APPENDIX H

DT LAYERING

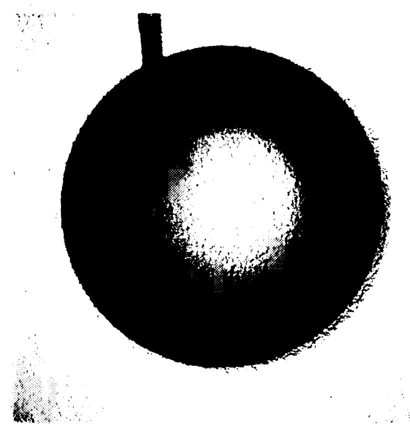
BY

JIM SATER

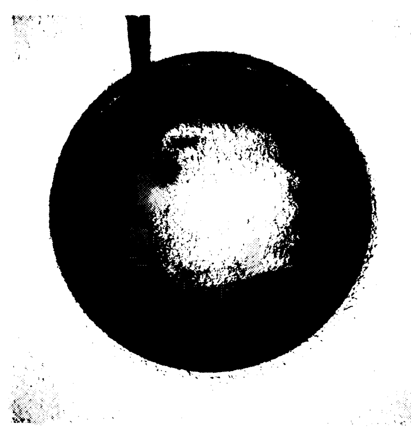
DT Layering in Spheres

Schafer

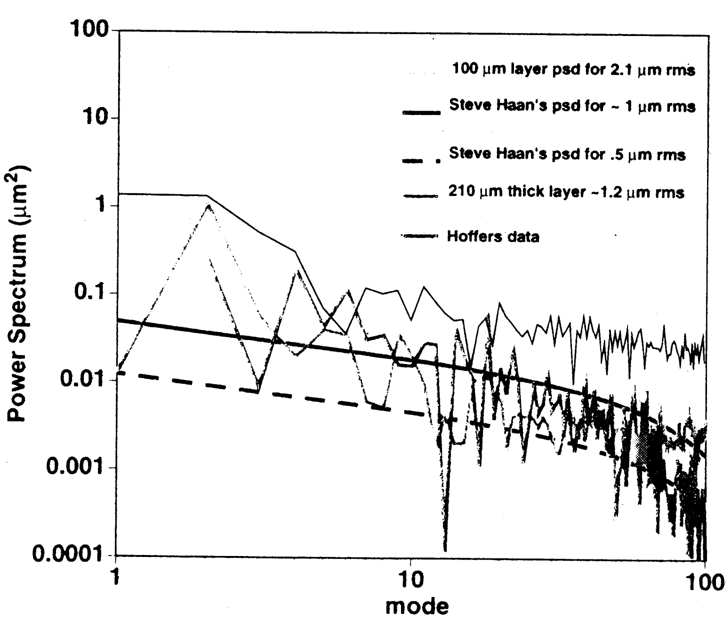
We have consistantly formed 1.2 to 1.5 μm rms layers at 19.7K.



Goal is to reduce the temperature to 18.3 K without reducing rms.



Direct drive designs typically call for even smoother layers.

