Target Heating Studies and Progress Making Cryogenic Foam Targets

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HAPL Review

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Summary

- The equipment to measure the sticking efficient and energy transfer of high-velocity, high-energy gas to D_2 ice is assembled and is being tested
- Expanding the analysis to include a method of measuring how the roughness of the inner ice surface changes with time for different heat fluxes
- Measured the thermal conductivity of gas, liquid and solid D_2— developing a method of measuring a foam/ice composite.
- Measured the roughness of the ice layer in a foam target

T2140

Equipment construction and testing continues

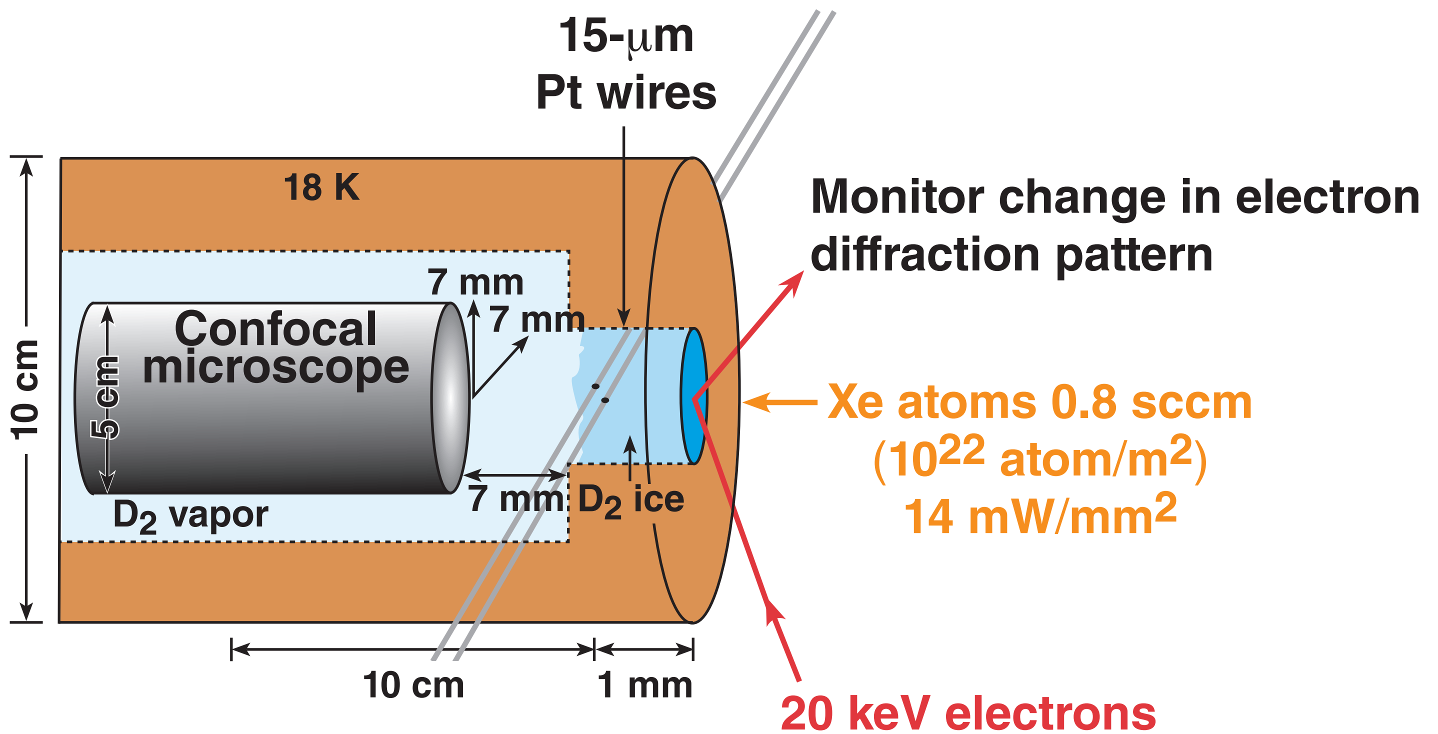
Progress

- Base pressure: 10^{-8} torr
- Operation pressure: 0.8×10^{-6} torr with 0.8 sccm Ar flowing (with just the turbopump)
- Liquid nitrogen tank installed and operational, $T < 80$ K at the radiation shield
- Cryocooler operational—demonstrated 11 K at the target
- Supersonic nozzle for Xe or D_2/D^+ operational
- Electron diffraction equipment for measuring the growth rate of Xe atoms is being installed
- Method for measuring ice temperature and determining the extent of melting demonstrated
- Thermal design of cell to contain the temperature probes and confocal microscope in progress
- Confocal microscope identified—purchase order pending

