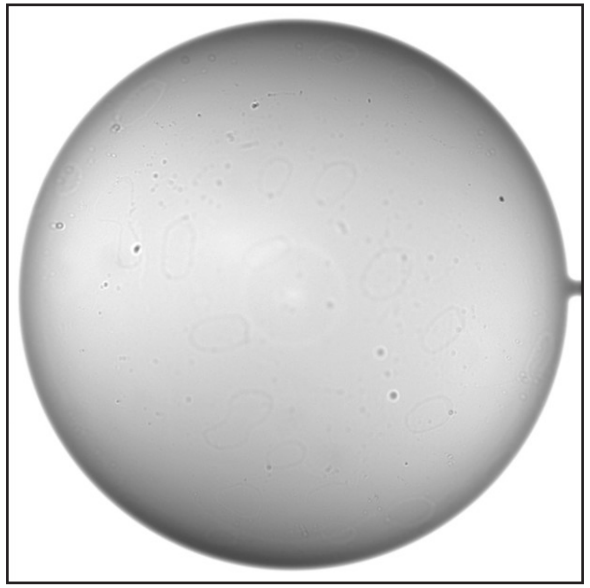
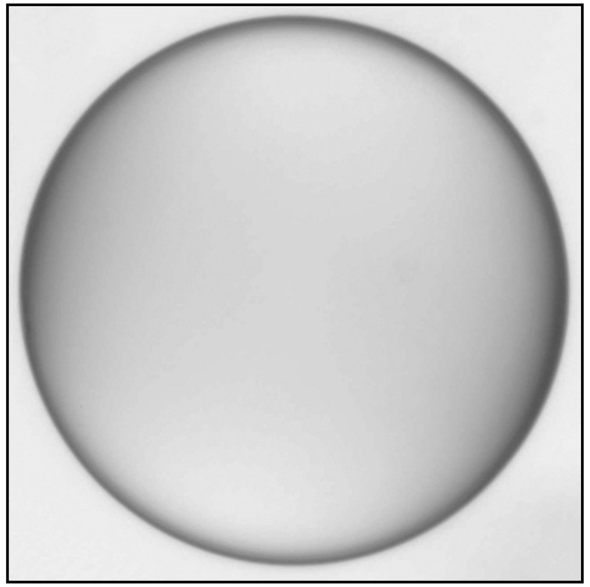
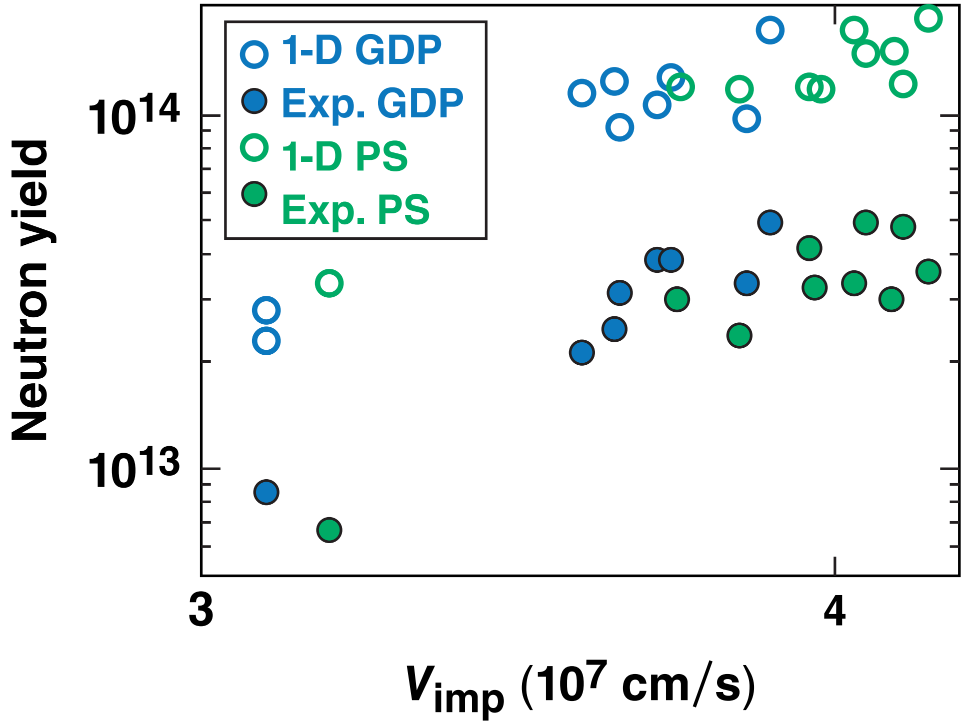
Comparison of the Performance of Polystyrene and Glow-Discharge Polymer Ablators Used in Cryogenic Implosions



Glow-discharge polymer (GDP)



Polystyrene (PS)



C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

59th Annual Meeting of the American Physical Society Division of Plasma Physics
Milwaukee, WI
23–27 October 2017

Summary

Polystyrene (PS) is a promising ablator material for direct-drive cryogenic implosion experiments

- **Simulations indicate that mix seeded by microscopic surface defects can severely degrade the performance of cryogenic implosions**
- **Glow-discharge-polymer (GDP) targets possess numerous surface features (>2 μm in size) that are intrinsic to the manufacturing process that are absent in PS targets**
- **Preliminary experiments show no significant performance difference between PS and GDP ablators for implosion designs with an adiabat between 3 and 5**
- **The target characterization pre- and post-fill will be significantly improved in the near future to meet the requirements of the 100-Gbar Campaign***

E26834

* V. N. Goncharov *et al.*, Plasma Phys. Control. Fusion 59, 014008 (2017).

