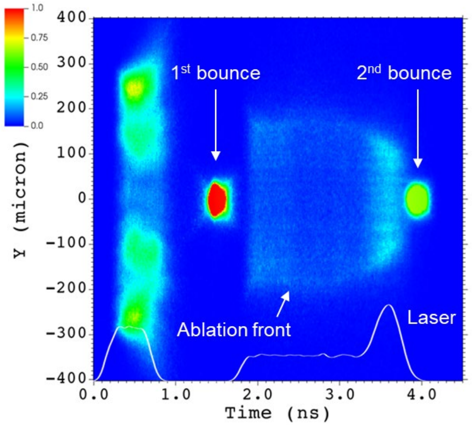
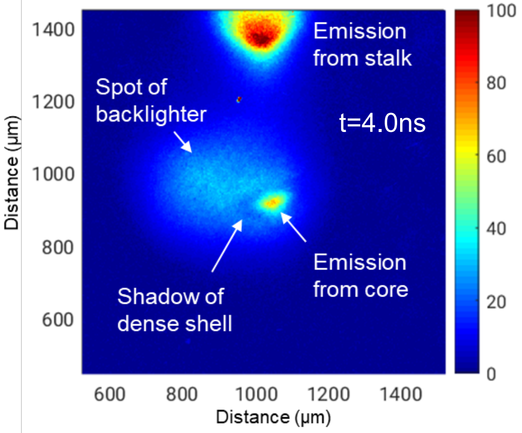
Proof-of-Principle Experiment on the Dynamic Shell Formation Concept on the OMEGA Laser

Three x-ray diagnostics evidence the formation of dynamic shells from foam-sphere targets

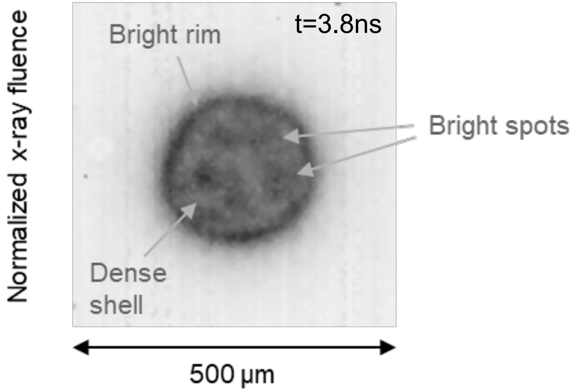
Streaked self-emission radiography



Backlighting radiography



Self-emission shadowgraphy



Igor V. Igumenshchev
University of Rochester
Laboratory for Laser Energetics

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- The experiments used reduced-scale DS designs, which were adopted for limiting power and pulse duration of the OMEGA laser
- Foam spheres were used as a surrogate for liquid-DT spheres, which are required for ignition DS designs[a]
- Three x-ray diagnostics have been employed to observe different stages of DS formation
- Experiments show good agreements with predictions of 3-D ASTER-IFRIIT radiation-hydrodynamic simulations[b,c]

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[a] Goncharov *et al*., Phys.Rev. Lett. **125**, 065001 (2020).

[b] Igumenshchev *et al*., Phys. Plasmas **24**, 056307 (2017).

[c] Colaïtis *et al*., J. Comp. Phys. **443**, 110537 (2021).

Collaborators

W. Theobald, C. Stoeckl, R.C. Shah, D. Bishel, V.N. Goncharov, P. Adrian, M.J. Bonino, E.M. Campbell, D. Cao, A. Chin, T.J.B. Collins, S. Fess, D.R. Harding, N.R. Shaffer, W.T. Trickey, S. Sampat, A. Shvydky, and L. Waxer

