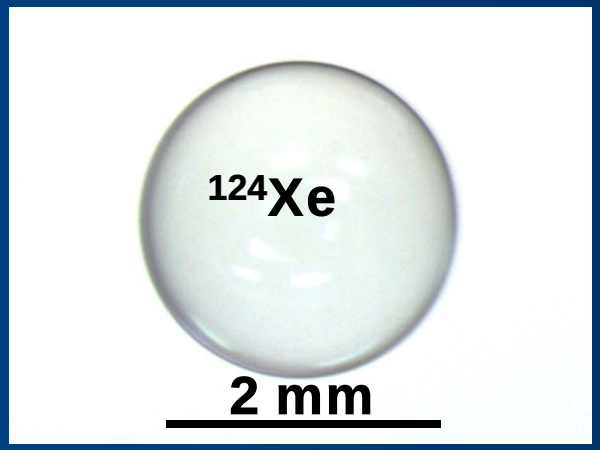
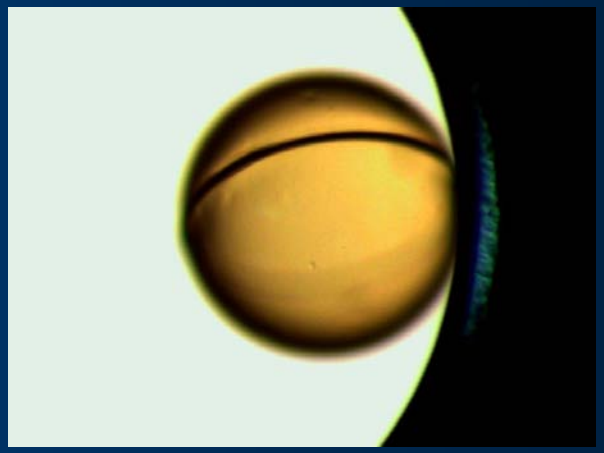
Advances in Glass Capsule Development Expand Target Fielding Capabilities





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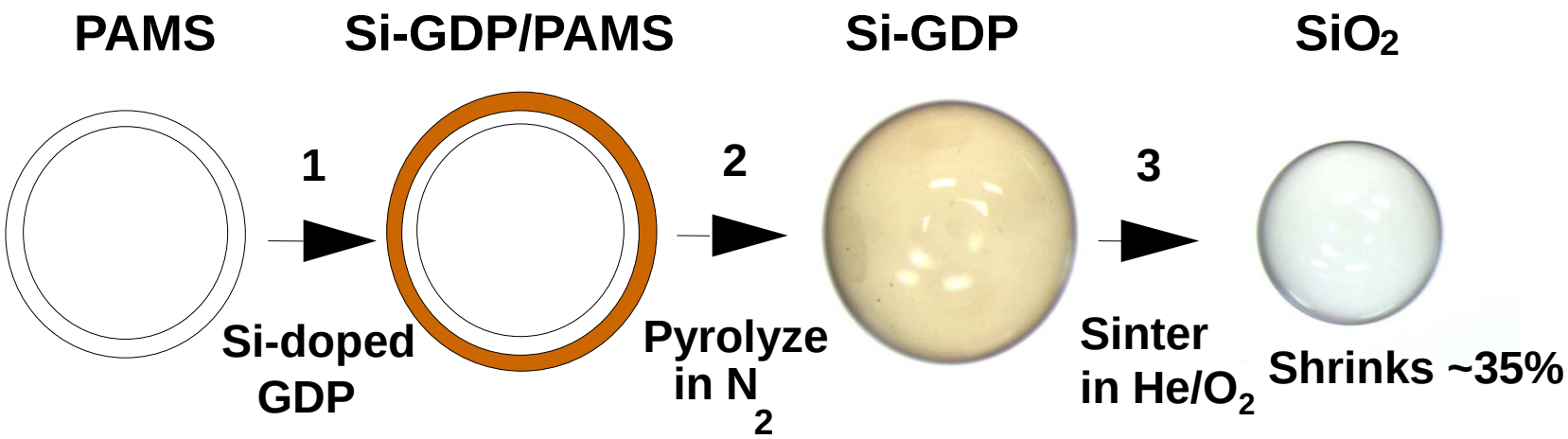
GENERAL ATOMICS

SiGDP→ Glass capsules met program needs over last two years

- **NIF Neutron diagnostics development**
  - **1600 and 2000 μm diameter can only be made by SiGDP-Glass conversion method**
- **MRS diagnostic operational qualification on NIF**
  - **Appropriate He Half lives for NIF fielding time**
- **RAGS diagnostic operational qualification for activated material collection and counting**
  - **Require Exploding Pusher capsules containing Xe124 and Xe126 stable isotopes**
  - **Measure Xe123, Xe125, and Xe127 activated by 14 MeV neutrons in Exploding Pusher capsules**
- **Trenched glass capsules enabled AWE defect experiment at LLE**

