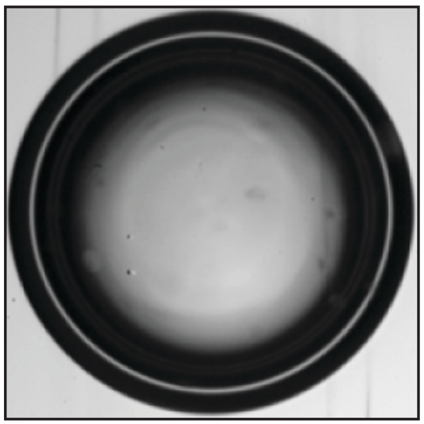
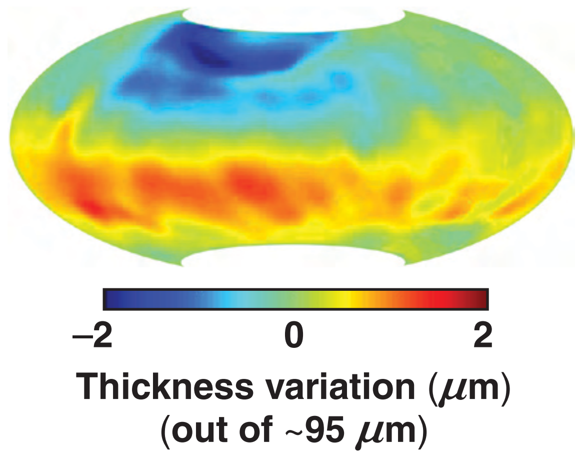
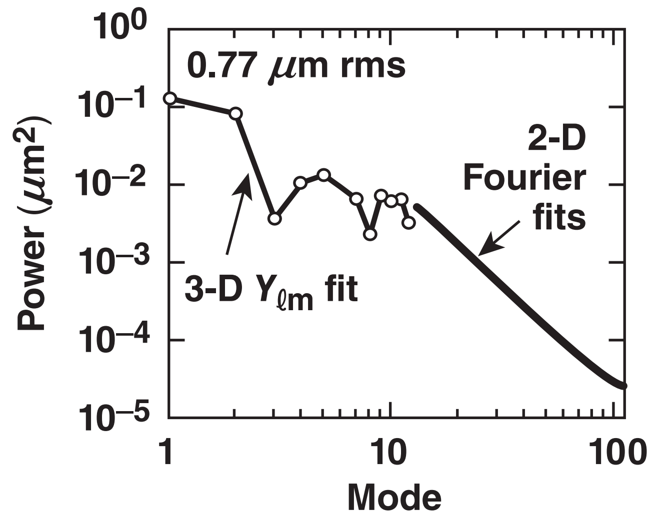
Forming Cryogenic DT Targets for OMEGA







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Summary

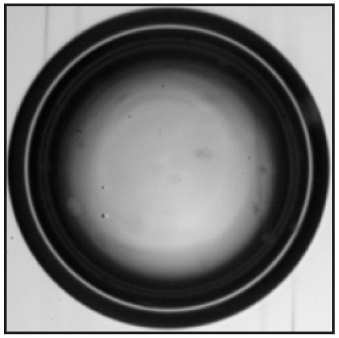
We routinely achieve the 1-μm-rms ice roughness specification (all modes) for DT targets

- Requires 12 h to form a DT-ice layer
  - 60% probability of achieving the 1-μm specification within 24 h
- The ice-layering process is very repeatable
  - median ice roughness is 1.0-μm rms—3-D, all modes
- Decay of tritium to form ^{3}He affects the ice smoothness
  - no evidence of He bubbles is observed
- Cooling the target by 2 K in 2 minutes gives a ~10-s window when the gas density is lowered to 0.3 mg/cc and the ice remains smooth.
- DT ice layers are visible in foam targets.

In the future, we will work to understand how ice roughness develops when the ice is rapidly cooled.

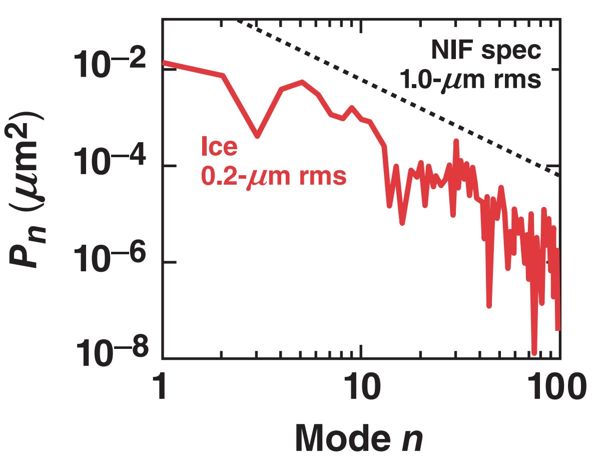
The ice-layer roughness is characterized from an optical shadowgraph