University of Rochester
Laboratory for Laser Energetics

A. Colaïtis and R. Loitard

Centre Lasers Intenses et Applications, France

S. Atzeni, F. Barbato, and L. Savino

Università degli Studi di Roma “La Sapienza,” Italy

N. Alfonso and A. Haid

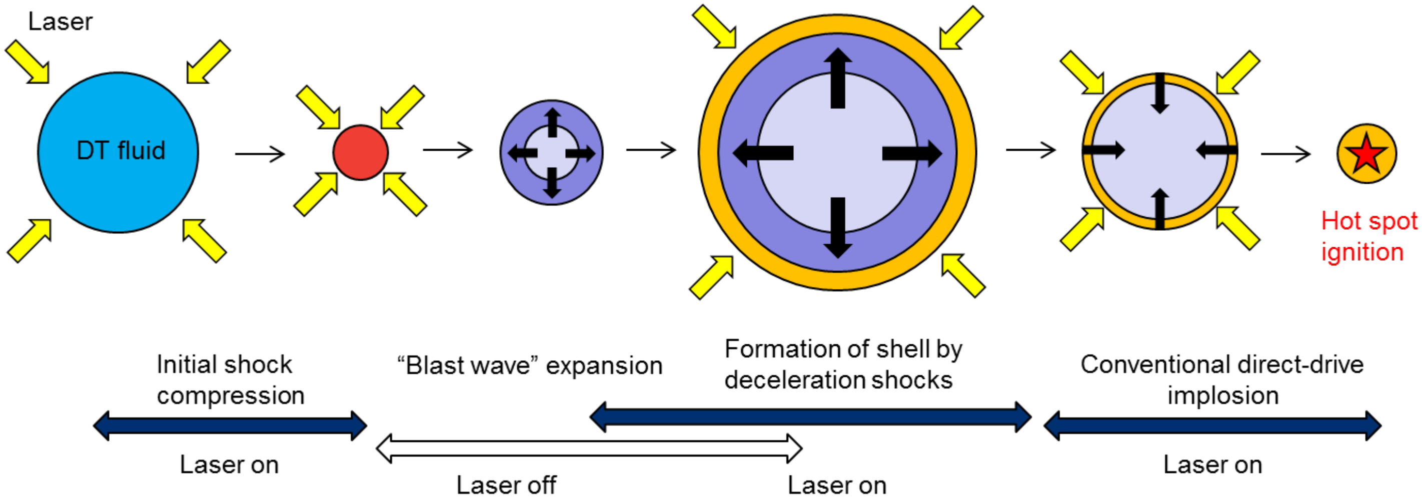
General Atomics

arpa·e CHANGING WHAT'S POSSIBLE

U.S. DEPARTMENT OF ENERGY | Office of Science

A dynamic shell (DS) concept in direct-drive ICF was proposed for enhanced control of 1-D implosion dynamics and easier target fabrication

The concept of DS ignition*



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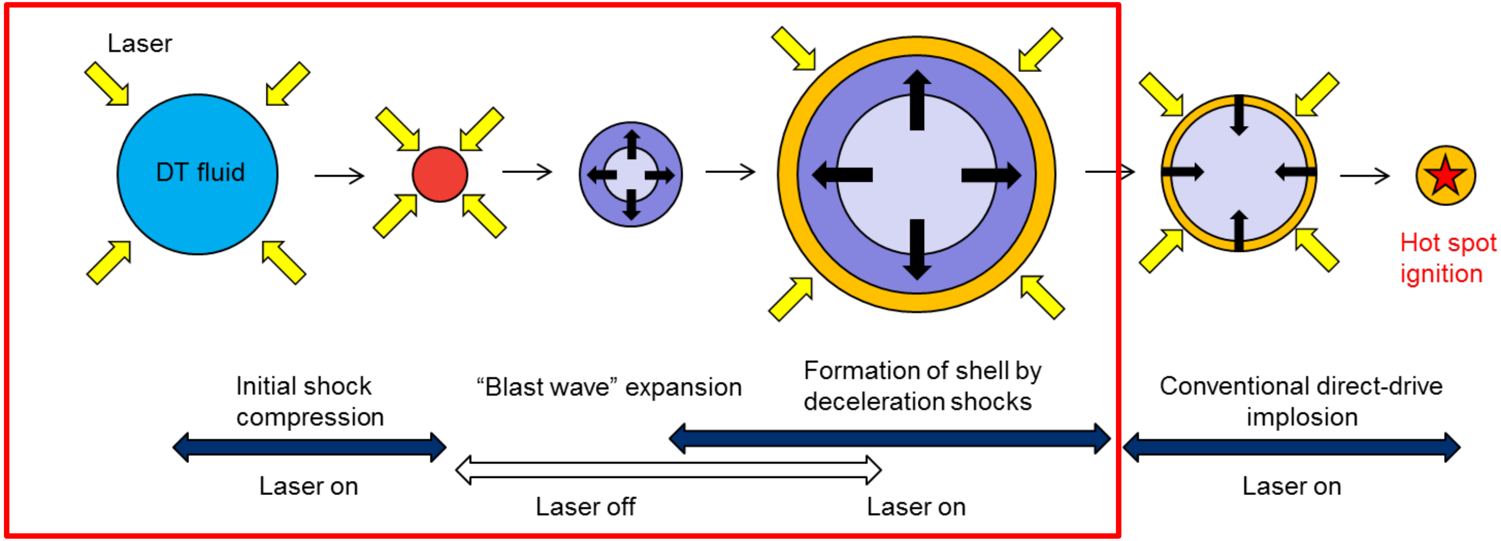