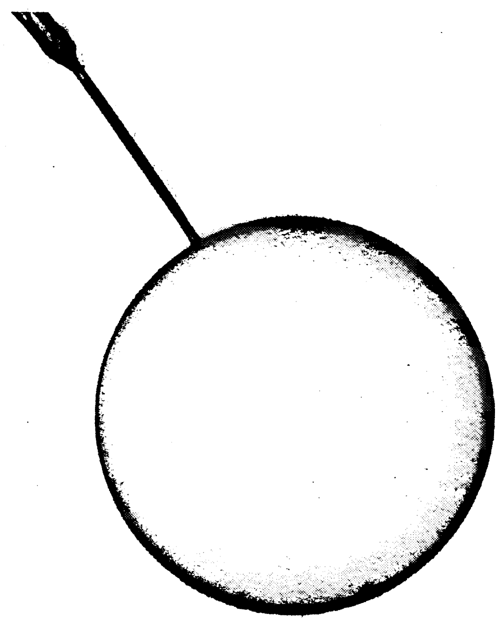


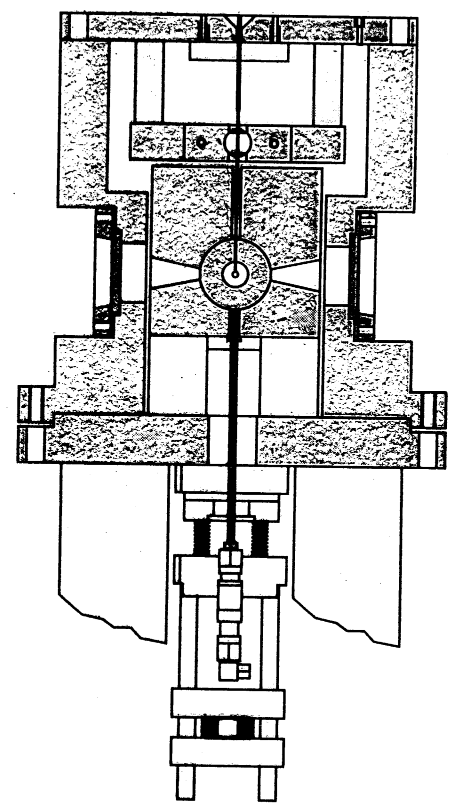
James Sater
Bernie Kozioziemski
James Pipes
Gilbert Collins

coverpage.ill

Layering occurs in a spherically symmetric geometry

- Sample cell is a 1 or 2 mm plastic shell on a fill tube.
- Surrounding cavity is a 25.4 mm diameter, OFHC hollow sphere.
- Layers are made at slightly below the triple point of DT (19.7K).





Good thin layers can be formed at the triple point but appear to degrade at the NIF design point

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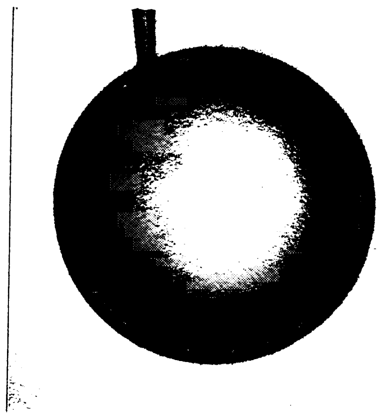
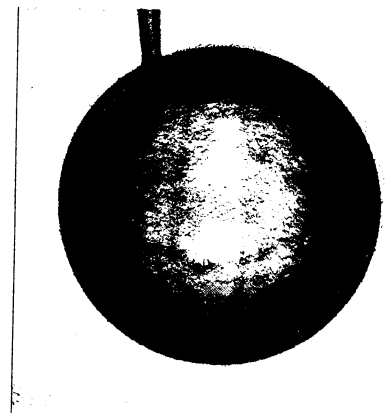
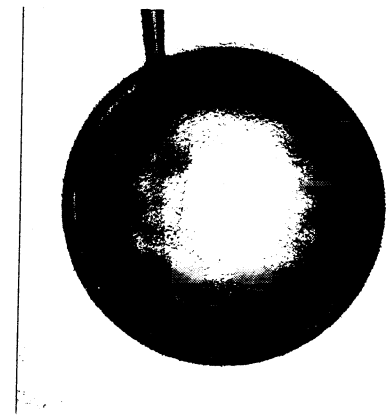
Started cooling from liquid at 19.82K at a rate of 1mK/min.
Formed a 100 micron layer.
Held at 19.68K for 226 minutes then step down to 18.2K.



Temp = 19.4K @ 1.3 mins after stepping temp. RMS 1.71 μm



Temp = 18.2K @ 10 mins after stepping temp. RMS 5.83 μm



Temp = 18.2K @ 355 mins after stepping temp. RMS 3.85 μm

- Initial layer forms just below the triple point by slowly cooling.
- Layers "rapidly" cooled to design point temperature and held.