T2147

Goal: Deliver high-velocity, high-temperature Xe, D, and D^+ atoms to a D_2 substrate and measure the rate of temperature rise, extent of melting, rate the ice roughens

- Also, measure the rate Xe accumulates on the surface to distinguish heat from impact from heat of condensation



T2141

A high-energy, high-velocity Xe beam is achieved using a 0.5 mm nozzle and e-beam heating

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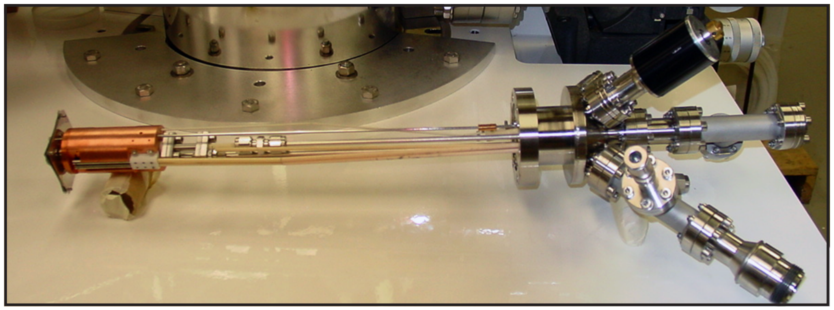
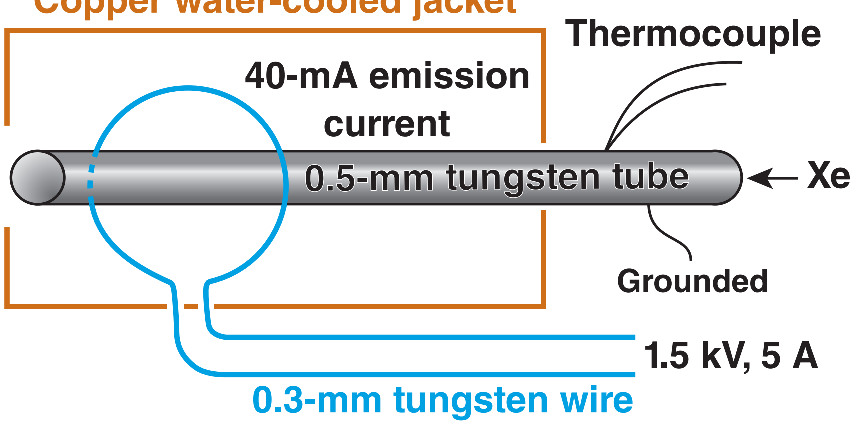
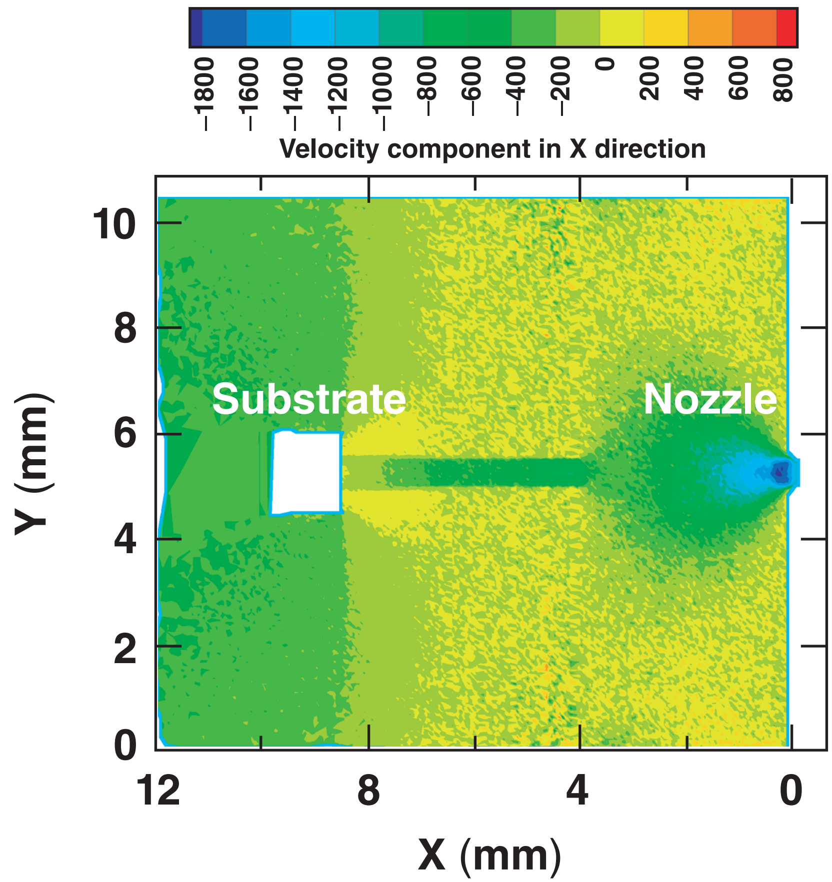
- Expanding a gas from a nozzle generates a focused (15° divergent) supersonic beam of atoms.