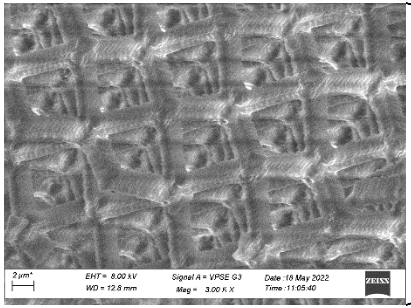
- Proof-of-principle experiments on the OMEGA laser have demonstrated the plausibility of DS formation using surrogate foam-sphere targets
- Stability to low-mode perturbations and to perturbations from stalk mount have been the main concerns

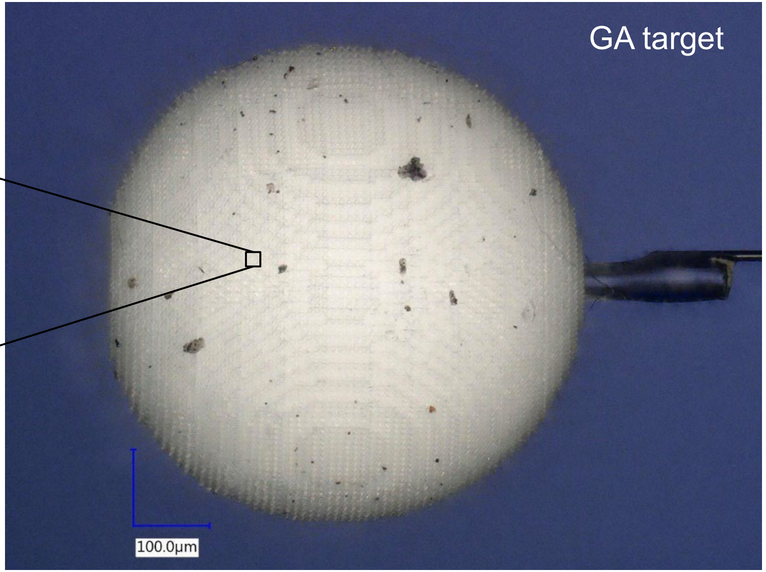
* Goncharov *et al*., Phys.Rev. Lett. **125**, 065001 (2020).

Sphere targets of highly uniform foam were fabricated by GA and LLE

Foam sphere and stalk were printed simultaneously using two-photon polymerization (2PP) technology