Collaborators

R. Epstein, R. Betti, C. J. Forrest, V. Yu. Glebov, V. N. Goncharov,
V. Gopalaswamy, D. R. Harding, I. V. Igumenshchev, D. W. Jacobs-Perkins,
R. T. Janezic, J. H. Kelly, D. T. Michel, F. J. Marshall, S. F. B. Morse,
S. P. Regan, P. B. Radha, T. C. Sangster, M. J. Shoup III, W. T. Shmayda,
C. Sorce, W. Theobald, J. Ulreich, and J. Zhang

University of Rochester
Laboratory for Laser Energetics

M. Gatu Johnson, J. A. Frenje, and R. D. Petrasso

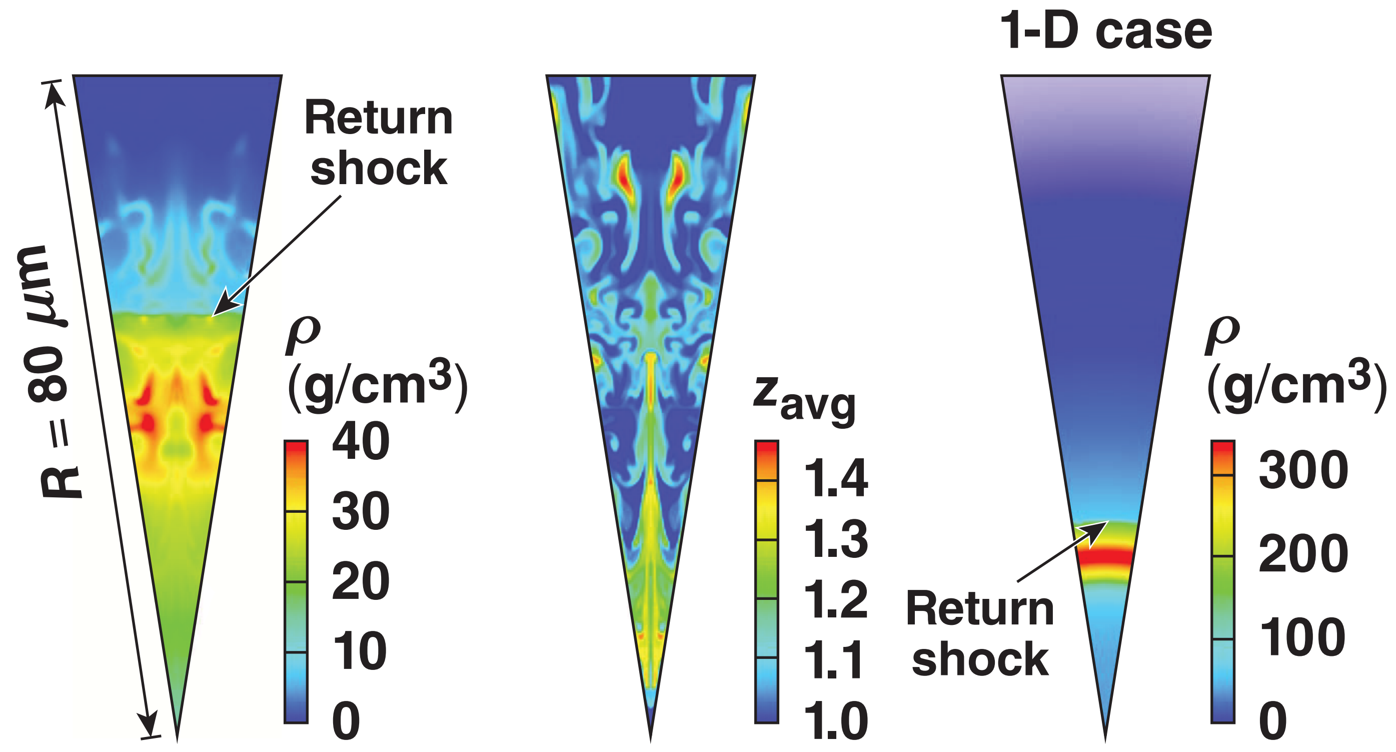
Massachusetts Institute of Technology
Plasma Science and Fusion Center

M. Farrell, A. Greenwood, M. Schoff, and W. Sweet

General Atomics

Simulations indicate that mix seeded by single- or multiple-surface defects can severely degrade the performance of cryogenic implosions

Two-dimensional defect simulations*



- 100-Gbar Campaign requirement**
  - N = number of features with $h/D > 2\%$; $D > 0.5\ \mu m$
    h = height, D = diameter in μm
  - mix fraction

    $f_{mix} = \sum_N 10^{-3} \times D^2$ must be < 1

The ablation-front instability causes the ablator material to be injected into the compressed fuel and hot spot.