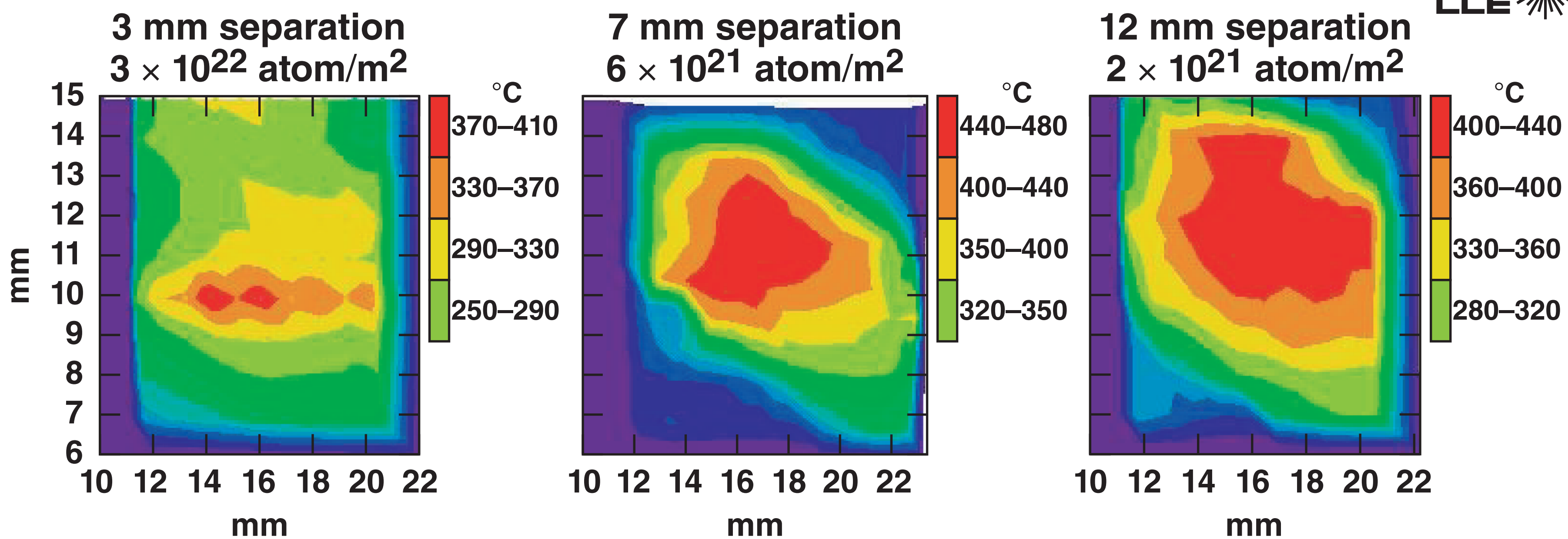


- Demonstrated $\dot{m}$ of 0.8 sccm (25 μg/s) with a chamber pressure $<10^{-6}$ torr

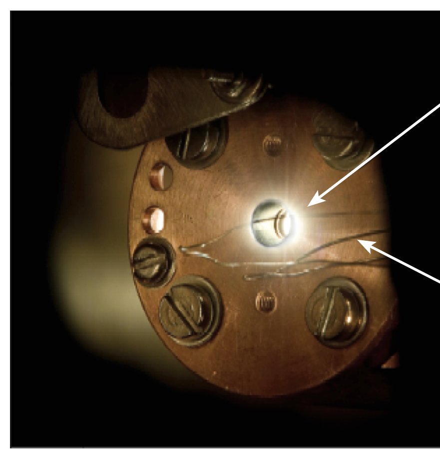
Reversing the polarity on the voltage source will produce high velocity ions to study the effect of D_2+ and D+ on the target.