Ordered lattice structure
of ~2-μm-diam fibers





Foam and stalk materials - CH

Foam density = 0.144 g/cc

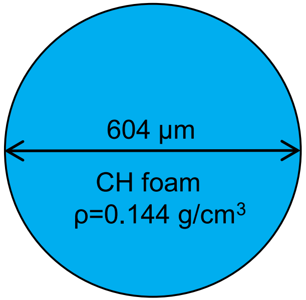
Target diameter = 604 μm

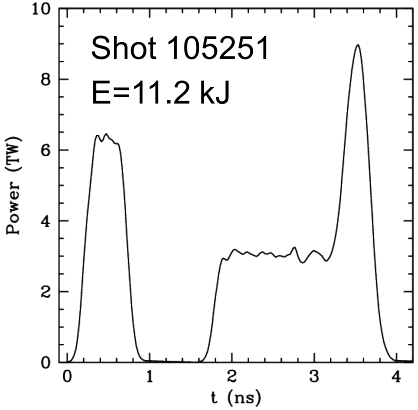
Stalk diameter = 50 μm

- Surface debris contribute to early-time x-ray emission

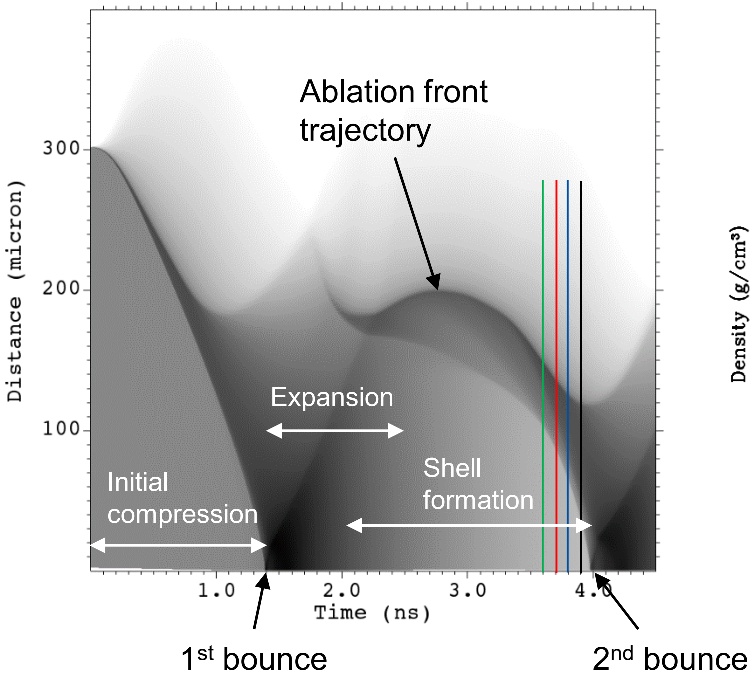
Hydrodynamic simulations of OMEGA shot 105251 illustrate the three stages of DS formation

Target and laser pulse

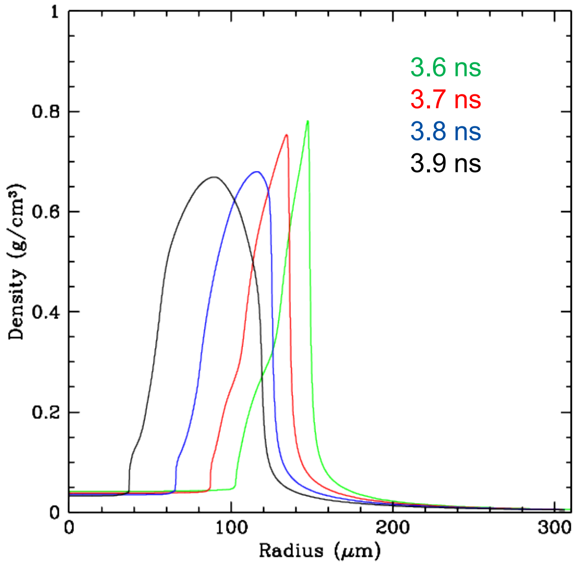




Shock diagram (log-density evolution)



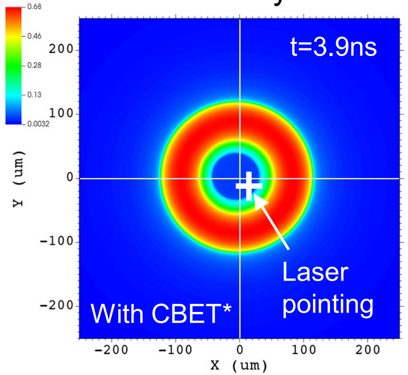
Predicted shell density



Three-dimensional ASTER-IFRIIT simulations predict small effects of mode-1 perturbations and perturbations from stalk mount

- Effects of large $\ell = 1$ mode were addressed in simulations assuming 20-μm target offset

