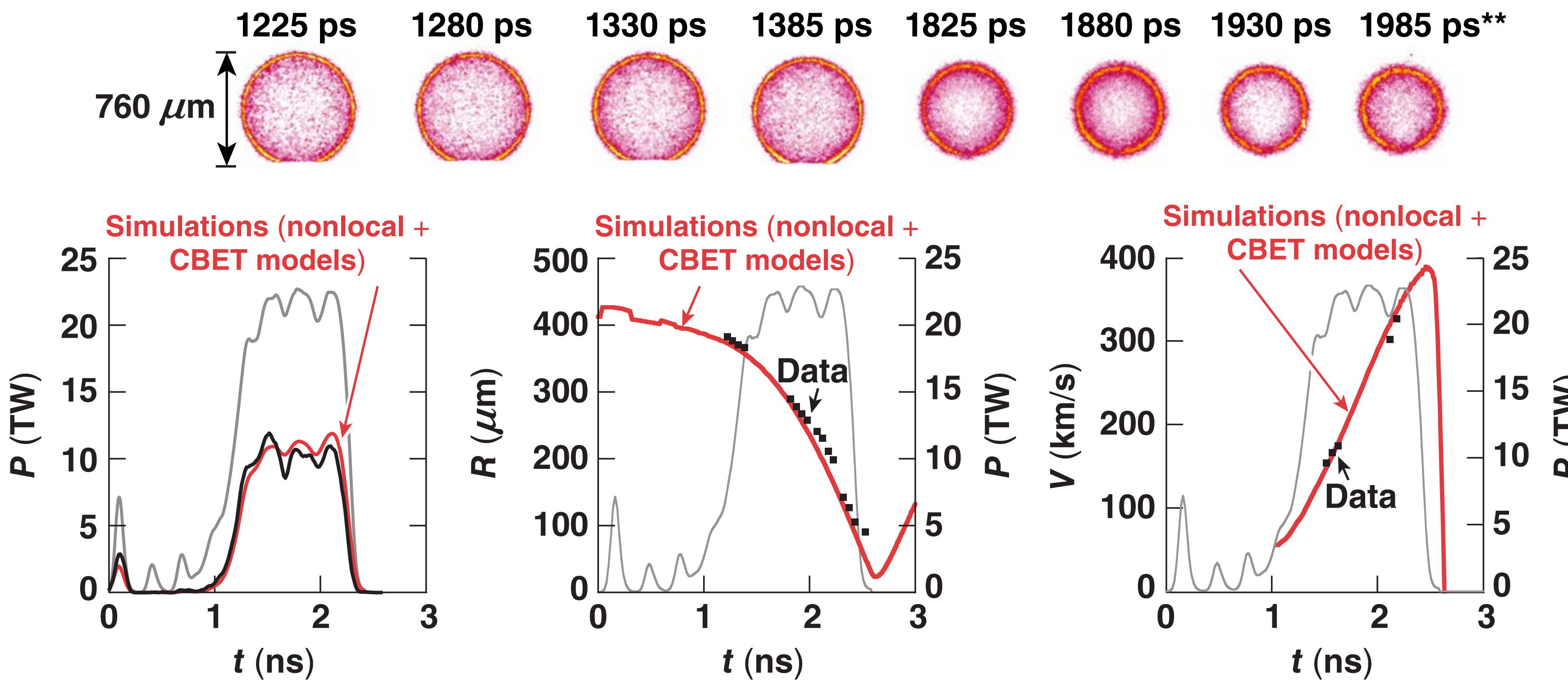
CBET is spatially limited near $M \sim 1$



Energy is transferred between beams by ion-acoustic waves

CBET reduces the most hydrodynamically efficient portion of the incident laser beams.

CBET modeling is required to match the experimental observables (scattered light, implosion velocity, and bang time)*



CBET reduces the ablation pressure by ~45%.

*I. V. Igumenshchev *et al*., Phys. Plasmas 19, 056314 (2012).
**D. T. Michel *et al*., Rev. Sci. Instrum. 83, 10E530 (2012).

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CBET reduces the ablation pressure by over 50% in hydro-equivalent OMEGA designs

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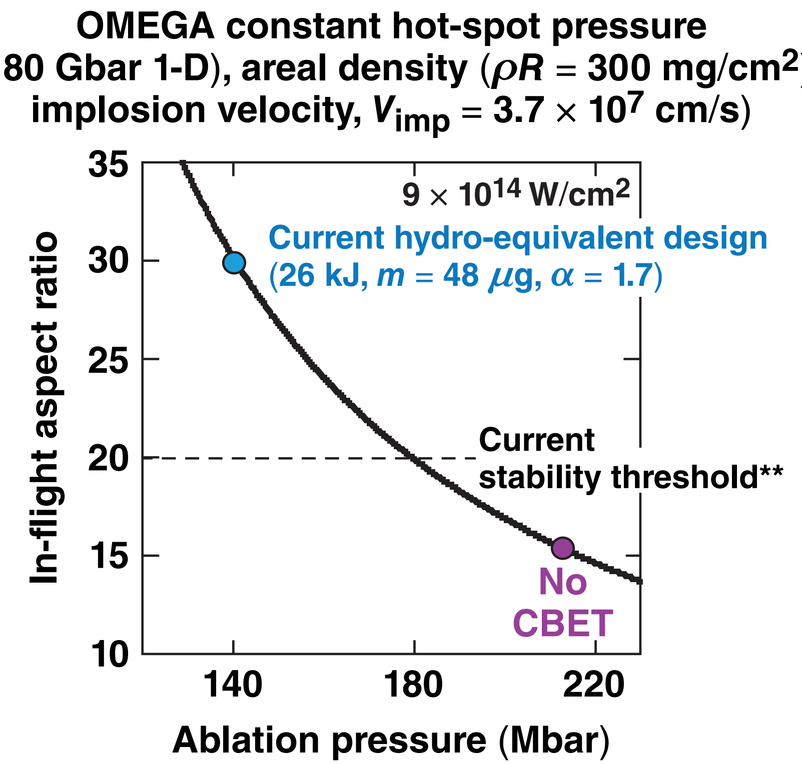

*Goncharov PoP (2014).
**Sangster PoP (2013).