T2142

The heat and atom flux achieved with an Ar beam are both in the range that is relevant to an IFE chamber with 0.05-torr Xe



- The maximum measured temperature of 480°C suggests a gas temperature >2000°C when radiation and thermal conduction losses are included. The heat flux is 14,000 W/m^2.

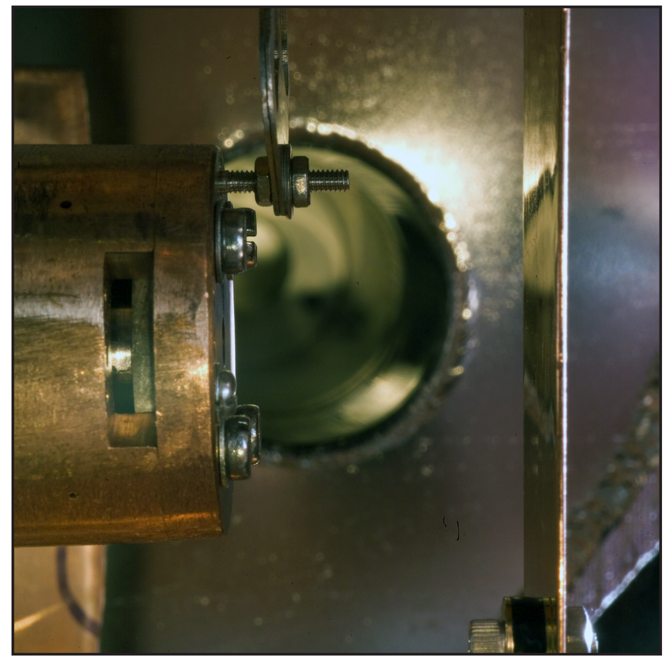


T2143

The growth rate of Xe on the surface of the target is measured using the change in the electron diffraction pattern of the Xe crystal

UR LLE

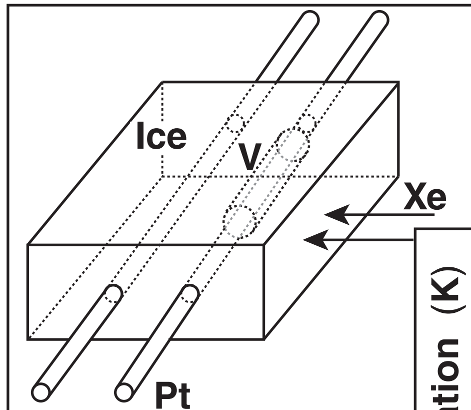
- Need to know how much Xe is accumulating on the surface for two reasons:
  1. Allows the heat from Xe condensation to be determined.
  2. If only a small portion of the incident atoms stick, the recoiled atoms form a buffer thermalizing Xe atoms.
     1. Need to determine the sticking coefficient
     2. Need to determine the accommodation coefficient



- Xe is known to condense to form an fcc crystal with lattice spacing, a_o = 6.1 Å and an atomic volume of 60 Å^3.
- Extensive TEM and LEED and He-recoil scattering measurements of Xe growth at temperatures of 7 to 40 K show that the film is crystalline, so the RHEED technique should be sufficiently sensitive.