> 1.5 mm Glass Capsules only possible via SiGDP ⟶ Glass Process



<u>Sizes Delivered</u>
1600 x 4 μm
2100 x 10 μm

<u>Fill Gases</u>
Kr; Xe; D_2; H_2D_2

Diagnostic gases (Ar-Kr-Xe) must be added during the glass conversion step

Si-GDP

940C; He/O_2

→

Ar; Kr; Xe

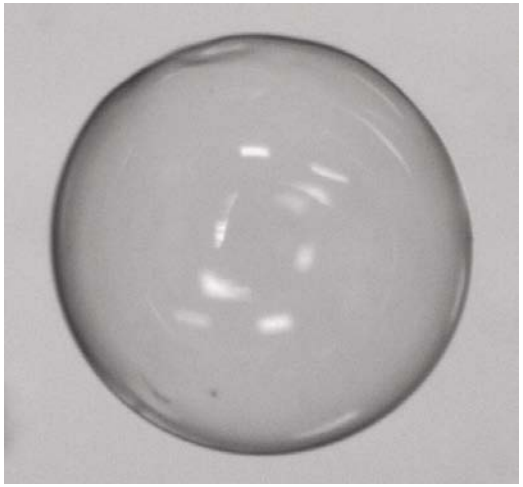
SiO_2

Glass shells are impermeable to Ar, Kr and Xe even at 940C thus must be trapped inside during the conversion process

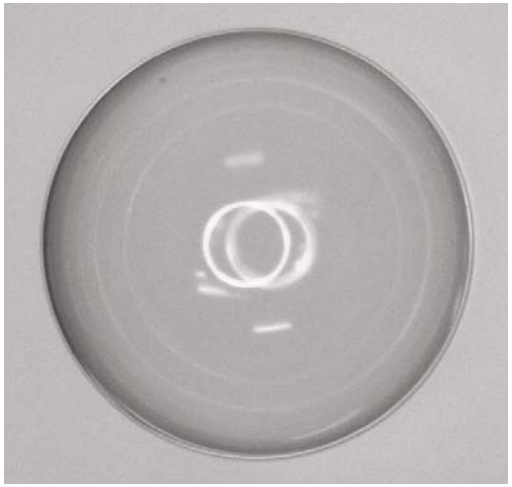
Possible concerns for glass capsules include:

- Dimples/Dent
- Residual gases
- Short He half-life when fielding on NIF
- precisely fill with diagnostic gases
- Cost concerns for expensive isotopes

Common surface attributes of exploding pusher capsules not a problem



A) Common for 1600x4μm capsules



B) Optically nice capsules uncommon

conversion process yield

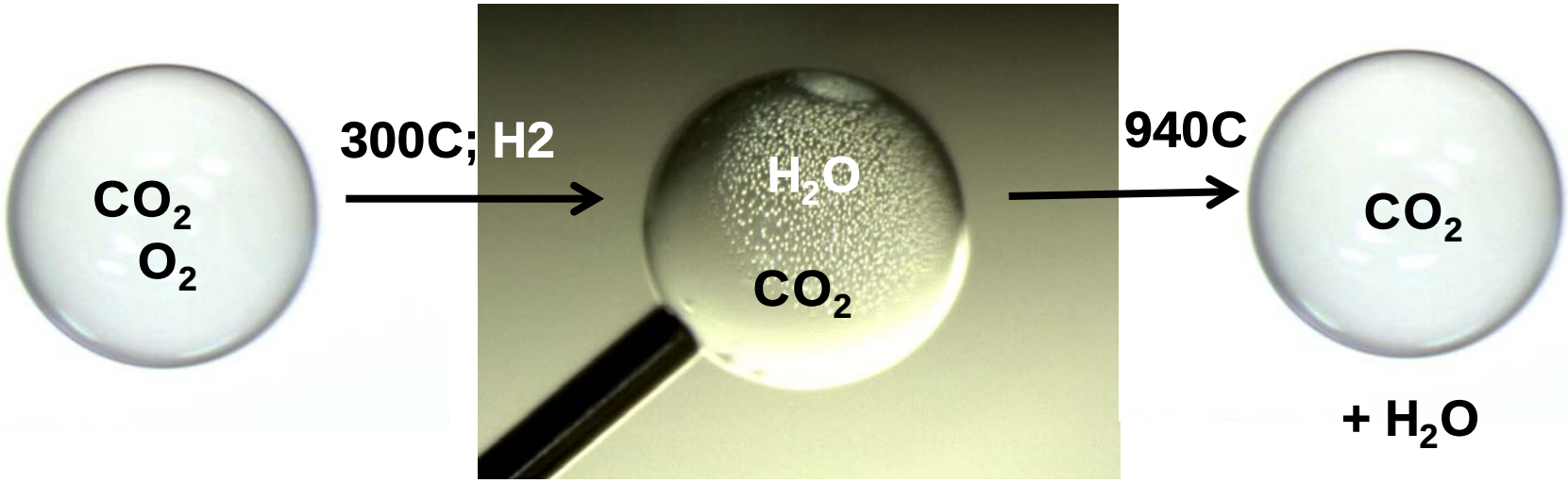
- Typically ~25% yield for type A
- Typically ~5% yield for type B
- (overall conversion yield of 1600x4μm glass capsules ~30%)

- <u>Neutron yields for type A capsules were not significantly different from type B capsules</u>

Residual gases inside glass capsules are: H_20, CO_2 and O_2 (~ 0.1 - 0.3 atm)

- **Water formed during process step removed by bake out at 940C before delivery**
- **Residual O_2 can be removed if required**

Capsule as delivered to LLE

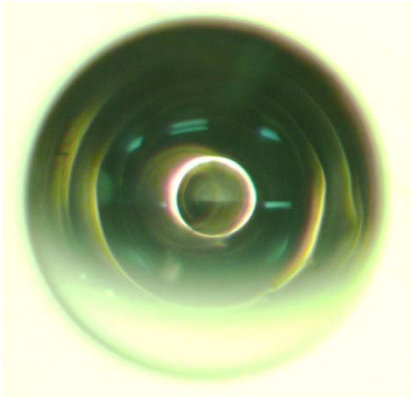


- **Residual CO_2 is permanent**

He gas retention improved by Al layer

- 1600 x 4 μm glass capsule He HL = < 3hr
- < 0.1μm Al layer improves He retention by ~ 4x
  - improved knowledge of He pressure at shot
  - less out-gassing reduces He over-pressure fills
  - enables longer target chamber fielding times