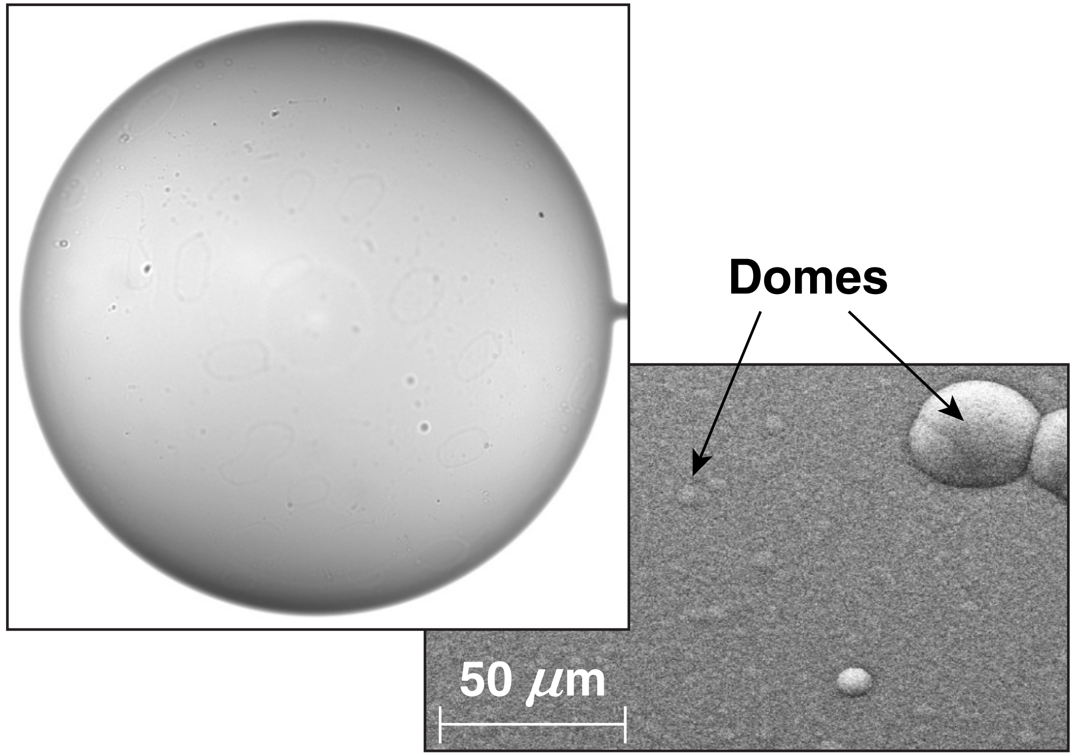
*I. V. Igumenshchev *et al.*, Phys. Plasmas 20, 082703 (2013).
**S. P. Regan *et al.*, "The National Direct-Drive Program: OMEGA to the National Ignition Facility," to be published in Fusion Science and Technology.

E26835

GDP targets possess numerous features that are intrinsic to the manufacturing process that are absent in polystyrene targets