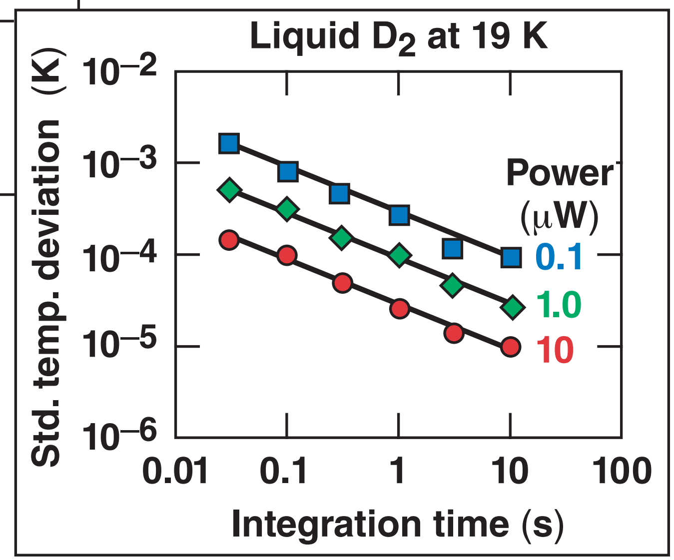
T2144

The ice temperature and degee of melting is determined from the voltage change in 15-μm Pt wires embedded in the ice



Temperature sensor

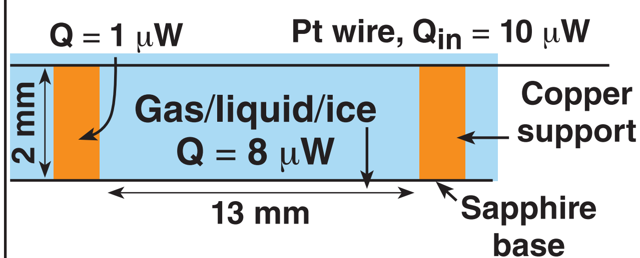
- ΔT in the ice → Δ resistance in the Pt wire → Δ voltage that is measured
- Resolve a 0.1 mK ΔT every 0.1 s using a 10 μW, 20 Hz signal



Technique

Measure the voltage (<μV) in a 3ω overtone that is produced when a pure 1ω sine wave passes through a 15-μm-diam Pt wire immersed in the ice/liquid/gas.

$\Delta T = (V_{3\omega}/V_{1\omega})4R(1/dR/dT)$



Phase change sensor: 3ω method

- 10-μW, <3-Hz signal produces ~10 mK oscillations in the Pt wire temperature due to a change in the thermal conduction of the fluid contacting the wire.
- A change in the 3ω voltage is a measure of the extent of melting.

T2145

The 3ω technique is used to measure the thermal conductivity of gas, liquid, and solid D_2

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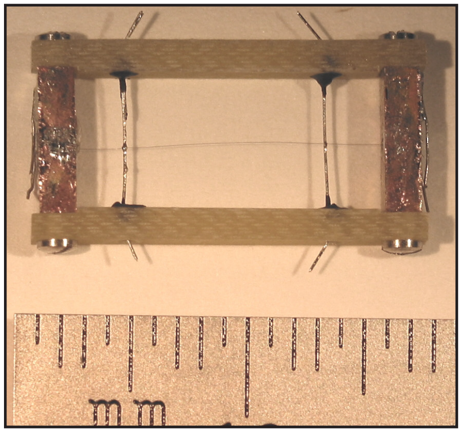
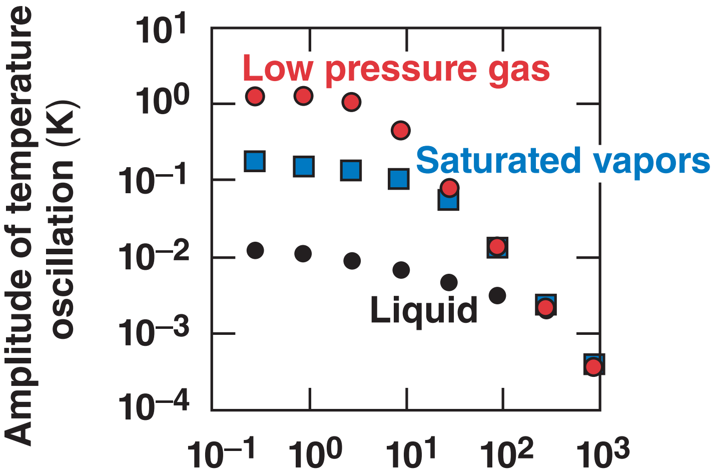


Deuterium at 19 K Power = 19.3 μW



Frequency of applied current (Hz)