~1600x4μm
He HL ~ 2.5hrs



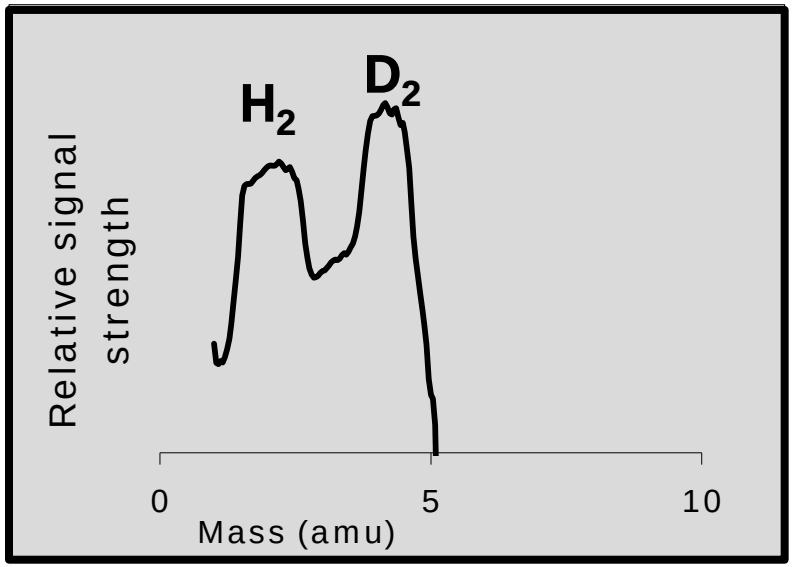
~1600x4μm
He HL ~ 10hrs

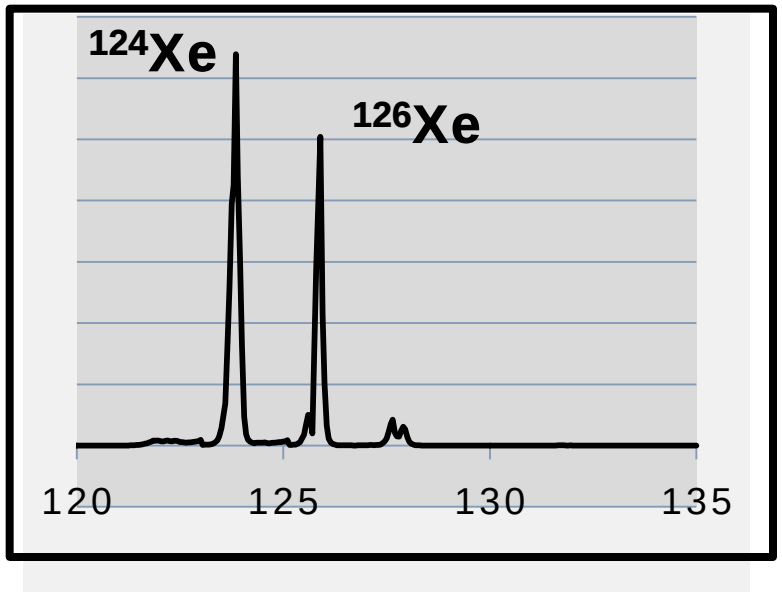
NIF startup experiments required precise H_2D_2 fills; RAGS experiments needed ^{124}Xe

- **Precise ratio and pressure of H2/D2 for Neutron Diagnostic Experiments**
  - needed to insure that neutron yield on NIF stayed within allowed limits during NIF startup

- **Glass capsules filled with ^{124}Xe gas for RAGS commissioning and NIS Diagnostics**
  - normal Xe is only ~.09% ^{124}Xe
  - 50% enriched ^{124}Xe gas costs ~$12,000/liter

Mass spec technique developed to confirm fills





Precise determination of H2/D2 ratio confirms that neutron yield should stay within the allowed limits

Accurately determined Xe isotope ratios allow for accurate analysis of RAGS performance