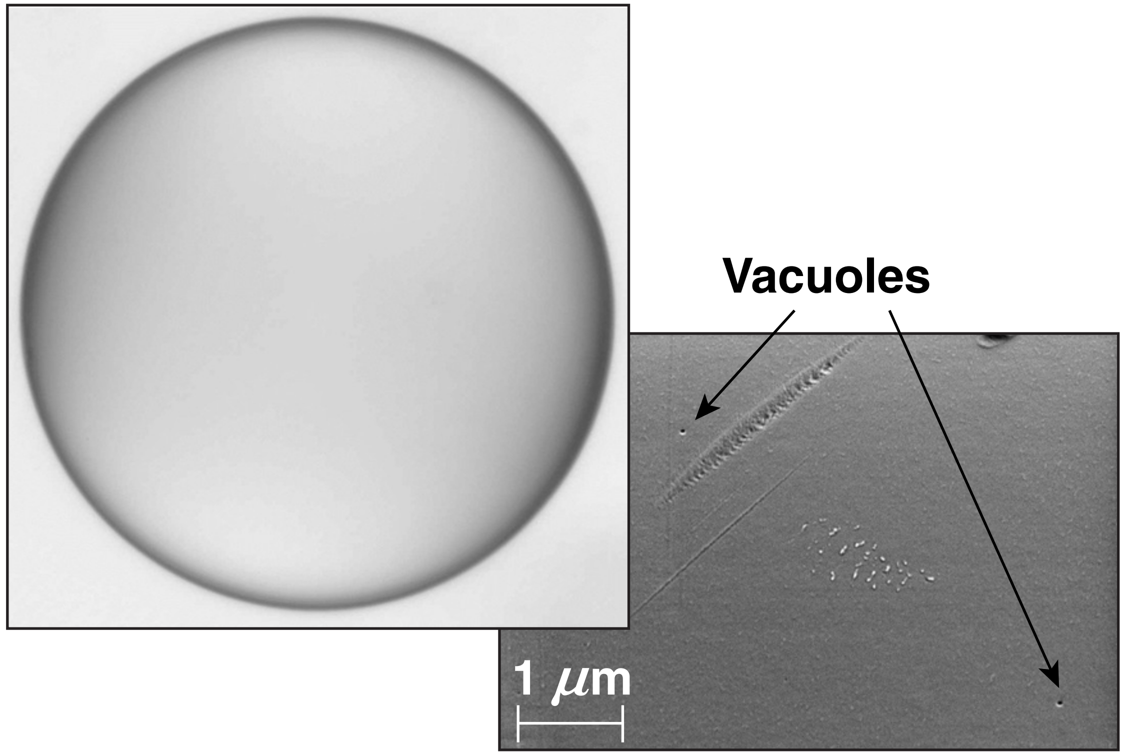
GDP

- Thousands of "domes" (<0.4-μm high × <3-μm diam)
- Up to 2% oxygen (nonuniform distribution)
- Wall uniformity <0.2 μm



PS

- Thousands of vacuoles <1 μm (in bulk)
- No oxygen
- Wall uniformity <0.2 μm



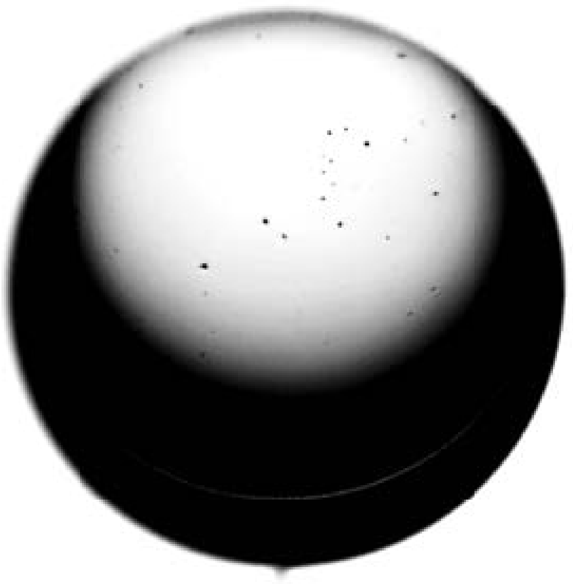
Optical images are acquired prior to filling the target with a resolution of ~1 μm

E26836

Heating to above the critical point for DT (~37 K) reduces the number of condensates on the surface (independent of the ablator)

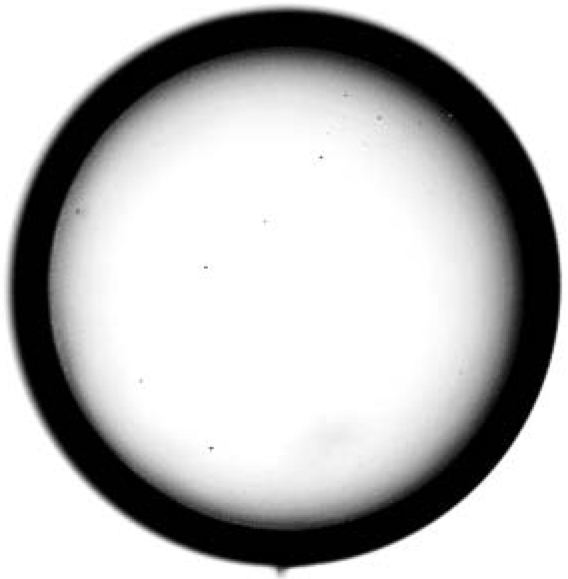
T **< 37 K**

Condensates visible on surface



T **~ 40 K**

Visible features reduced; most likely a result of evaporation of tritiated methanes