- Optical system locates the gas–ice interface (precision ±0.1 μm)

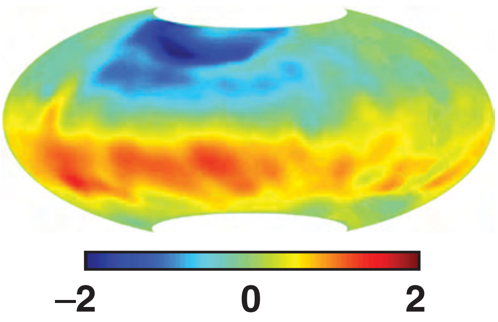


- Numerical analysis:

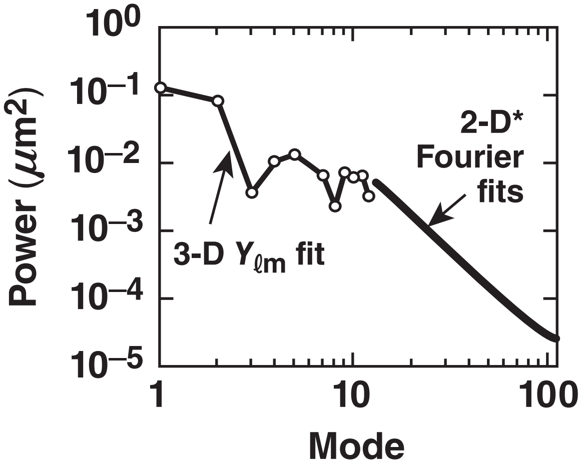
(i)
Fourier power spectrum of the great circle, roughness values include all modes



(ii)
compile a 3-D surface map



(iii)
generate a representative 2-D power spectrum



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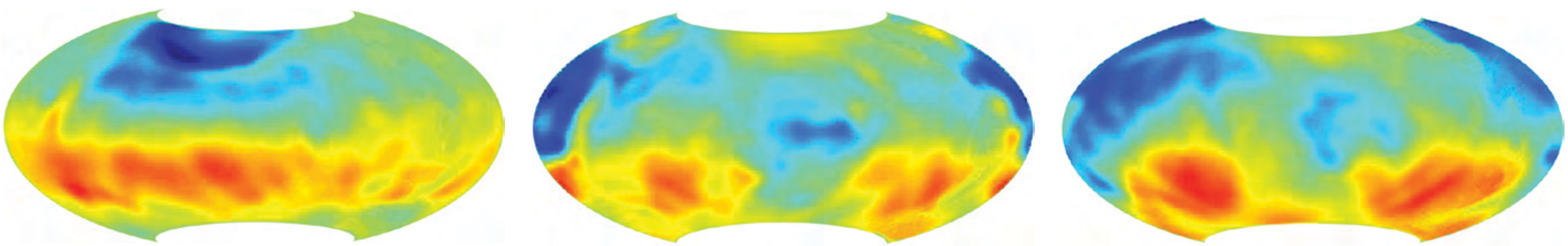
*S. Pollaine and S. Hatchett Nucl. Fusion 44, 117 (2004).

The layering process is very repeatable: melting and reforming the ice layer using the same protocol yields a similar roughness

1st ice layer | 2nd ice layer | 3rd ice layer



0.77-μm rms | 0.84-μm rms | 0.92-μm rms

Thickness variation (μm)

- Variability in the ice roughness is attributed to the variability in the initial location of the seed crystal and how it grows.
- The average ice roughness of 25 targets is 1.1±0.4 μm. The median value is 1.0 μm.

Unless an ice layer is free of defects and perturbations, multiple views are required to characterize it accurately

- $\sigma^{3\text{-D}}$-rms roughness from the 3-D analysis
- $\sigma^{2\text{-D}}$-rms roughness from averaging 50 2-D analyses

Defect-free DT target

- $\sigma^{3\text{-D}} = 0.8\ \mu m$
- $\sigma^{2\text{-D}} = 0.6\ \mu m \pm 0.1\ \mu m$