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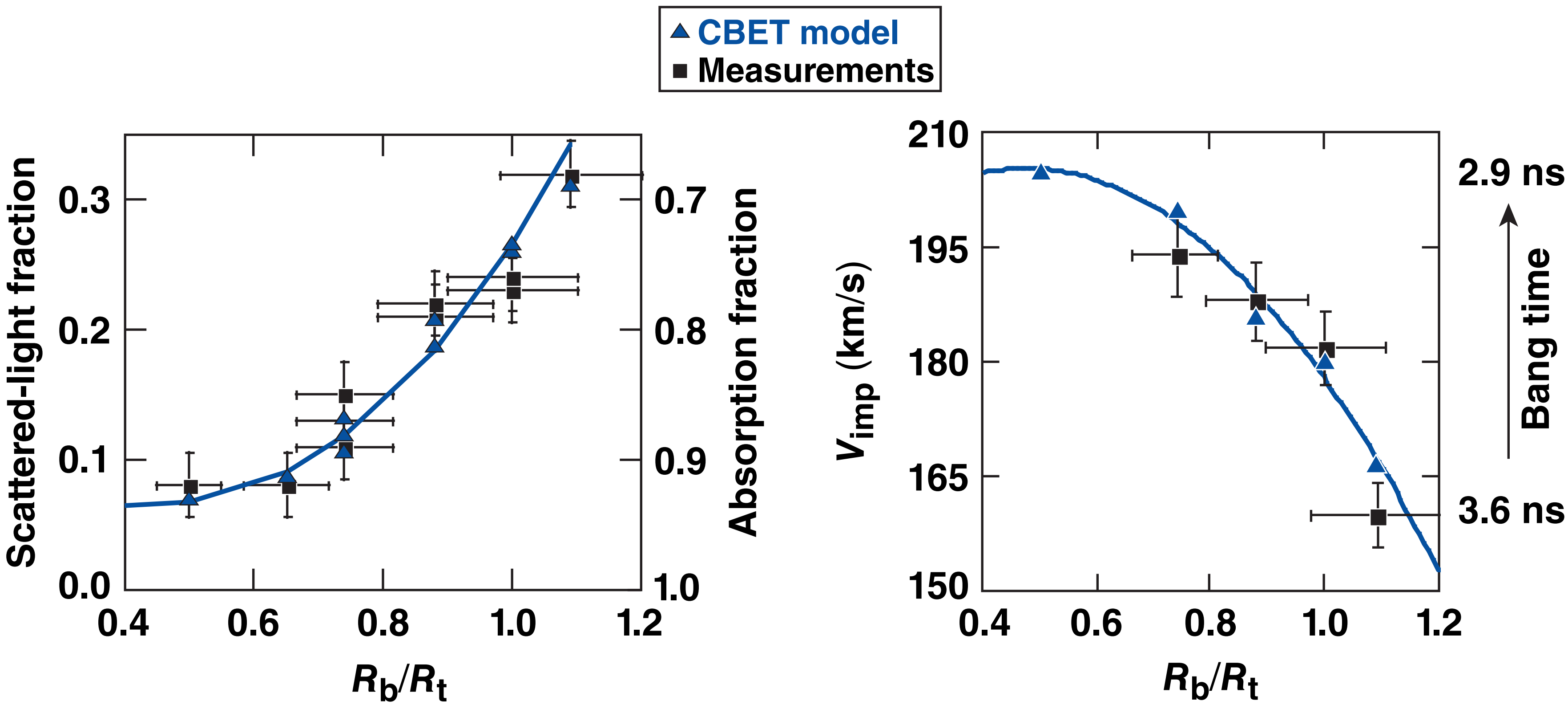
Experiments have demonstrated that CBET can be mitigated by reducing the energy that propagates past the target