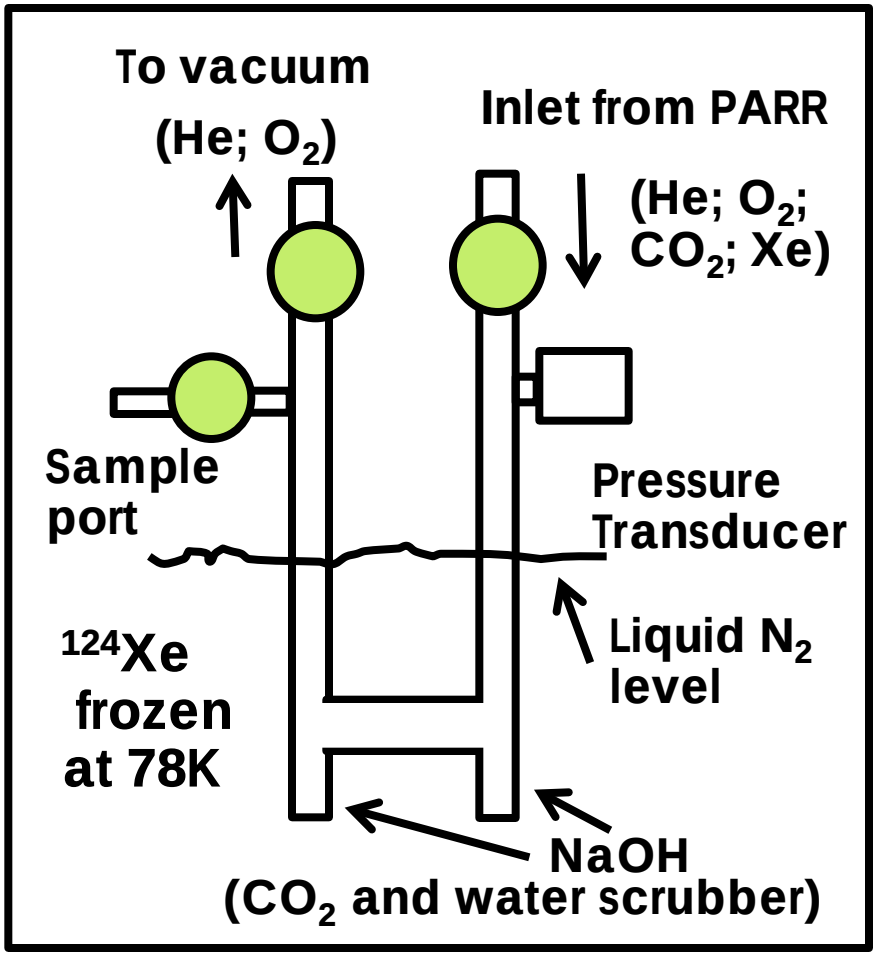
Gas recovery system built to reclaim expensive fill gases

- Recent NIF experiments required very expensive (~$20k/liter) ^{124}Xe

  – volume of PARR conversion oven is ~6 liters thus a relatively large volume of ^{124}Xe was required

  – an effective recovery system immensely lowers cost when doing multiple glass conversion runs

Diagram of Recovery System



Test of recovery system demonstrates that it works

Initial Trial Gas Composition in PARR Oven

13% Xe; 66% He; 21% O_2 (normal Xe)

Recovered Trial Gas Composition

Purity: 99% Xe; 0.8% He; 0.3% O_2 (by mass spec)
90% of initial Xe recovered

Actual Recovered DDC 920 ^{124}Xe Results

Purity: 99% (^{124}Xe+^{126}Xe); 0.1% He; 0.3% O_2; 0.5% CO; <0.1% CO_2
88% of initial ^{124}Xe recovered
~$4800 ^{124}Xe in PARR; ~$4200 ^{124}Xe recovered

Trenched glass capsules were fabricated for AWE experiments at LLE

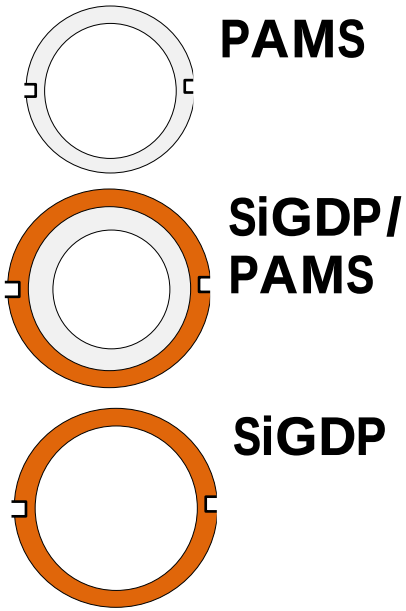
- **Request: 580 x 4 μm glass shells with an equatorial trench ~ 2 μm deep, overcoat with ~ 30 μm of CH**

- **Three different approaches attempted to make glass shell**

  - machine trench in PAMS mandrel then overcoat with SiGDP

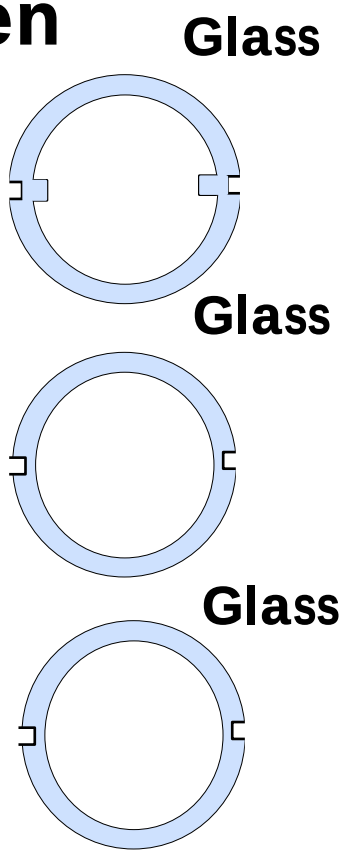
  - coat PAMS mandrel with SiGDP then machine trench