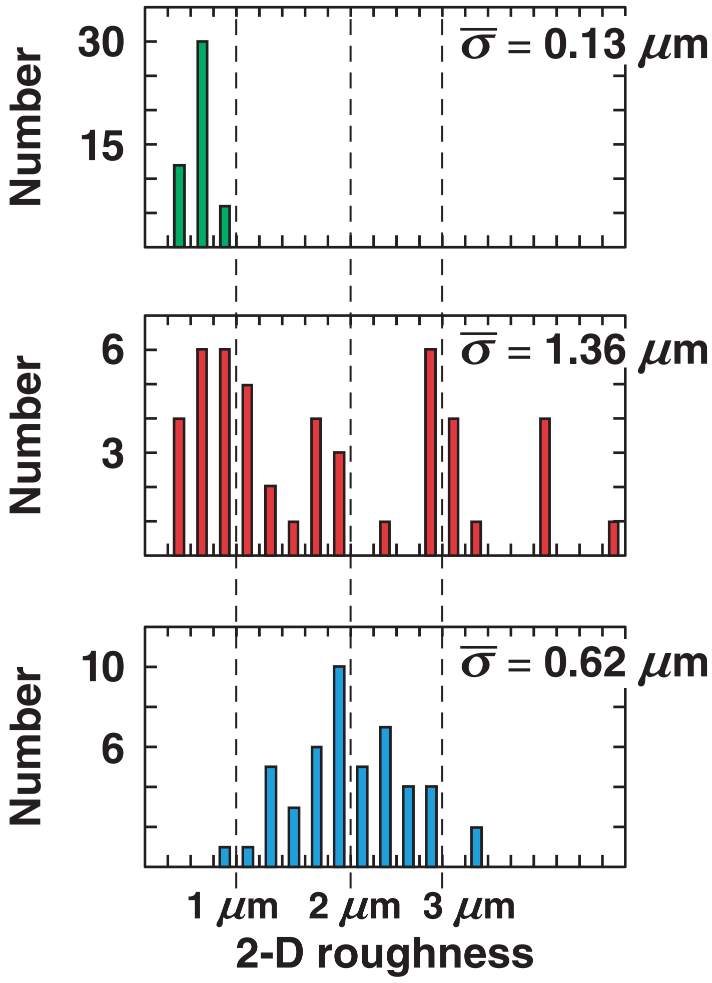
DT target with defects

- $\sigma^{3\text{-D}} = 1.9\ \mu m$
- $\sigma^{2\text{-D}} = 2.9\ \mu m \pm 1.4\ \mu m$

D_2 target with a systemic thermal perturbation

- $\sigma^{3\text{-D}} = 2.8\ \mu m$
- $\sigma^{2\text{-D}} = 2.3\ \mu m \pm 0.6\ \mu m$

Histogram of the 2-D analyses



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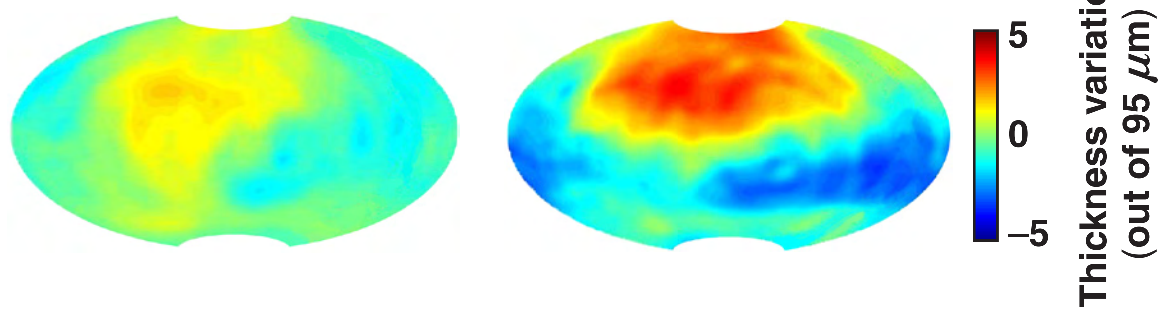
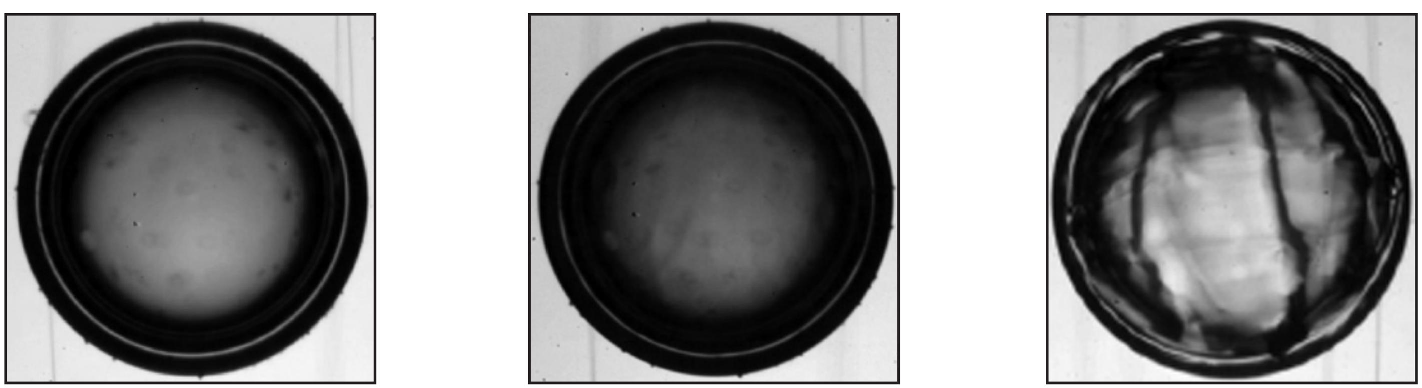
The roughness of a DT-ice layer increases with time; there is no similar behavior with D_2 targets