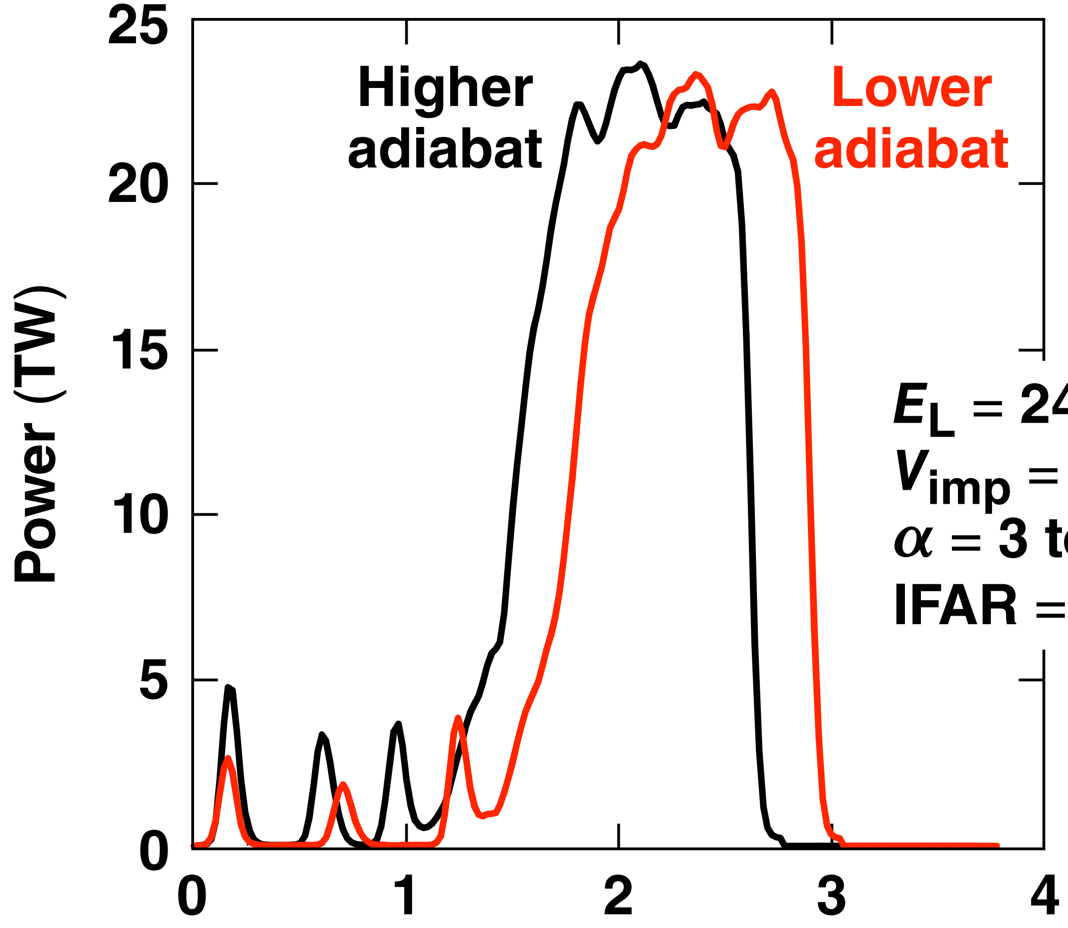


Optical images are acquired after the target fill at cryogenic temperatures with a resolution of ~3 μm; features <3 μm cannot be observed.

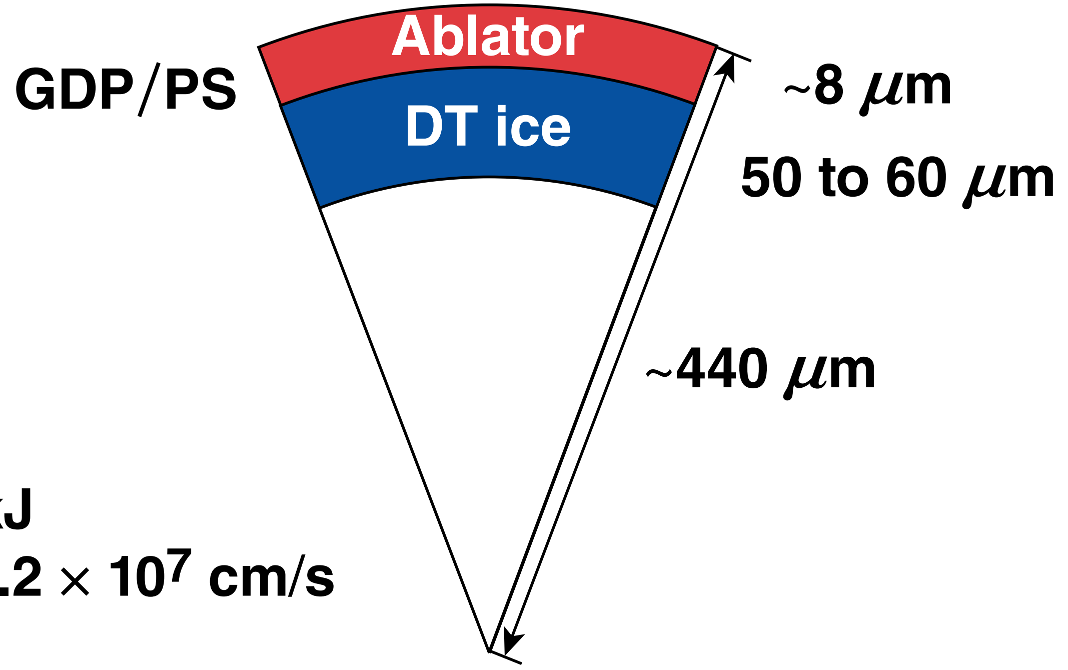
E26837

The target performance is determined by the laser pulse shape and the target dimensions