  - coat PAMS mandrel with SiGDP then remove PAMS then machine trench



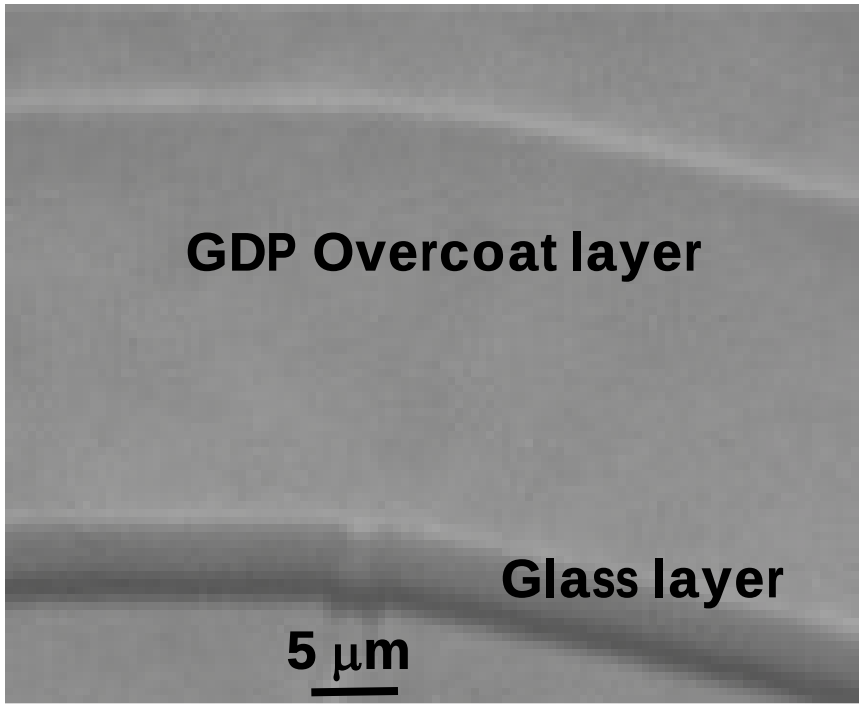
Two methods produced glass capsules after SiGDP to glass conversion

- **Machine trench in PAMS mandrel then overcoat with SiGDP**
  - Three of six shells survived
- **Coat PAMS mandrel with SiGDP then machine trench then remove PAMS**
  - One of six shells survived
- **Coat PAMS mandrel with SiGDP then remove PAMS then machine trench**
  - Zero of six shells survived

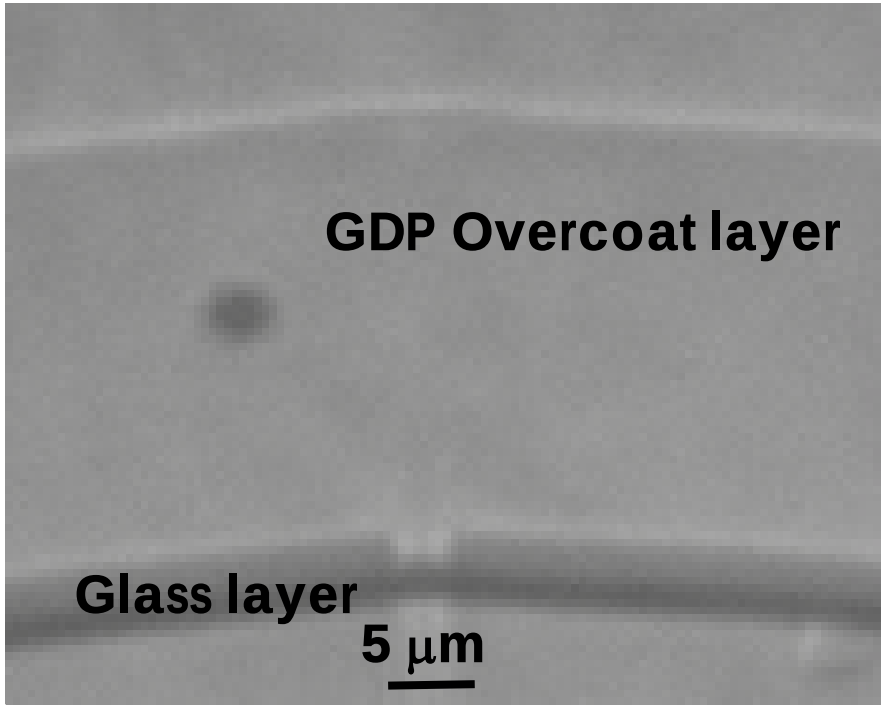


30 μm GDP overcoat fills in 2 μm deep trench and resulted in bulge on outer GDP surface