- Effect is attributed to the decay of tritium and accumulation of ^{3}He; there is no evidence of He bubbles in the ice layer.

<u>Initial quality</u>
1.0-μm rms

<u>19 days later</u>
2.0-μm rms





Initial

19 days at 19.5 K

40 h at 17.7 K—no bubbles

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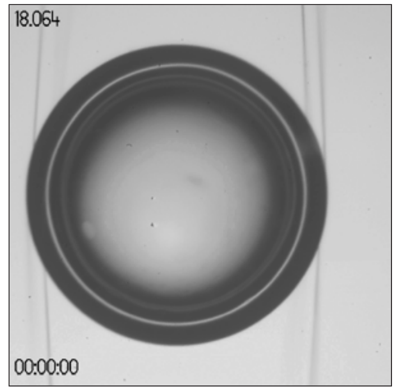
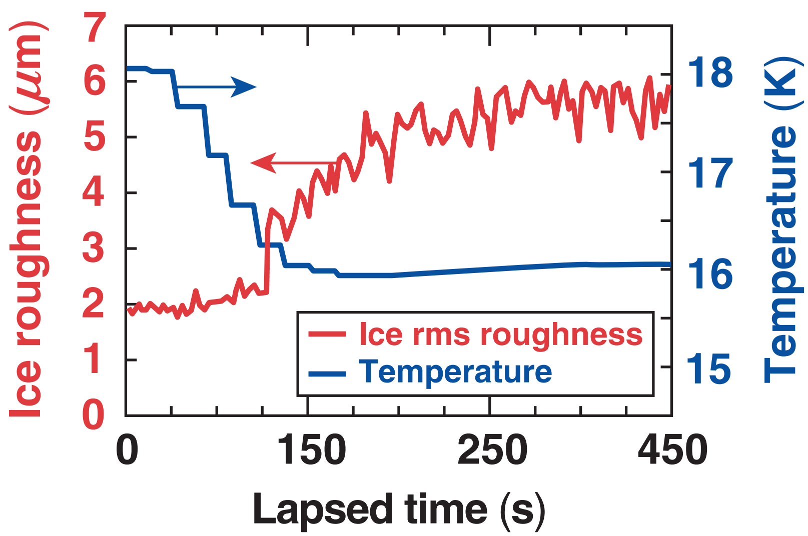
Rapidly cooling the target allows a brief window before the ice roughens