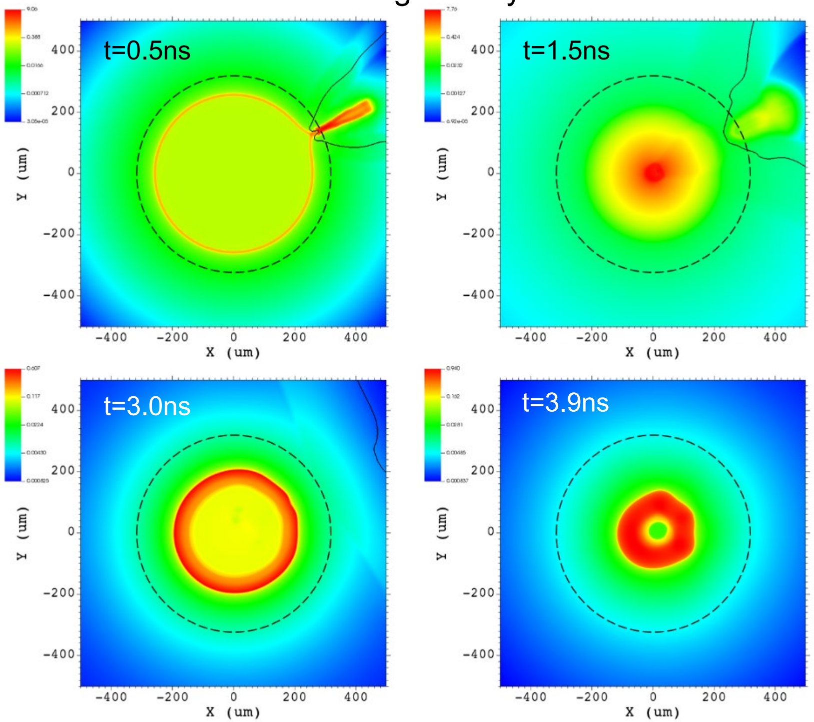
Density



- Target offset can be an issue in DS designs using broad-band lasers that mitigate CBET