Type 1



Type 2

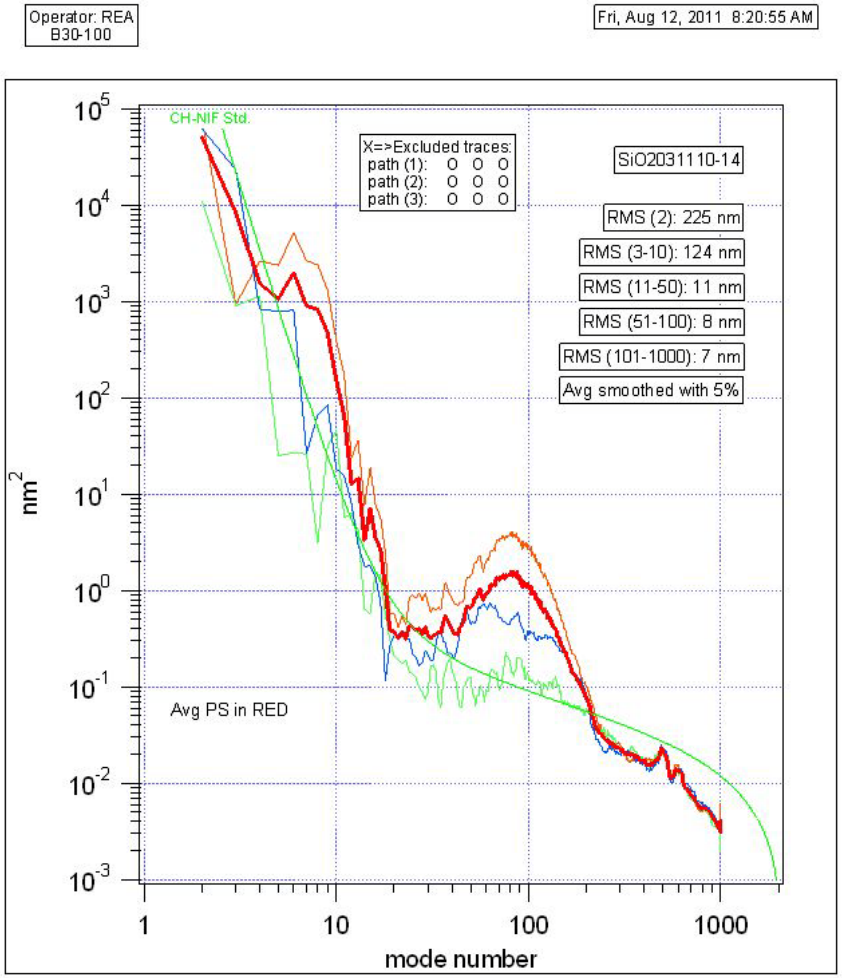


Future plans / new requests

- 2-3 micron wall trials
- 2800 micron OD
- dimpling evaluation
- Ongoing yield improvement/understanding
- Improved burst/buckle strength – increased handling capability