T2146

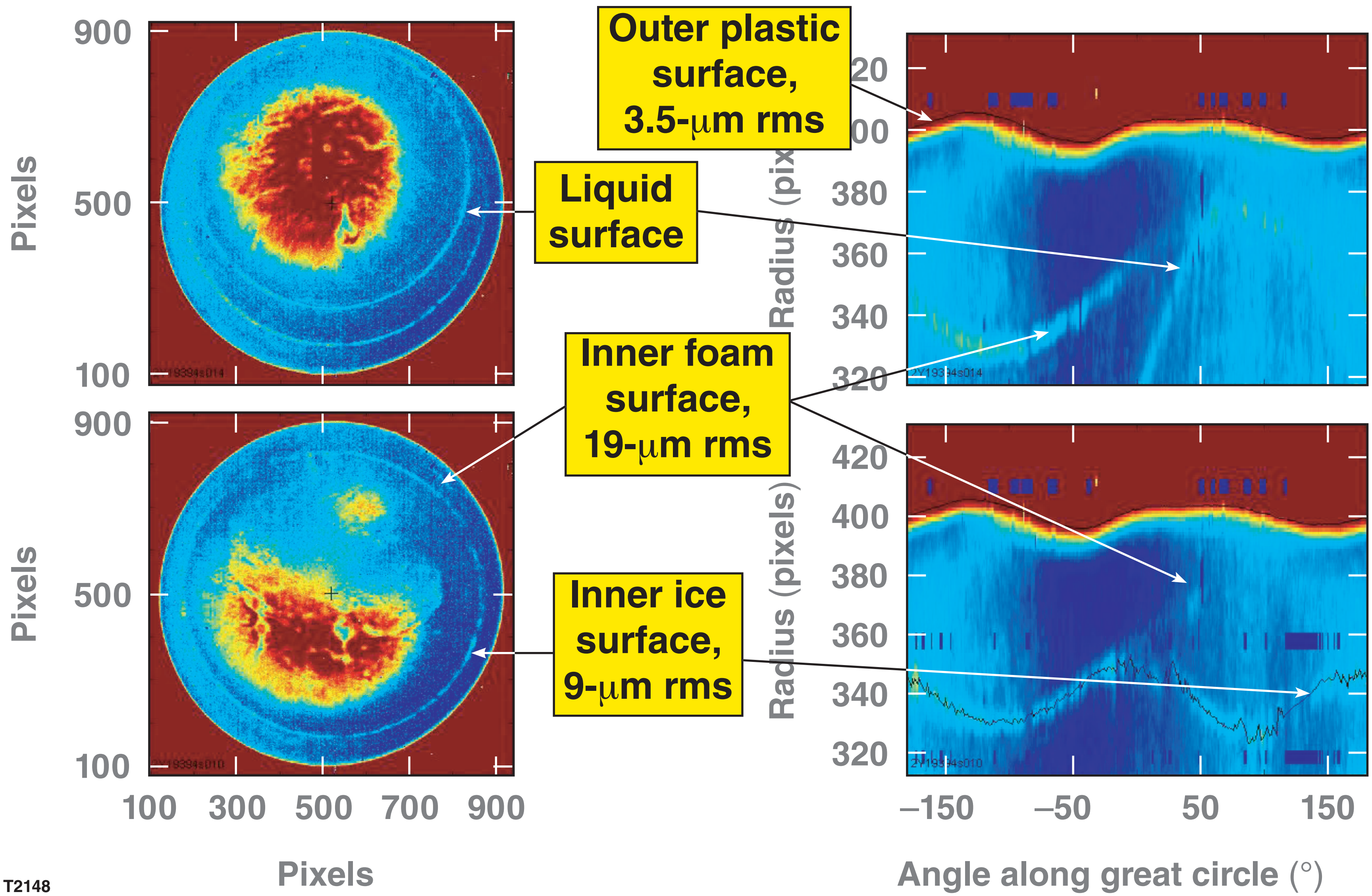
Thermal conductivity (W/m-K)

	Measured	Literature
Plastic	0.08	
D_2 gas	0.011	0.009
D_2 liquid	0.13	0.12
D_2 solid	0.14 to 0.48*	0.38

*depends upon ice quality (polycrystallinity)

1. Need to understand the effect of ice crystal size on thermal conductivity
2. Measurement of the thermal conductivity of a D_2-filled foam target is in progress