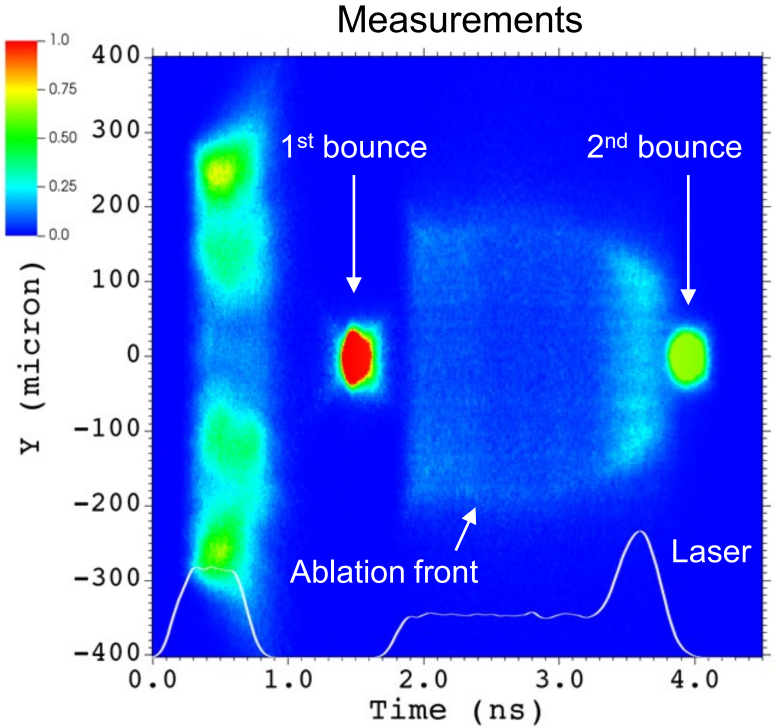
Simulations assuming 50-μm diam stalk

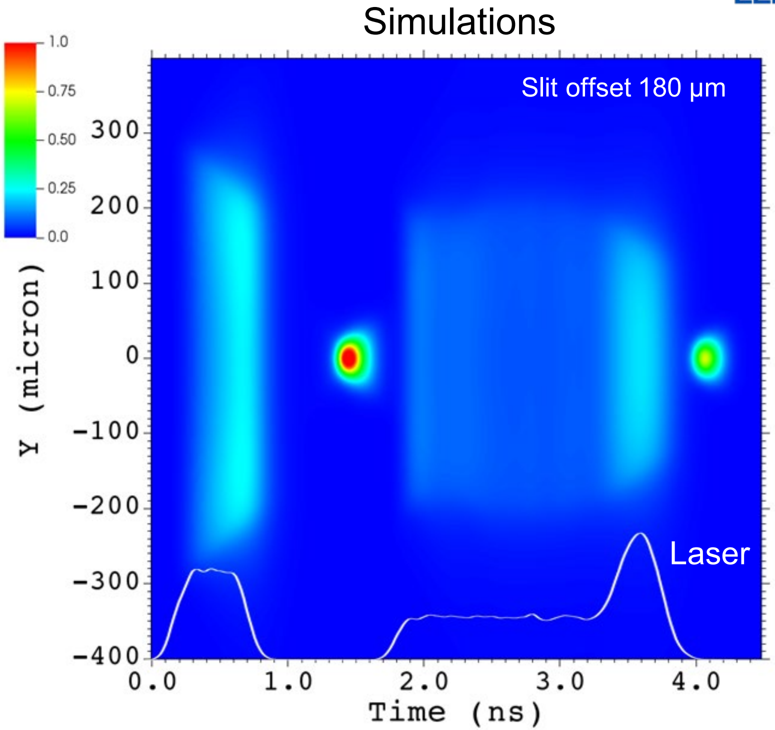
Log density



*Colaïtis *et al.*, J. Comp. Phys. **443**, 110537 (2021).

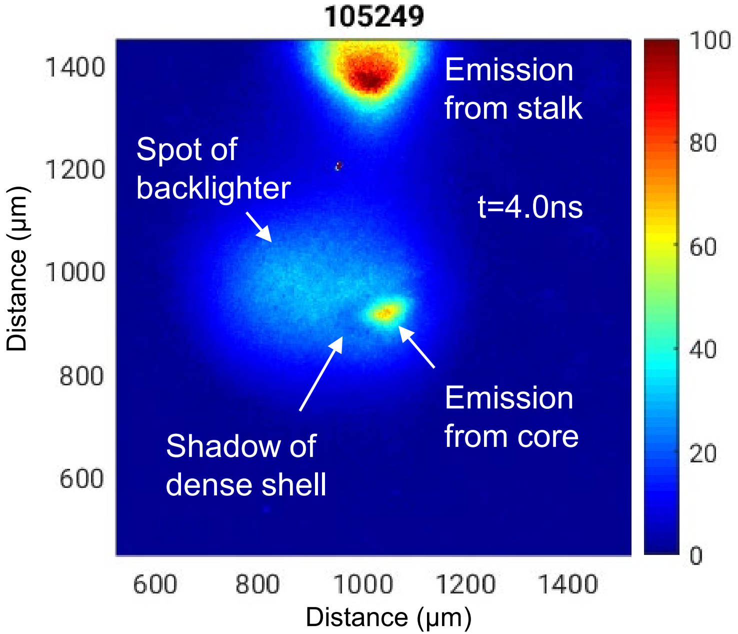
Streaked self-emission radiographs* for shot 105251 capture shock-bounce events and ablation front trajectory in good agreements with simulations