D. H. Froula *et al*., Phys. Rev. Lett. 108, 125003 (2012);
D. T. Michel *et.al*., Rev. Sci. Instrum. 83, 10E530 (2012).

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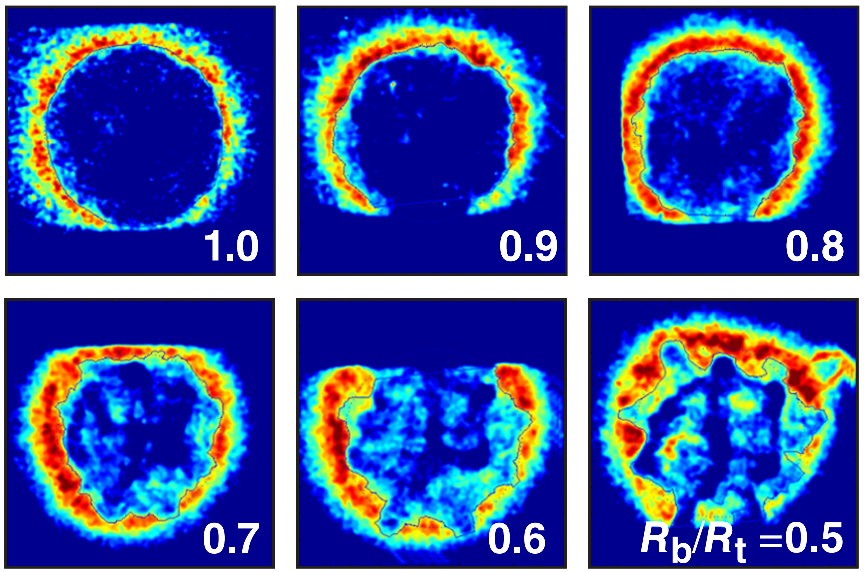
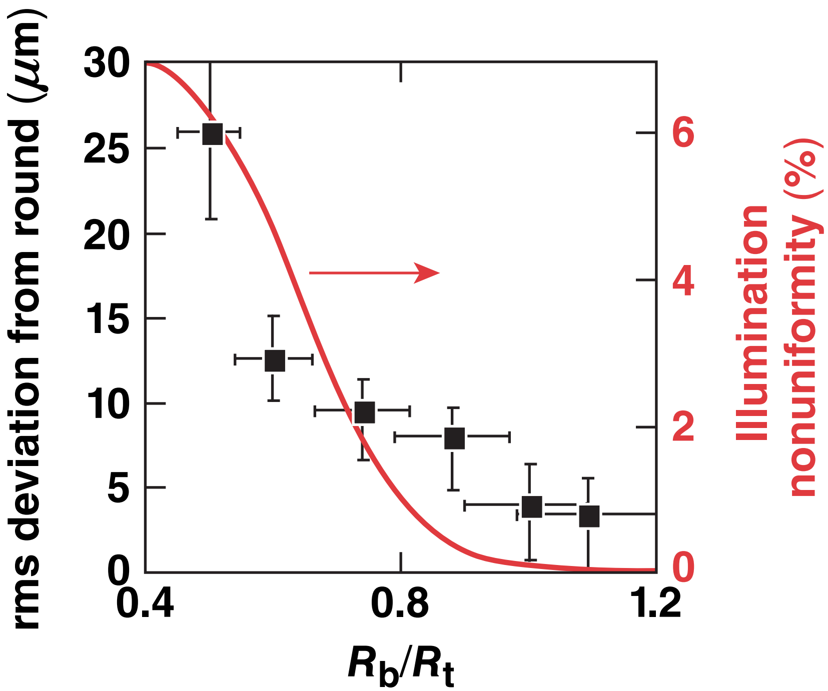
The reduced-beam overlap results in nonuniformities on the imploding shell



Convergence ratio = 2.5



Reducing the beam diameters is a trade-off between improved coupling (thicker shells) and increased low-mode nonuniformity.

U1265g

D. T. Michel *et al.*, Rev. Sci. Instrum. 83, 10E530 (2012).

Simulations suggest that reducing the beam diameters by 20% ($R_b/R_t = 0.8$) will have minimal impact on the hot-spot symmetry

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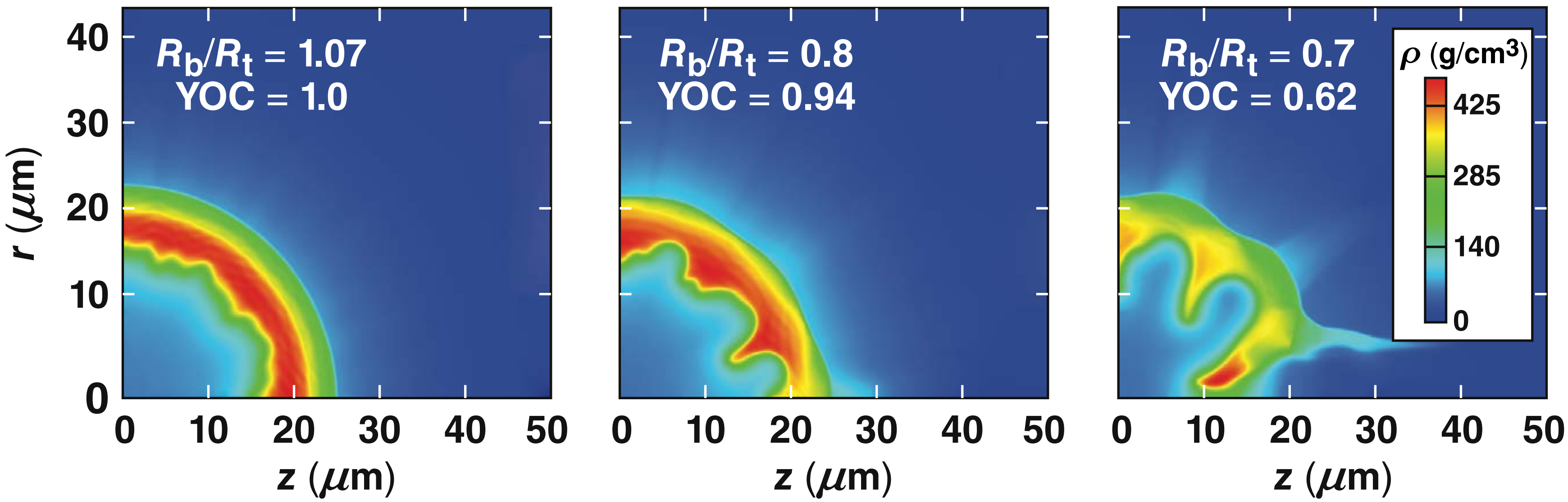
2-D *DRACO* simulations
(low-order nonuniformities only)



Reducing the beam diameters by more than 20% significantly degrades the target performance.