Adiabat and IFAR are controlled by pulse shaping



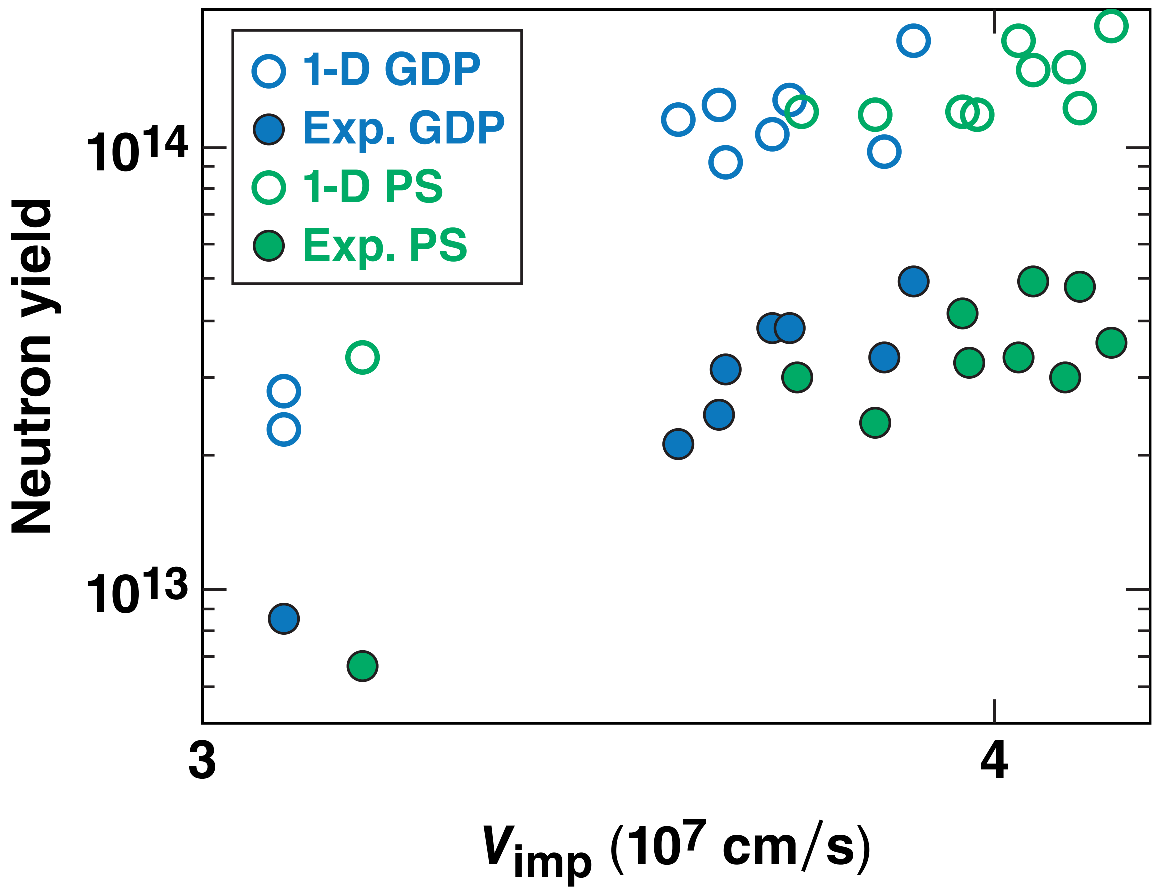
E_L = 24 to 27 kJ
V_{imp} = 3.1 to 4.2 $\times 10^7$ cm/s
α = 3 to 5
IFAR = 20 to 30