Thermal stress builds as the temperature is lowered

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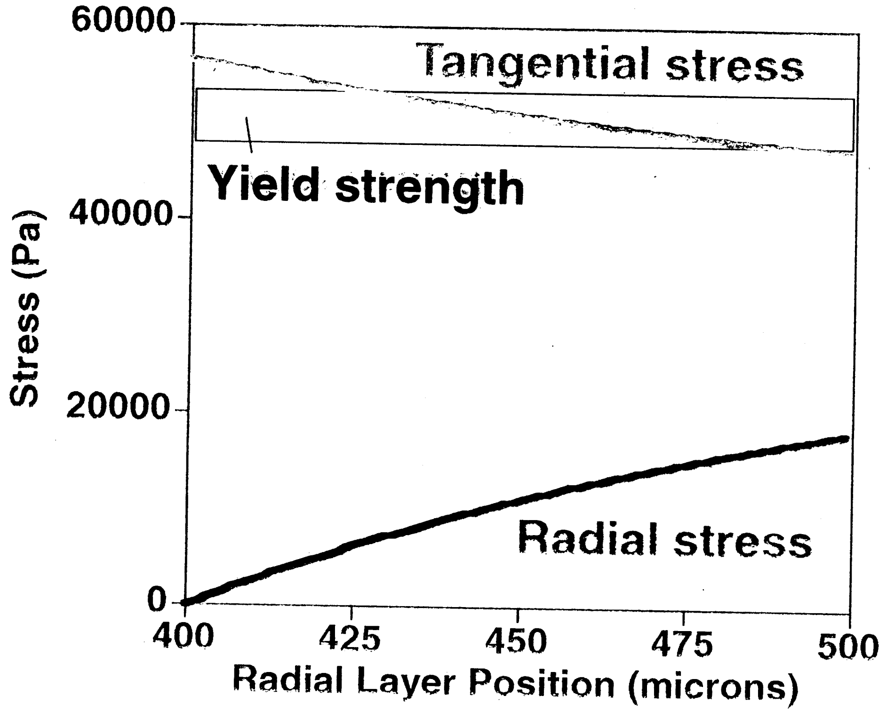
NIF
The National Ignition Facility

Stress caused by ΔT=-0.5 K in 100 μm layer



- This thermal contraction stresses the solid
- The D-T molar volume decreases by 0.18 cm^3/mole = 0.9% between 19.7K and 18K
  - A 100 μm thick layer contracts radially by 0.4 μm

- Calculation based on estimated elastic properties shows the yield stress of ~50kP is reached after a 0.5K temperature drop for a 100 μm thick layer

Beta layers can be slowly cooled to ~19.3 K before they begin to degrade

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The National Ignition Facility

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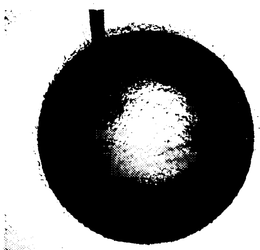

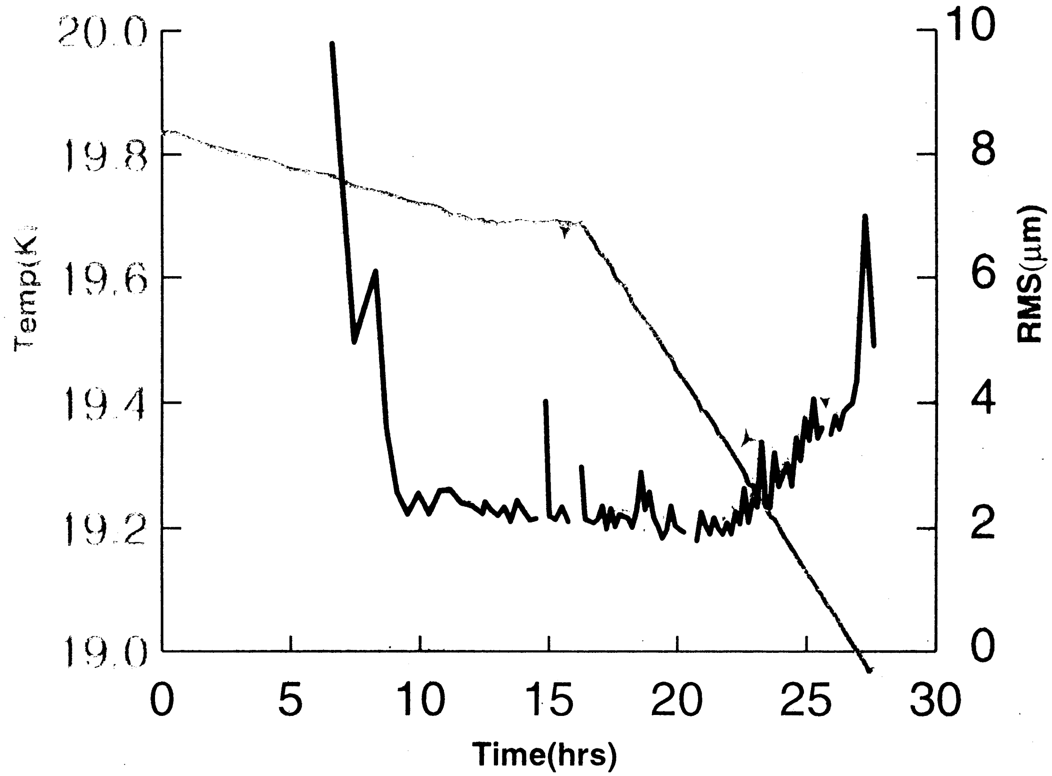

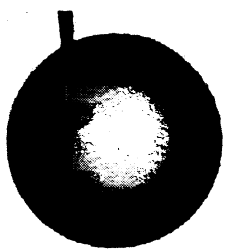

- **We are investigating several techniques to develop layers at 18K.**

Slower cooldown rate
Regrowth through vapor phase
Enhanced layering techniques

Experiments on flats show surface temperature gradients, δT/δh, reduces roughness.