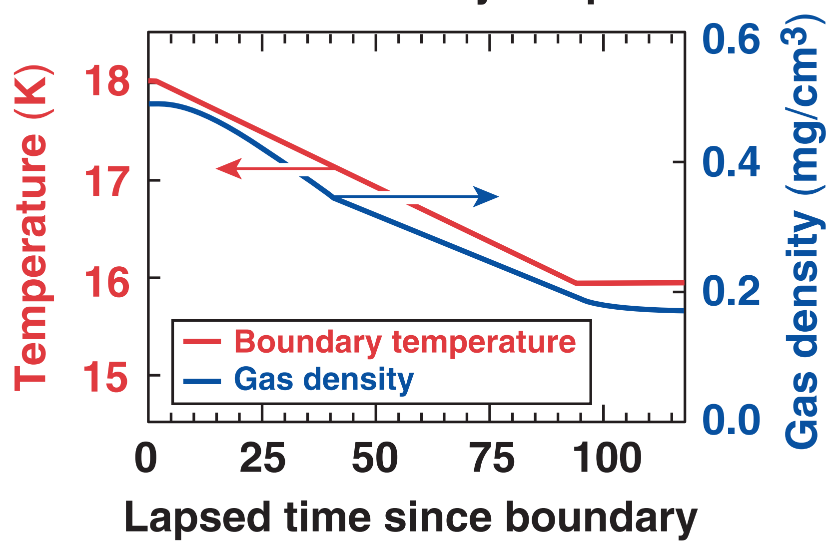
Rapidly cooled D_2 target



Lowering the boundary temperature has a delayed rise in the ice roughness



Calculated gas density closely follows the boudary temperature



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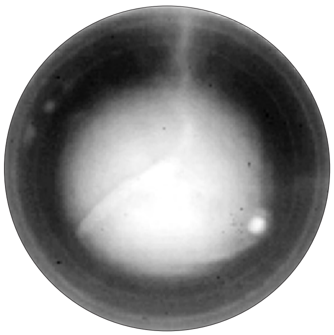
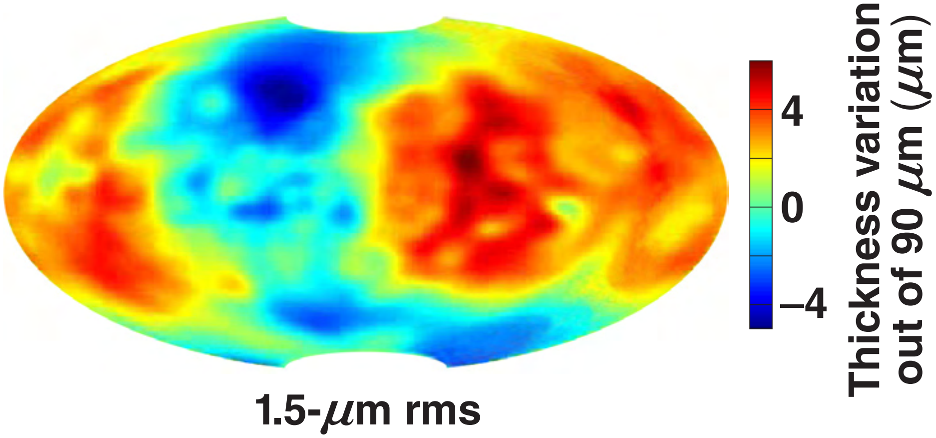
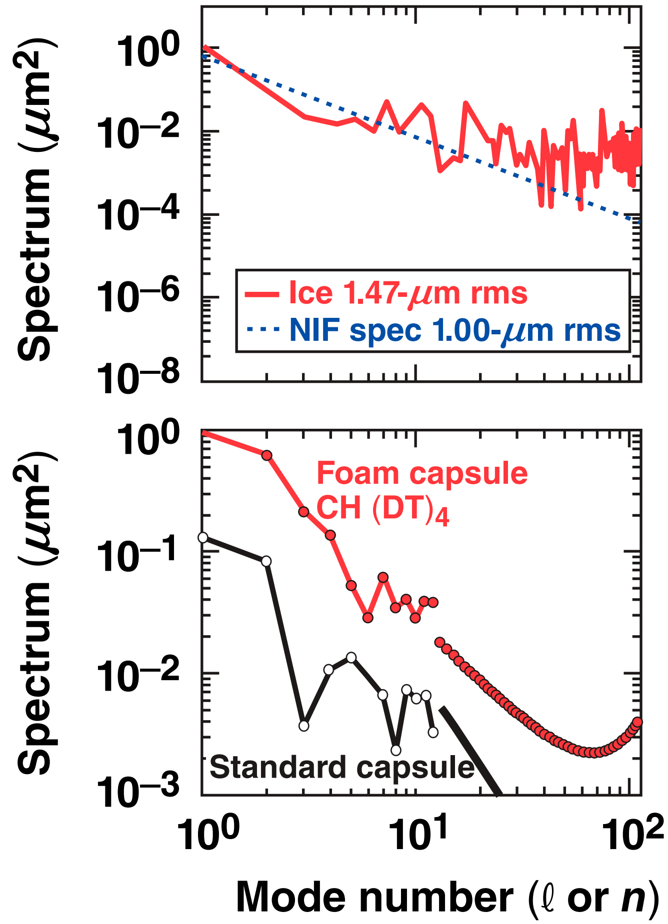
The DT ice layer in a foam capsule possessed a greater roughness than typically obtained in non-foam capsules







Transparent ice layers in foam targets are achieved by melting and refreezing the ice layer to reduce the void content.

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Summary/Conclusions

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