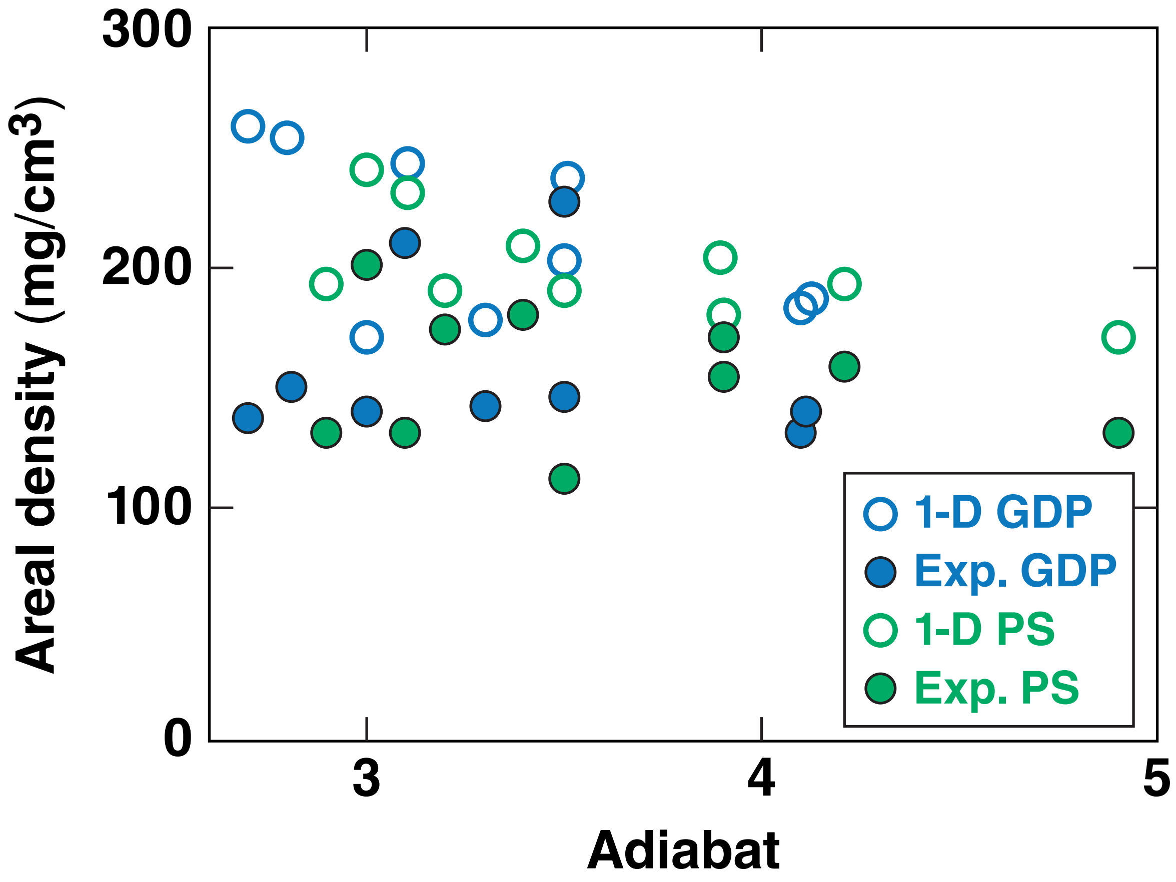


- Adiabat $\alpha = P/P_{Fermi}$
- V_{imp} = implosion velocity
- E_L = laser energy
- IFAR = in-flight aspect ratio (shell radius/shell thickness)

TC10248w

No significant difference in performance is observed between PS and GDP ablators in preliminary experiments





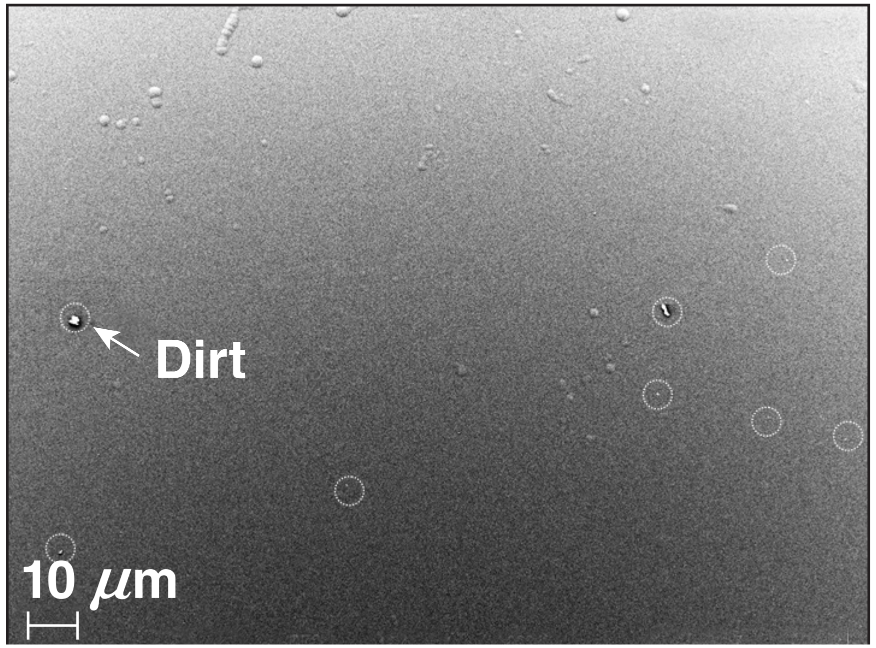
E26838

The preliminary experimental data indicate that debris from the filling process may impact the performance