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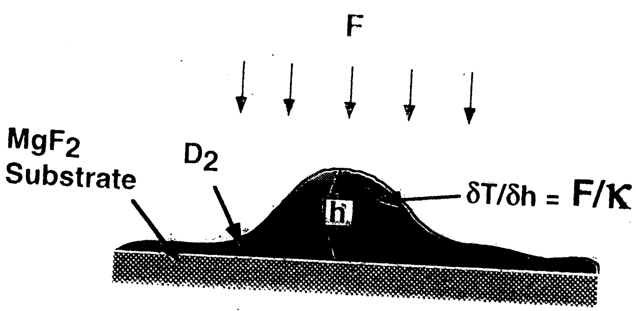
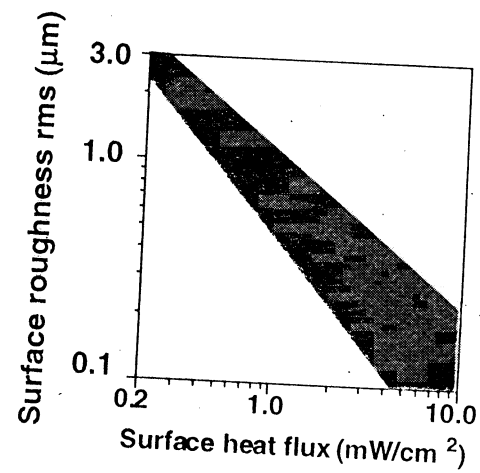
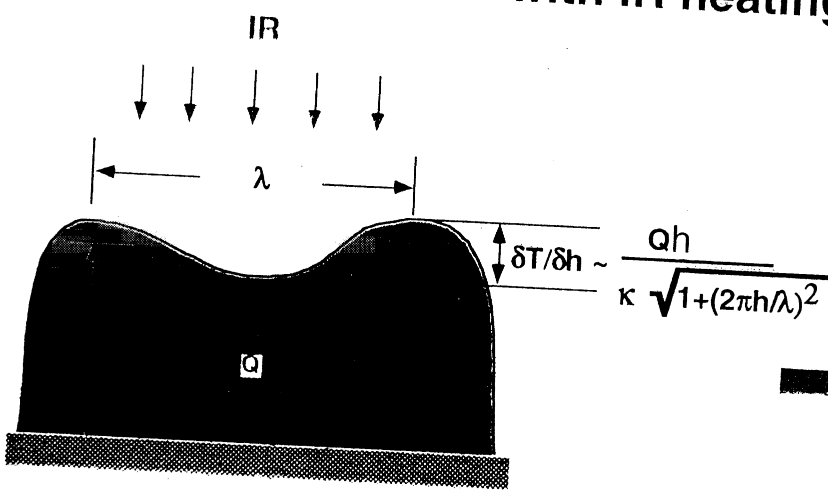
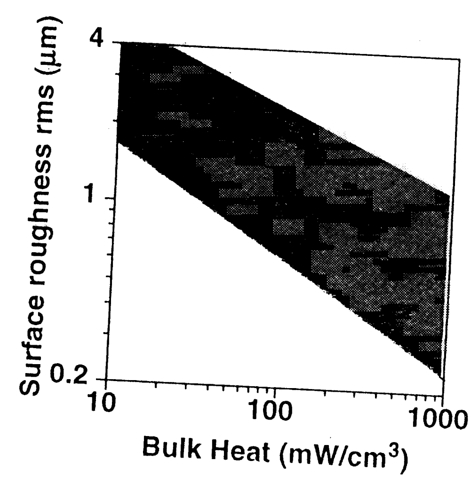
(1) Heat flux across the gas/solid interface