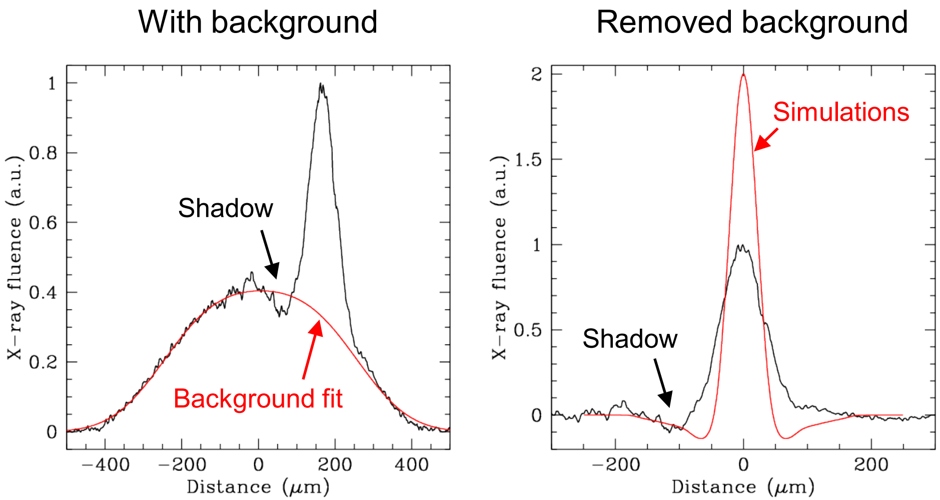


* Ressel *et al*., Phys. Plasmas **29**, 072713 (2022).

The final stages of DS formation were observed using x-ray backlighting radiography in OMEGA and OMEGA-EP joint shots*



Lineouts



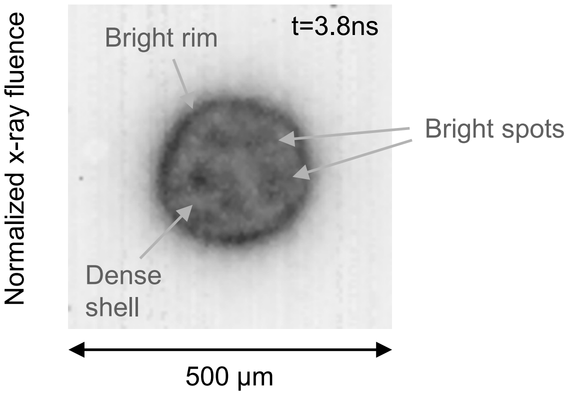
- Backlighting x-rays (1.865 keV) from Si foil irradiated by the OMEGA-EP short pulse beam

* Stoeckl *et al.*, Rev. Sci. Instrum. **85**, 11E501 (2014).

Framing camera shadowgraphs* reveal images of dense shells despite of nonuniformities caused by the OMEGA 60-beam illumination pattern

105251

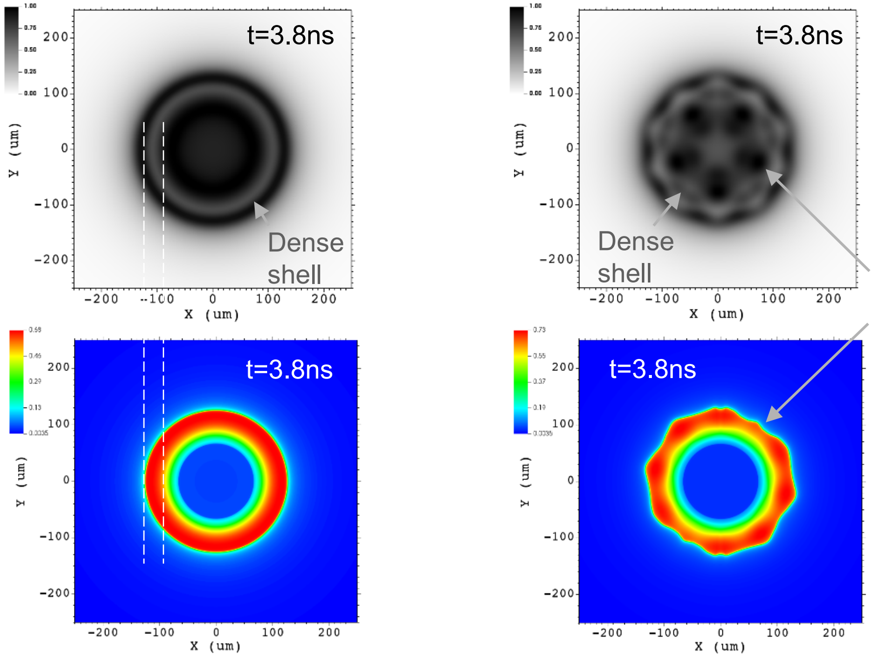
SFC3CCD



TIM1 (P3) view

Nominal 3-D simulations

3-D simulations with enhanced perturbations



Synthetic self-emission radiographs

Bright spots because of radiation escaping through the density dips

Simulated distributions of density

- Nominal simulations underestimate the effects of OMEGA beam-port modes

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

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