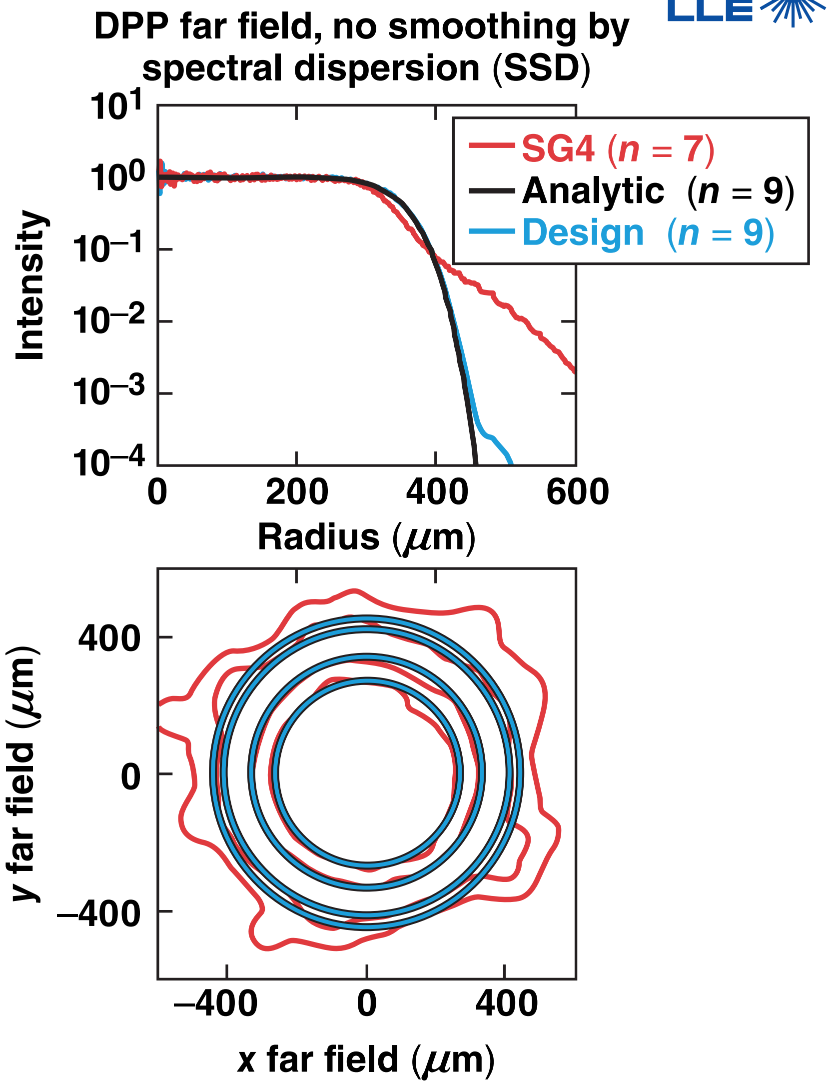
TC9894a

I. V. Igumenshchev *et al.*, Phys. Plasmas 19, 056314 (2012).

New phase plates are currently being fabricated for OMEGA that will provide the flexibility to vary the target diameter while maintaining relevant intensities

- The new distributed phase plates (DPP's) (R_{95} = 400 μm, n^{SSD} = 5) will have improved azimuthal symmetry and reduced tails
- Experiments will scale the target radius to test a range of CBET reduction options

Experiments with R_t = 480 μm (R_b/R_t = 0.8) will recover half of the ablation pressure lost to CBET.



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To reduce the laser spot without introducing nonuniformities, the diameter of the laser beams must be reduced after a sufficient conduction zone has been developed

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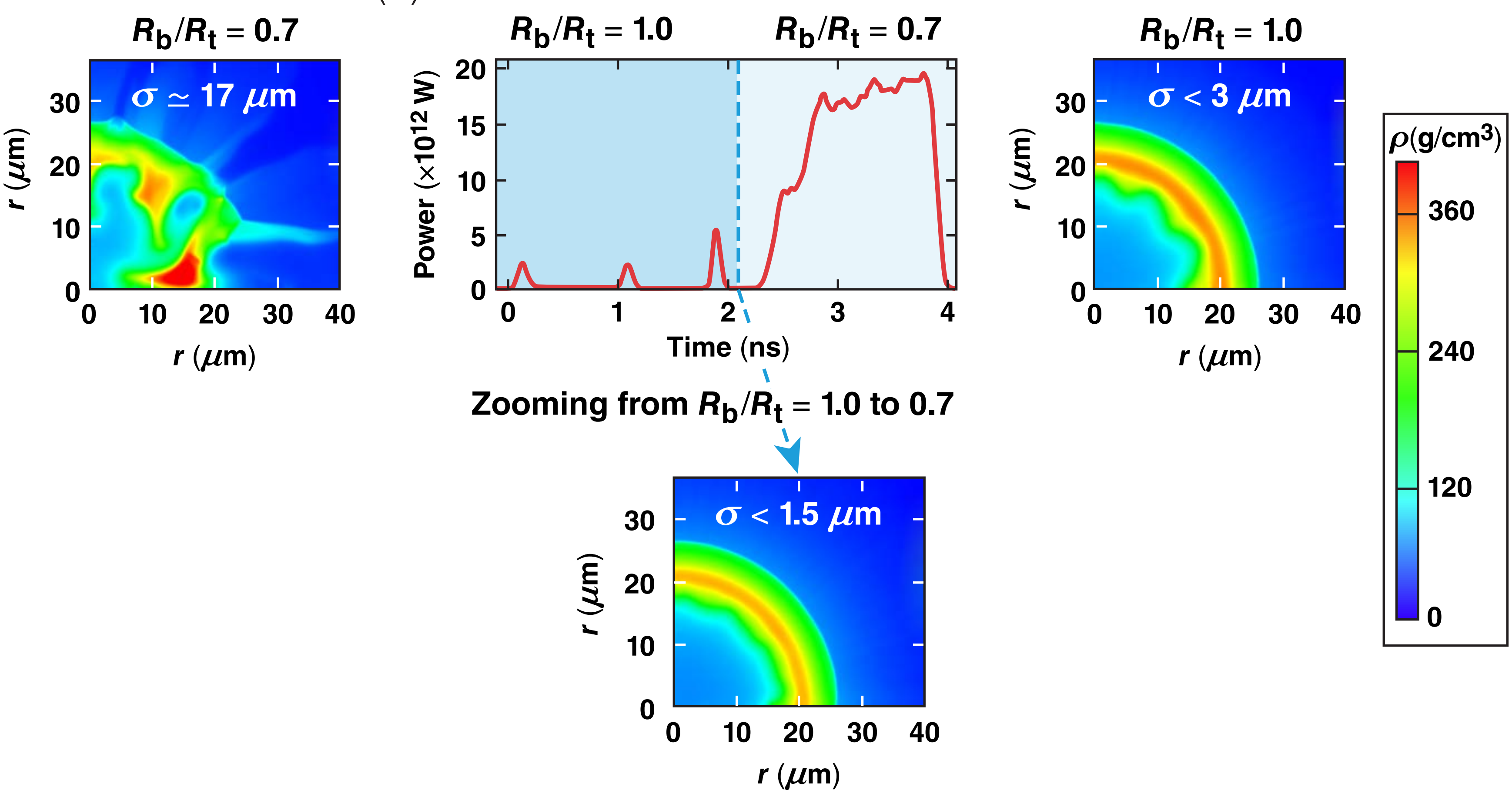
rms deviation from round (σ)