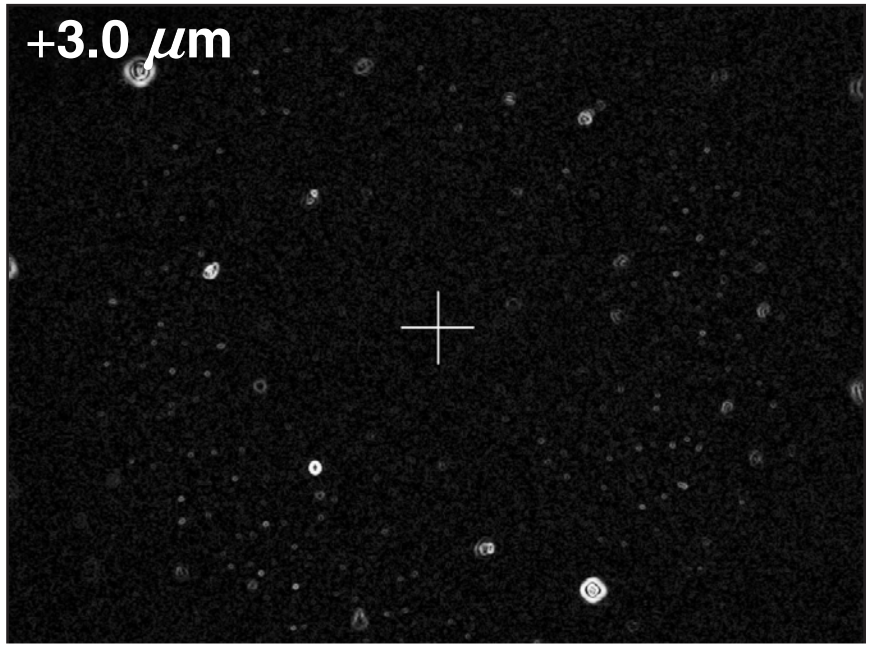
- Using PS ablator material improved the level of pre-fill target-surface imperfections by more than an order of magnitude compared to GDP
- The post-fill target-characterization capabilities are limited by the ~3-μm spatial resolution of the optical system
- Surface imperfections on a spatial scale of <3 μm introduced during the fill could be the cause of the performance degradation
- The impact of other engineering features like the target stalk is also being investigated experimentally*
- The target-characterization capabilities pre- and post-fill will be significantly improved to meet the requirements of the 100-Gbar Campaign

*S. P. Regan, YO7.00007, this conference.

Higher-quality electron microscopy and dark-field imaging will improve the pre-fill characterization



GDP shell, SEM surface image
180 × 130-μm^2 area
<1% of the total surface area
Domes can be clustered together



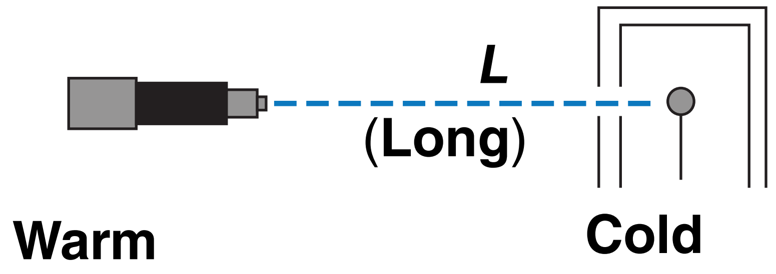
PS shell, dark-field image
80 × 60 μm^2 area
~0.4-μm resolution, <1-μm depth of focus
Vacuoles are seen 3 μm from surface

General Atomics has made rapid progress with the development of high-quality PS shells and is working to reduce the number of vacuoles.

E26839

The spatial resolution of the the post-fill Target Characterization Station will be improved to <1 μm

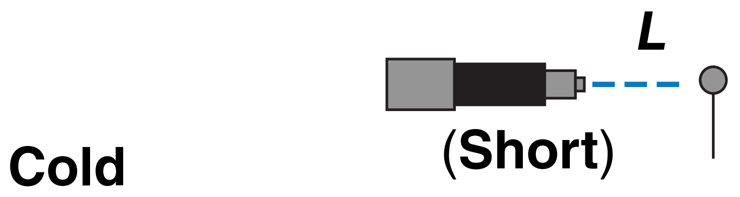
Characterization Station (existing imaging system)



Numerical aperture = 0.10
L = 15 cm
Resolution = 3.1 μm

Target Filling Station (future imaging system)

FTS#2 digital microscope



Numerical aperture = 0.65
L = ~1 mm
Resolution = ~0.4 μm

E26840

FTS: Fill and Transfer Station

Polystyrene (PS) is a promising ablator material for direct-drive cryogenic implosion experiments

- Simulations indicate that mix seeded by microscopic surface defects can severely degrade the performance of cryogenic implosions
- Glow-discharge-polymer (GDP) targets possess numerous surface features (>2 μm in size) that are intrinsic to the manufacturing process that are absent in PS targets
- Preliminary experiments show no significant performance difference between PS and GDP ablators for implosion designs with an adiabat between 3 and 5
- The target characterization pre- and post-fill will be significantly improved in the near future to meet the requirements of the 100-Gbar Campaign*

* V. N. Goncharov *et al.*, Plasma Phys. Control. Fusion 59, 014008 (2017).