2000 x 4 μm glass capsules have been demonstrated

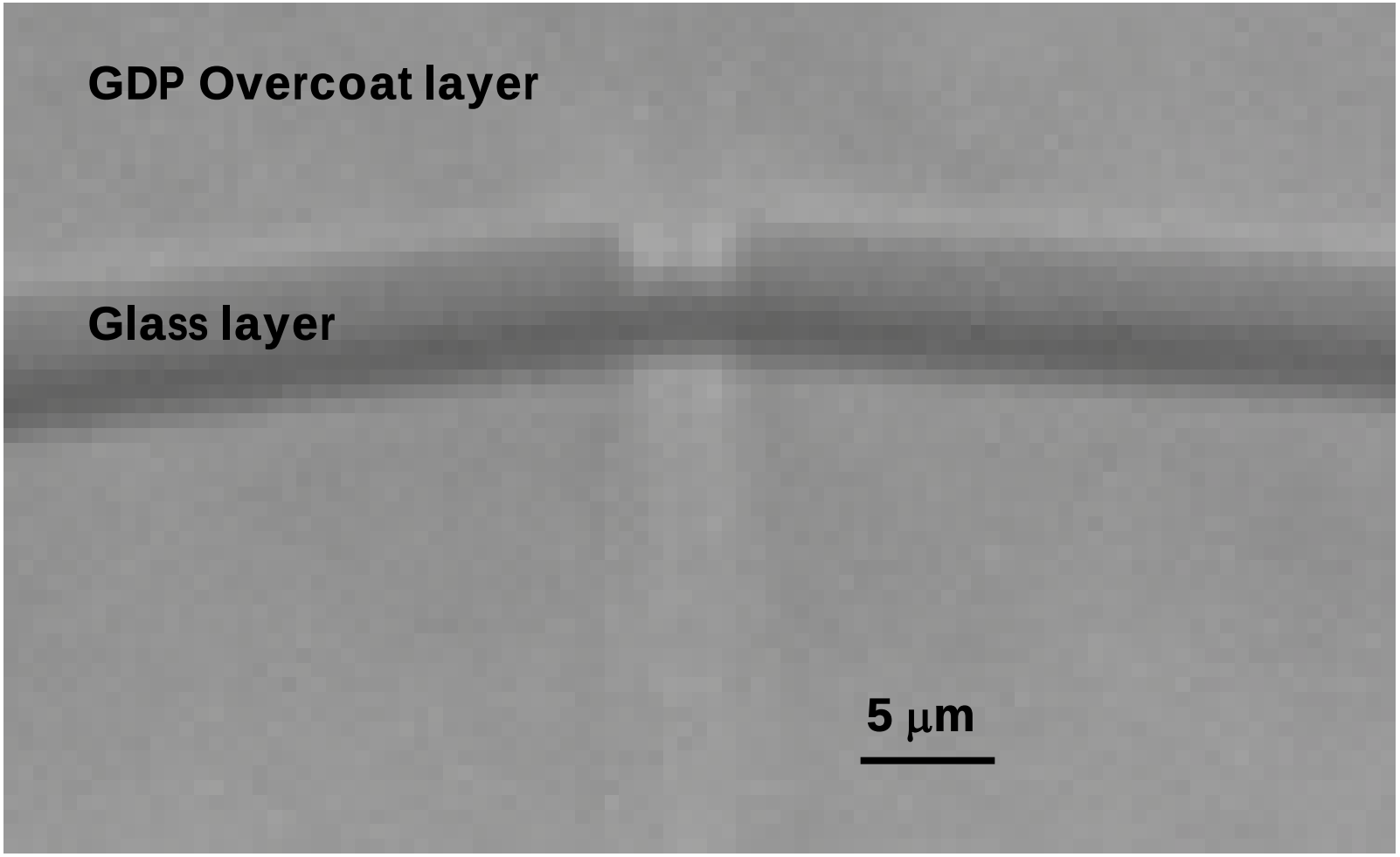
2061μm OD x 4.0μm wall



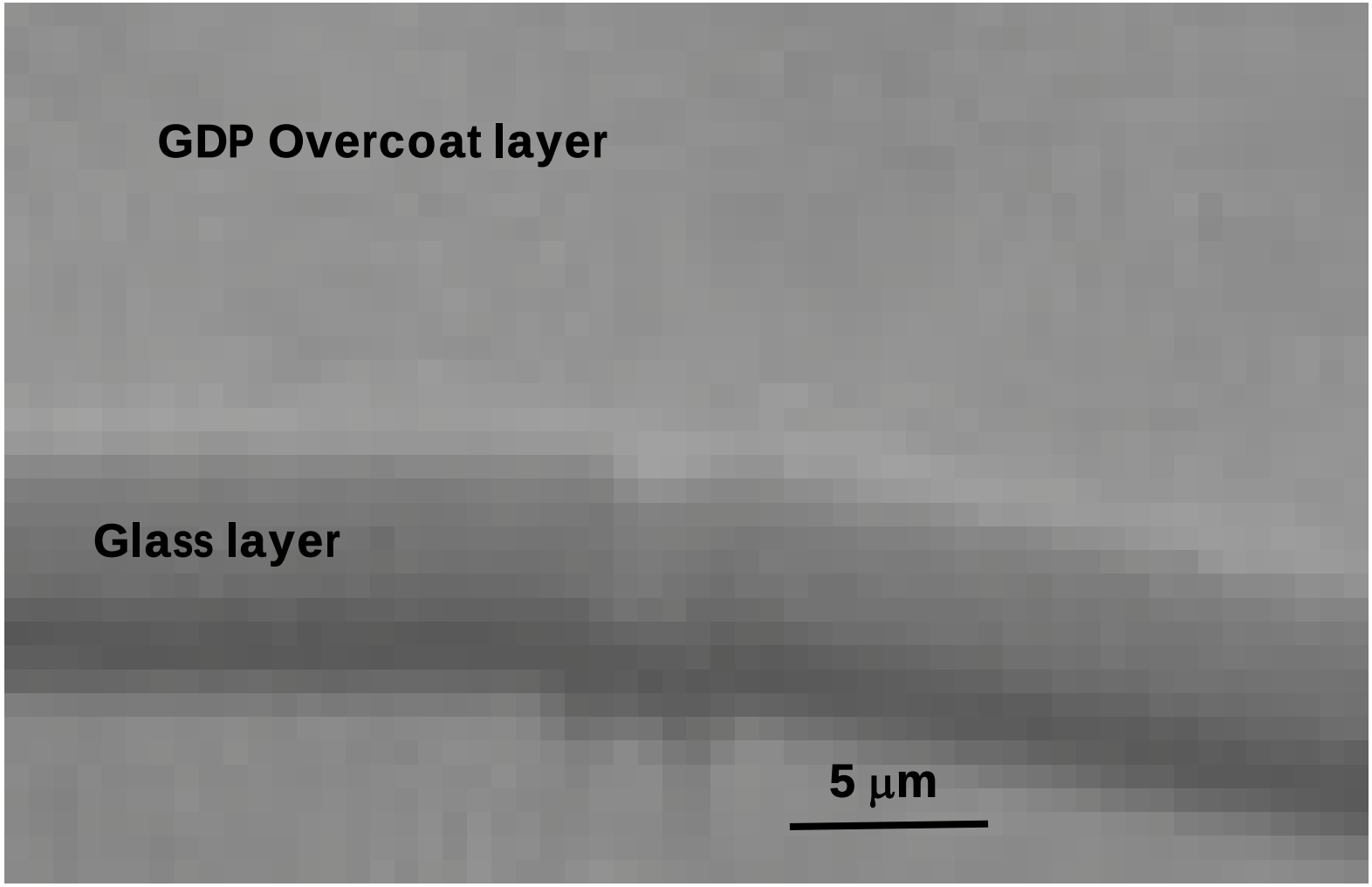
SiGDP ⟶ Glass capsules continue to satisfy ICF community needs

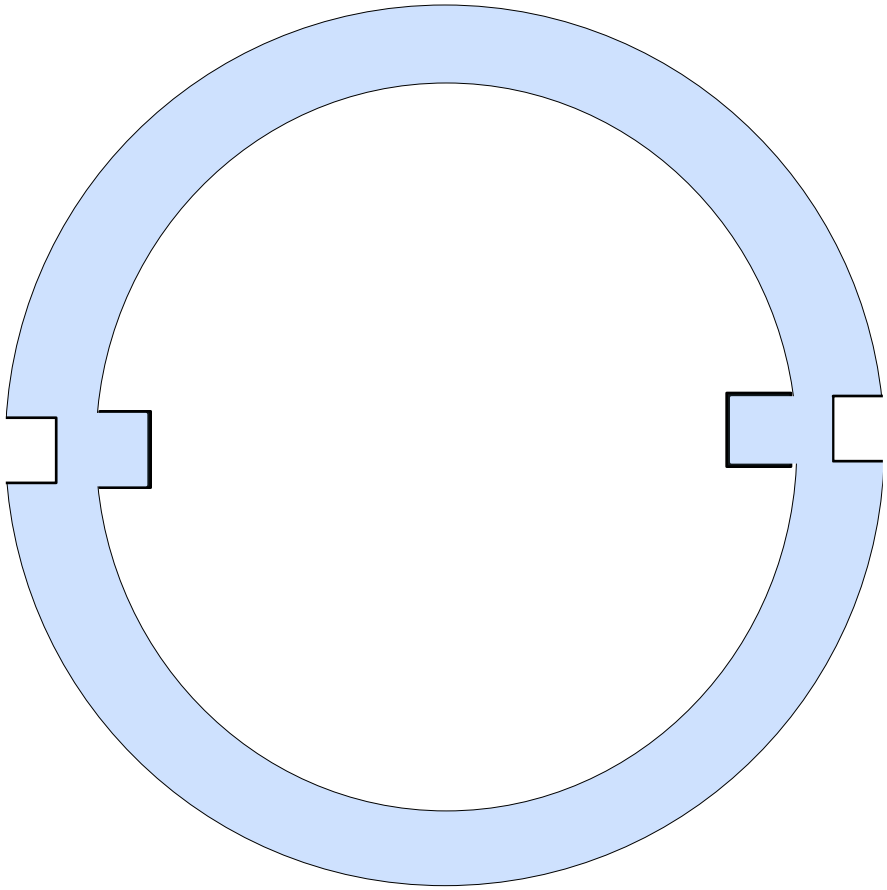
- Glass shells up to 2.1mm in diameter are reliably available
- recovery system developed to reduce cost
- Mass Spec based characterization developed to meet specific needs (H_2/D_2; ^{124}Xe)
- Al coatings allow helium half-lives to be adjusted for reliable fielding on the NIF
- First-ever engineered defect glass capsules manufactured in support experiments at LLE