Zooming after the third picket is predicted to maintain good low-mode uniformity.

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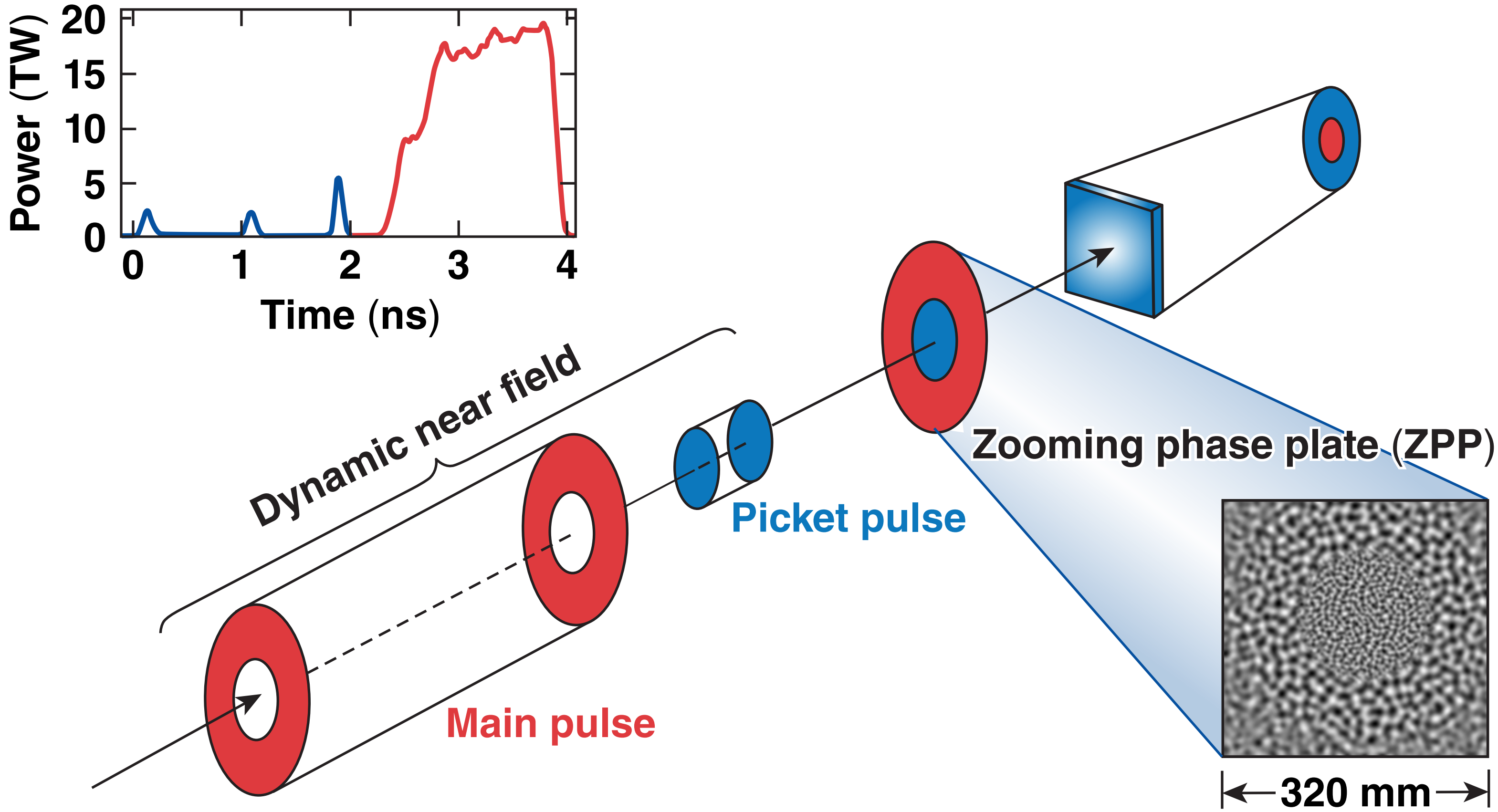
I. V. Igumenshchev *et al*. Phys. Rev. Lett. 110, 145001 (2013).

Zooming could be implemented on OMEGA using a radially varying phase plate and a dynamic near field*



A ZPP design has a region of high-spatial-frequency phase to produce a large spot and a region of low-frequency phase to produce a small spot.