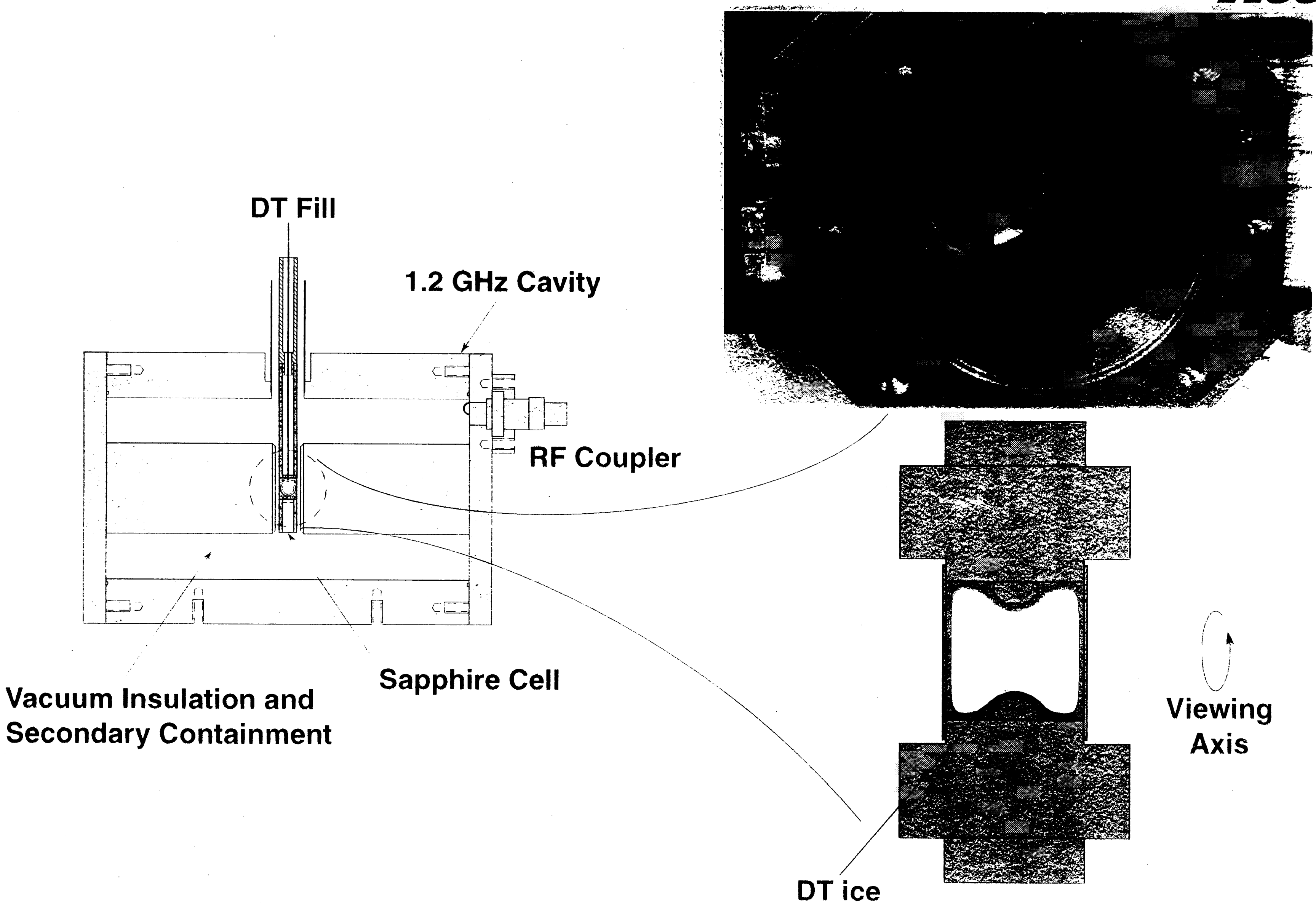


(2) Bulk heat generated with IR heating



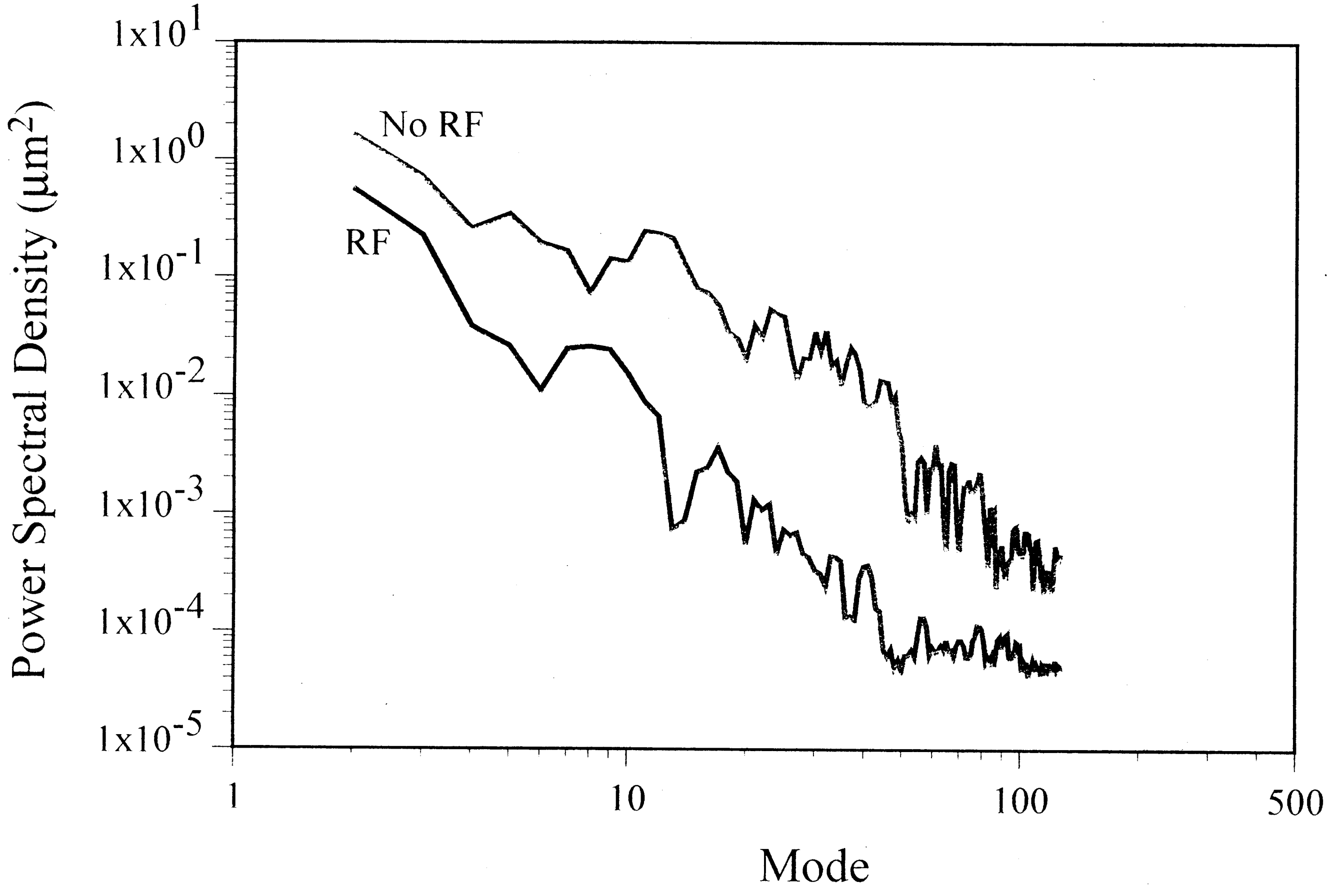


The experiment uses a complex sapphire cell inside a 1 Ghz reentrant cavity



Application of the electric field produces a significant improvement in the power spectra of the layer