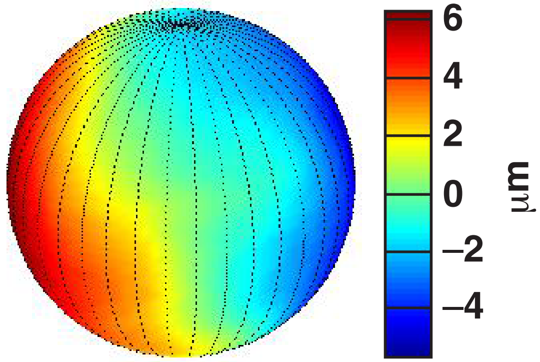
Sizable nonuniformities in the thickness of the foam and ice walls are observed



T2148

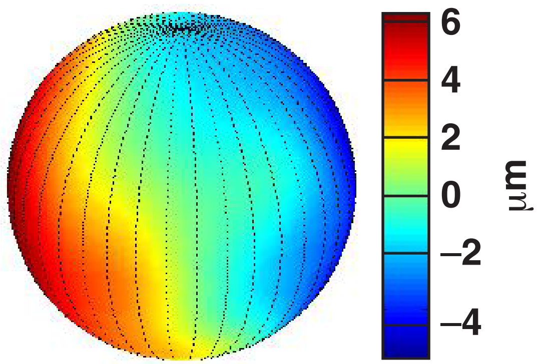
Foam target development

3-D characterization of the uniformity of the foam wall

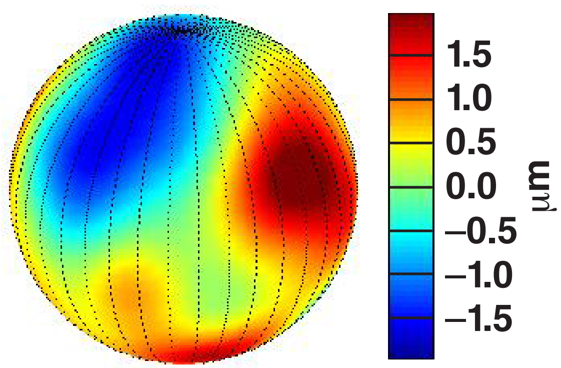


3-D from measurements

180-mg/cc RF foam,
100 μm wall

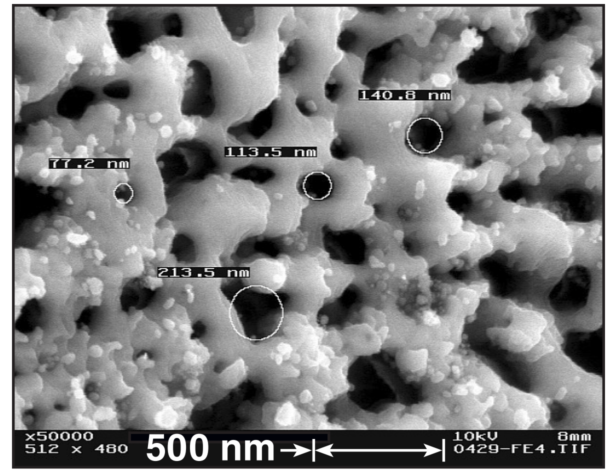


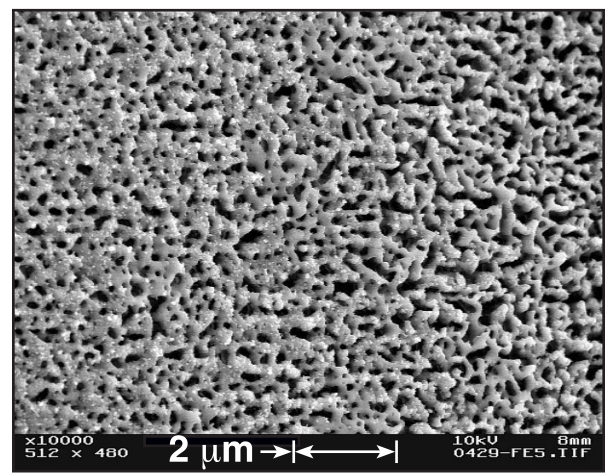
3-D from Yℓm reconstruction (ℓ = 1–10)



3-D from Yℓm reconstruction (ℓ = 2–10)

Vapor-deposited pure carbon foam





T2149

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