*D. H. Froula *et al*., Phys. Plasmas 20, 082704 (2013).

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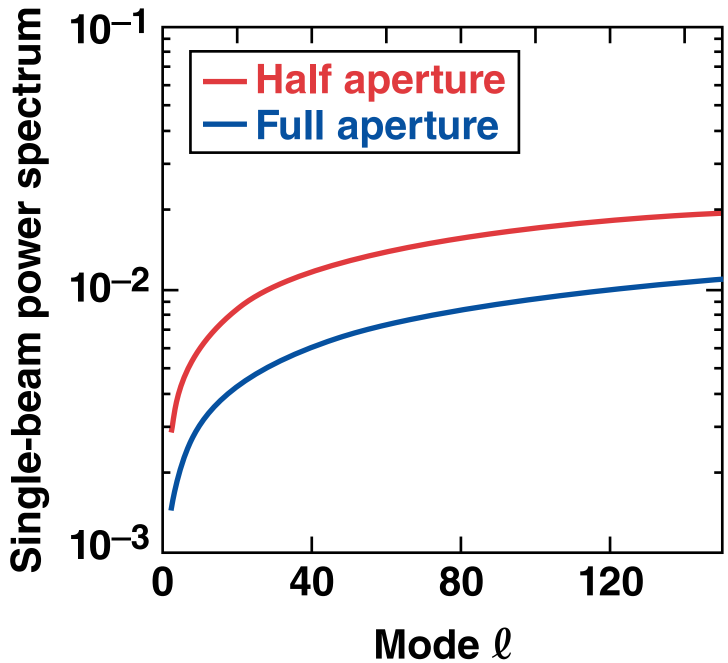
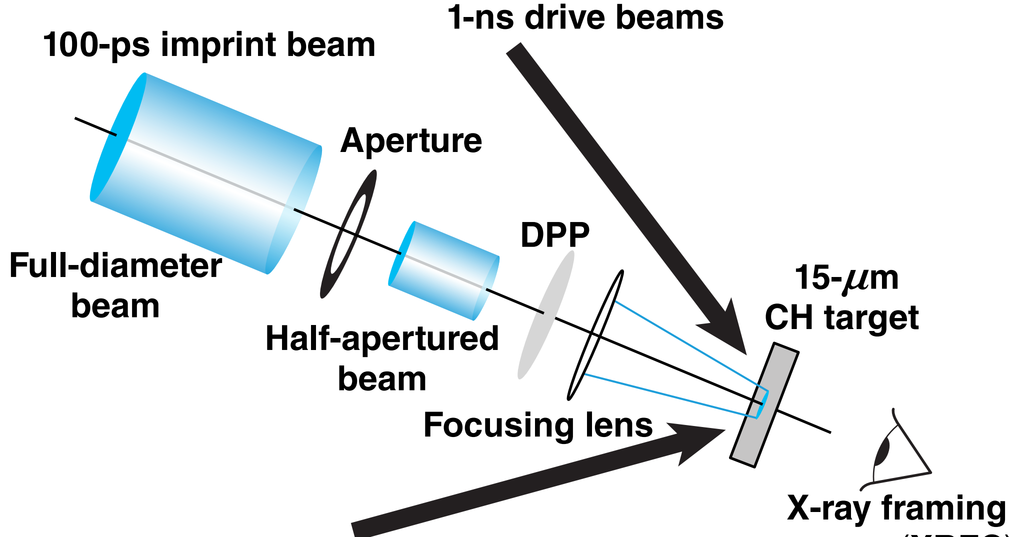
The smaller-diameter laser beams used during the pickets increase the power spectrum over the modes with the highest Rayleigh–Taylor growth rates

Analytic calculations*



Sub-aperture imprint experimental setup



The effect of increased power spectrum resulting from the reduced beam diameters was tested in planar experiments.

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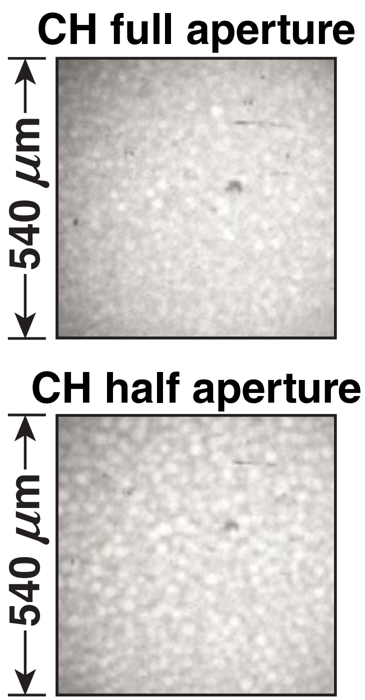
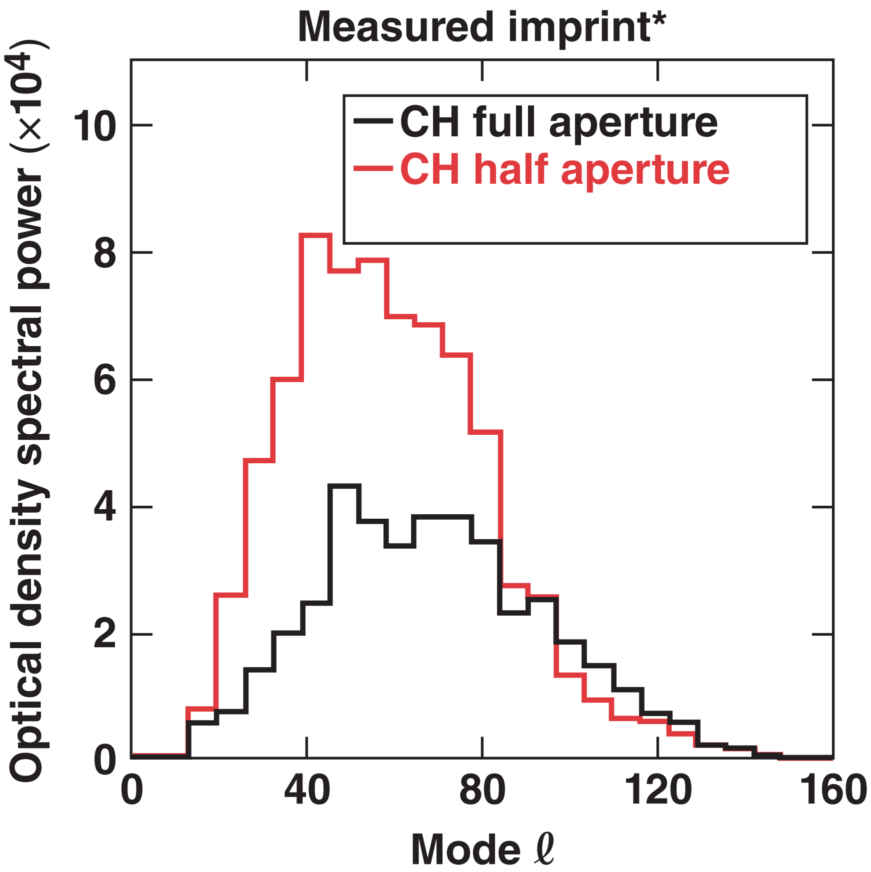
*R. Epstein, J. Appl. Phys. 82, 2123 (1997).