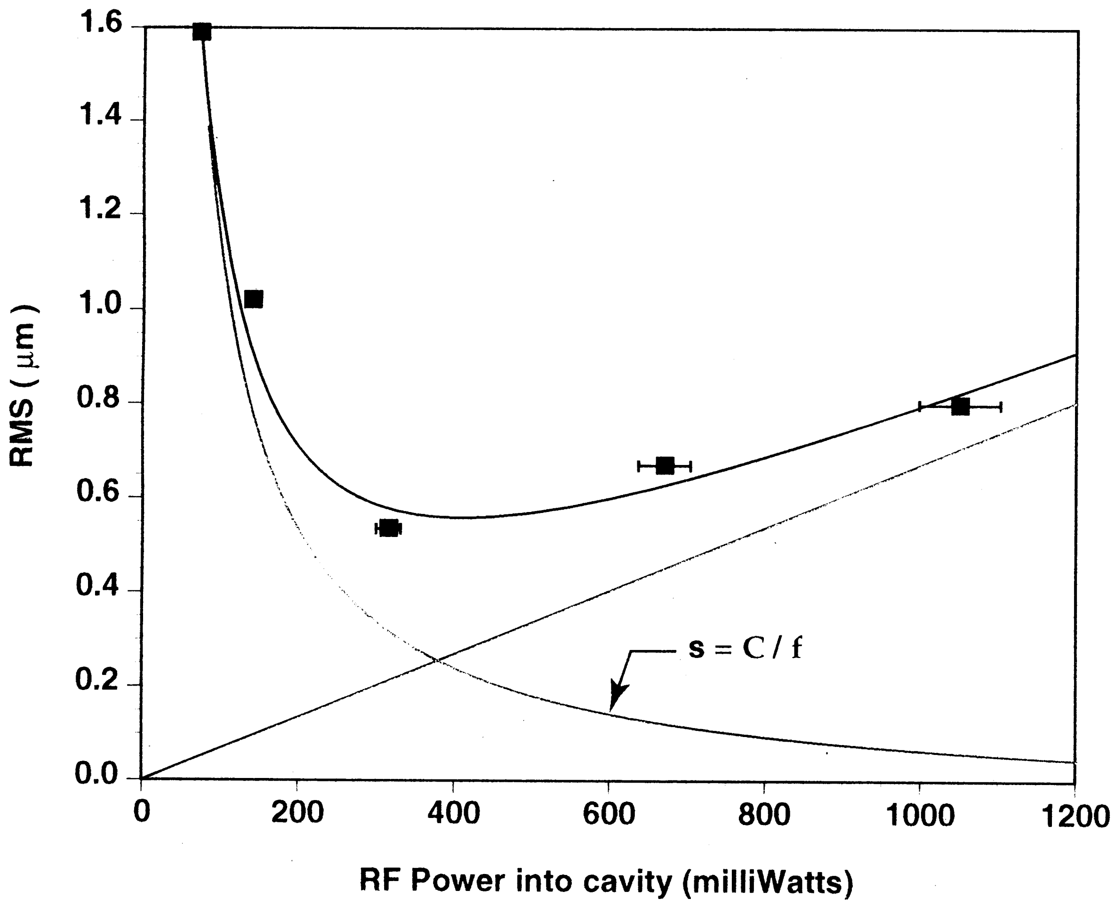
WJSA



The roughness of the layer decreases rapidly with power but is limited by the anisotropy of the field

WJSA

The data can be fit to a combination : $s = C / f + C_1 * f$



The scaling constant for smoothing is:

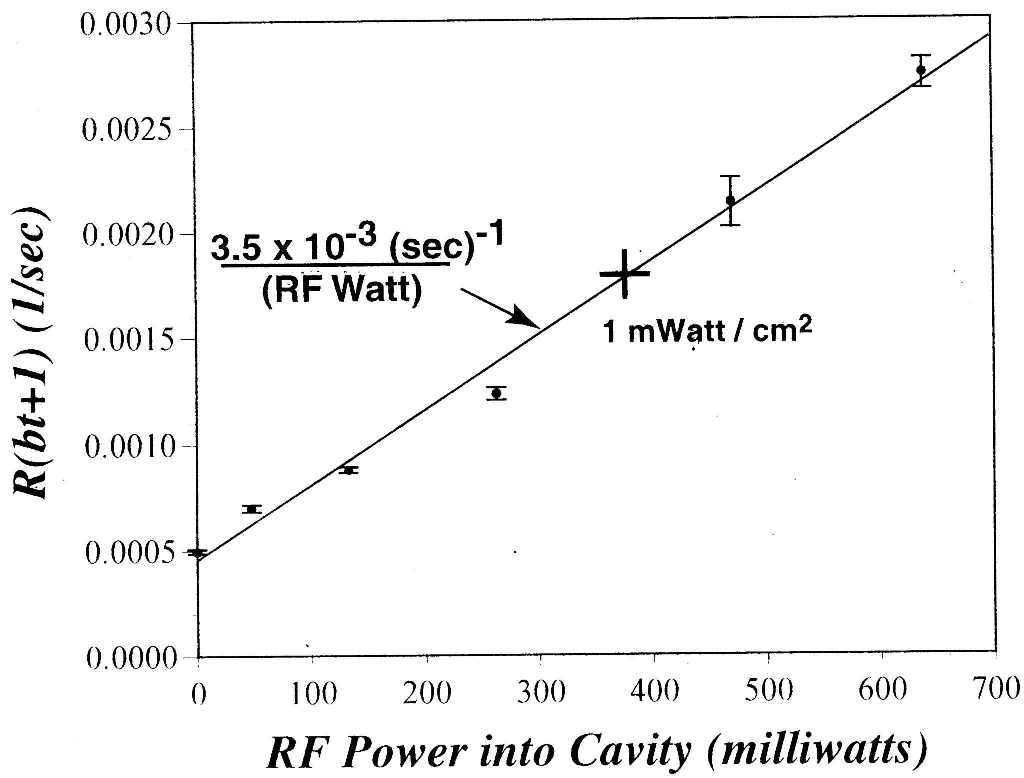
$C=0.35\ \mu$ milliwatts/cm^2

The linear rise in roughness with power is due to field anisotropy

RMSvsPowerVG

The layering rate can be used to estimate the heat flux generated at the solid-vapor interface

WJSA



- The rate produced by a heat flux goes like:

$$(bt + 1)\frac{dR}{df_s} = 1 / \rho_s h_s s$$

ρ_s is the density

s is the heat of sublimation

f_s is the heat flux

h_s is the layer thickness

- We have produced layering rates five times faster than beta layering in 100 μm DT layers
- The slope indicates that the heat flux generated is 2.65 milliwatts/cm^2-(RF Watt)

Asymmetry of the shell wall effects joule heating.

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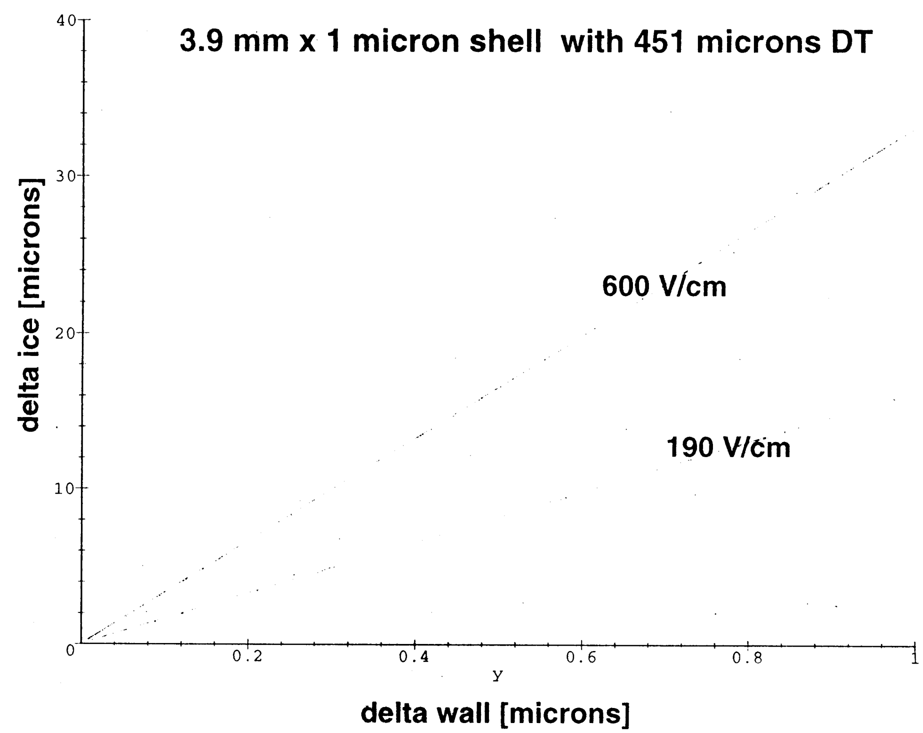
- **imaginary part of dielectric constant in "CD" plasma polymer is $\varepsilon'' = 5 \times 10^{-4}$ $P_{ave} = \omega\varepsilon''\varepsilon_0 E^2_{rms} Vol.$**

- **for a 3.9mm x 1 μm target the slope is about 33μm Δice/μm Δwall**

- **neglect dielectric loss of foam and effects of gold doping in wall**



1-d calculation of Δ ice from Δ wall and E field

Summary

Schafer

- **Current state of the art**

  ß layering will produce ~1.2 μm RMS layers at temperatures between 19.2K and the triple point

  It isn't clear how to push this further

- **Enhanced techniques are attractive for IFE**

  Possibility of higher layer quality

  Faster layering rates => higher target throughput

- **Target material issues**

  Need to know dielectric loss of CH/CD foam and of 5% Au doped CH/CD

  Higher loss tangent => tighter thickness specs