The increased power spectrum was measured to produce increased imprint levels over the mid-frequency modes





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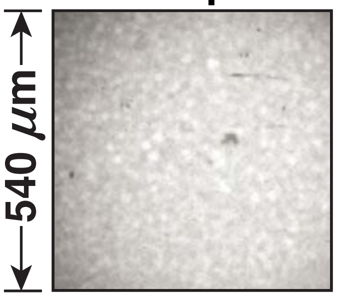
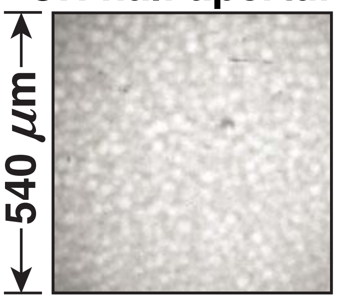
*Experiments by G. Fiksel.

X rays from a thin, high-Z layer (600-Å Pd) were used to reduce the imprint*

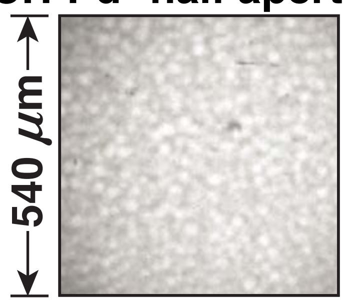
CH full aperture



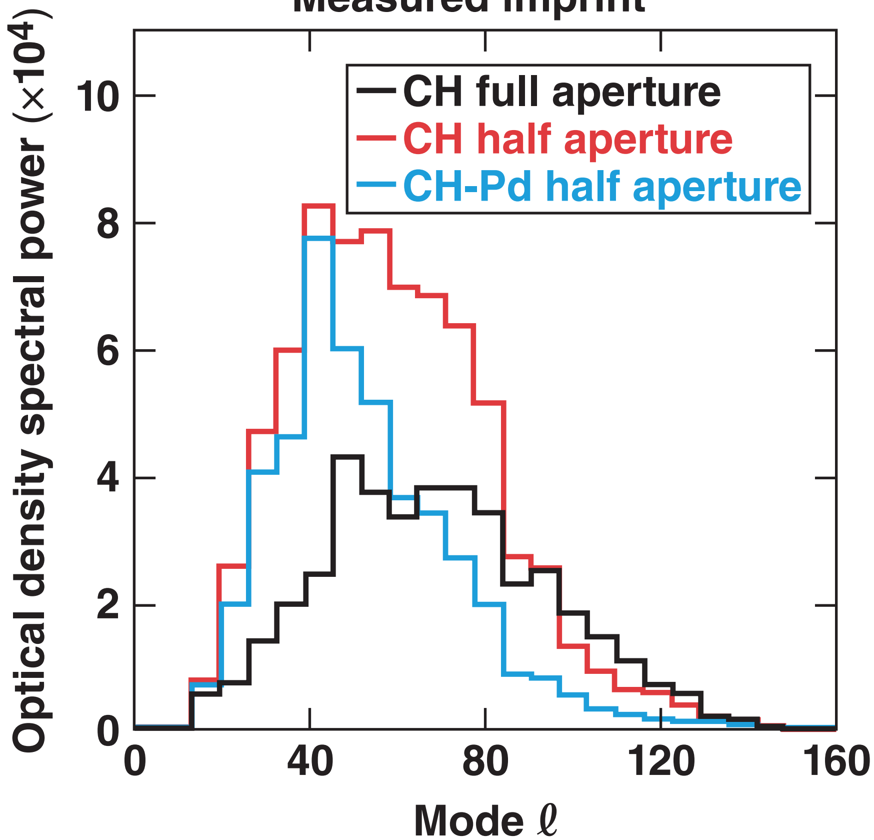
CH half aperture



CH-Pd* half aperture



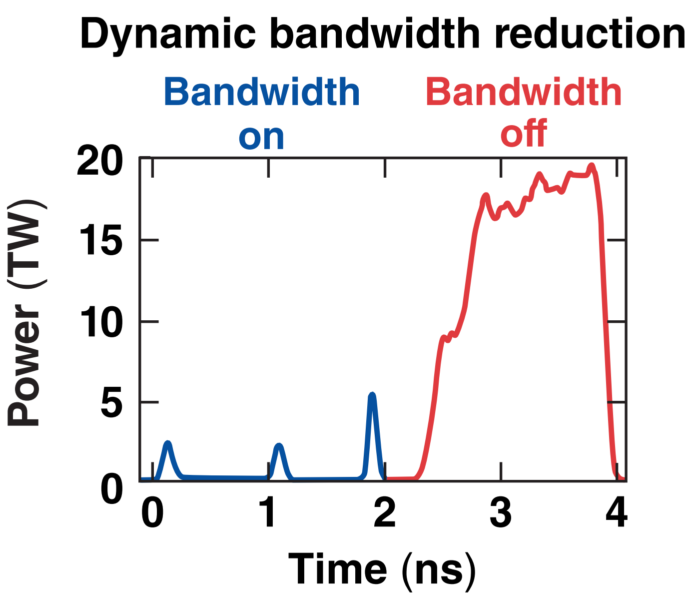
Measured imprint**

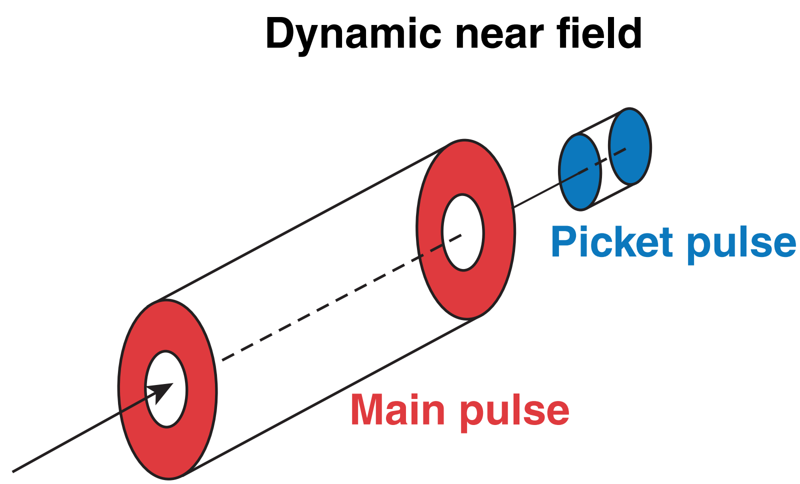


Pd mitigates the high frequency growth (>80) but the increased mode ~30 perturbation is still a concern.

* M. Karasik *et al*., Bull. Am. Phys. Soc. 58, 370 (2013).
** Experiments by G. Fiksel.

A multipulse driver line is currently being implemented on OMEGA to support CBET mitigation projects



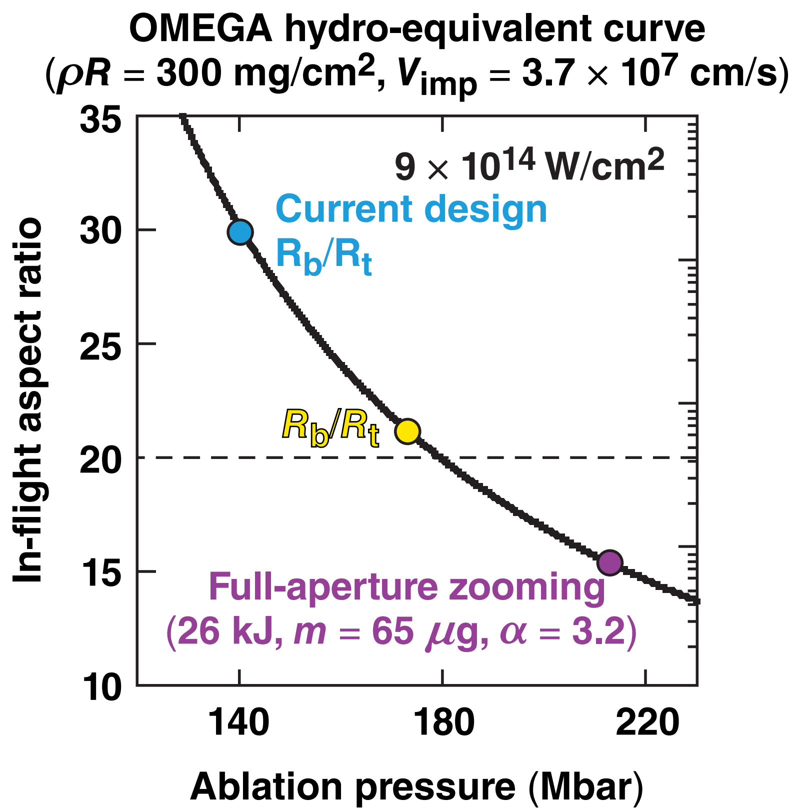


- The reduced bandwidth during the main drive leads to ~10% higher frequency conversion (~28-kJ total energy)
- The near-field laser profiles will be independent, allowing spherical experiments to test imprint mitigation schemes

Mitigation of imprint from sub-aperture beams could lead to coaxial zooming in FY16.

A full-aperture zooming scheme is being developed that uses bandwidth to control the focal-spot size and could provide more on-target energy (28 kJ) with full laser-beam smoothing

- Full-aperture zooming will provide the flexibility to increase target diameter
  - larger hot spot for improved stability threshold
  - reduced hot-electron fraction
- A new optic is under development that uses dynamic bandwidth reduction to control the spot size of the laser
- A model of the new zooming/smoothing scheme will be
  - integrated into our hydrocodes to assess their performance
  - used to optimize the design of the new optics



Full-aperture zooming provides a viable path to hydro-equivalence but will likely require multilayer targets to mitigate TPD.

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Summary/Conclusions

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