X-Radiograph of GDP/Glass Shell with Type 2 Trench Confirms Thinner Glass with No ID Offset



X-Radiograph of GDP/Glass Shell with Type 1 Trench Confirms Uniform Glass with ID Offset

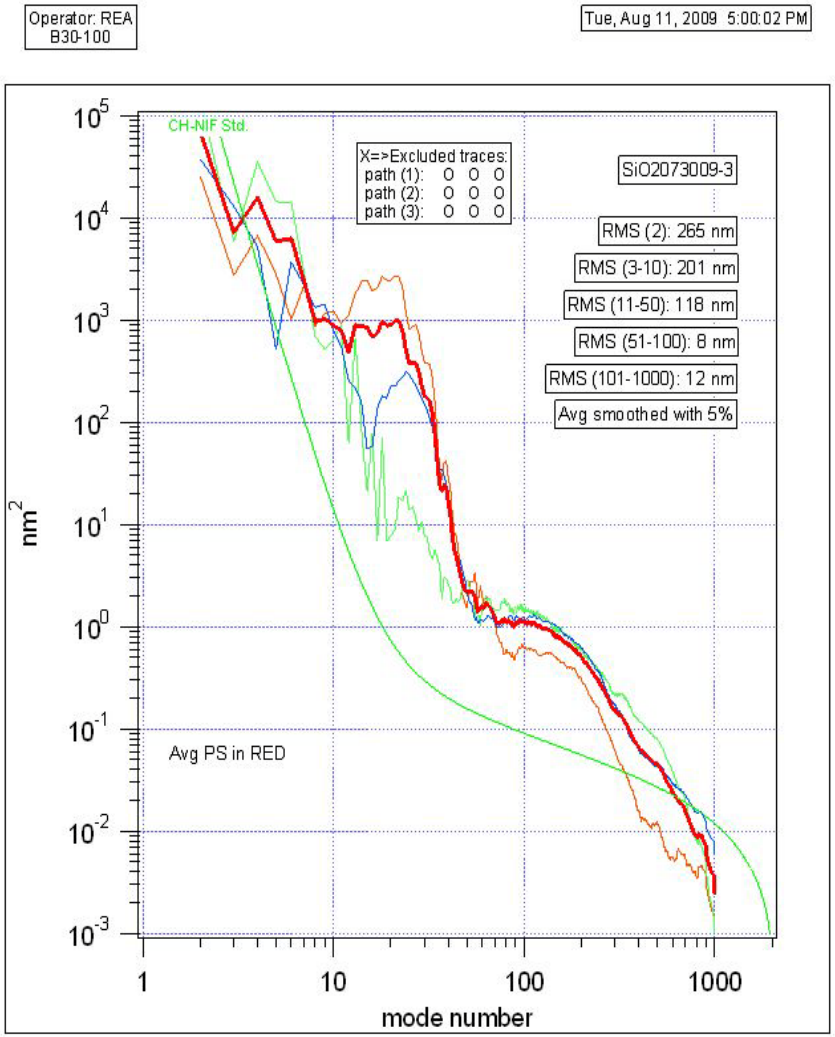


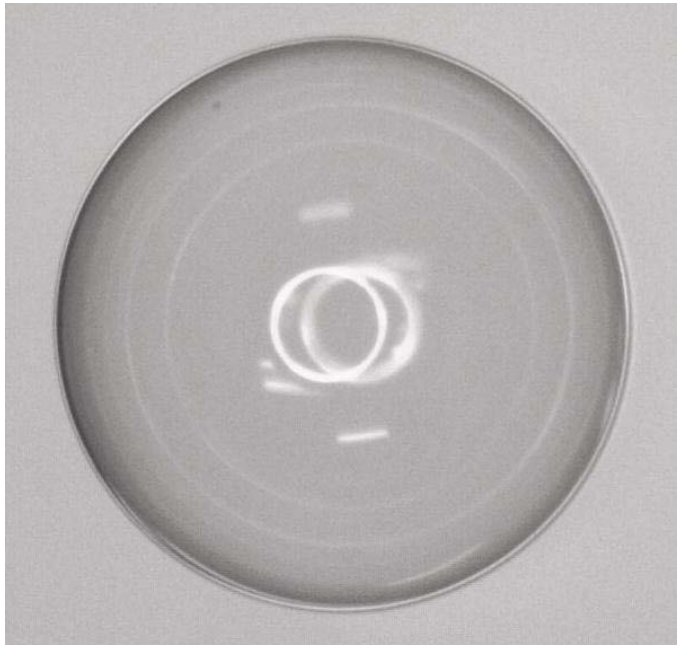


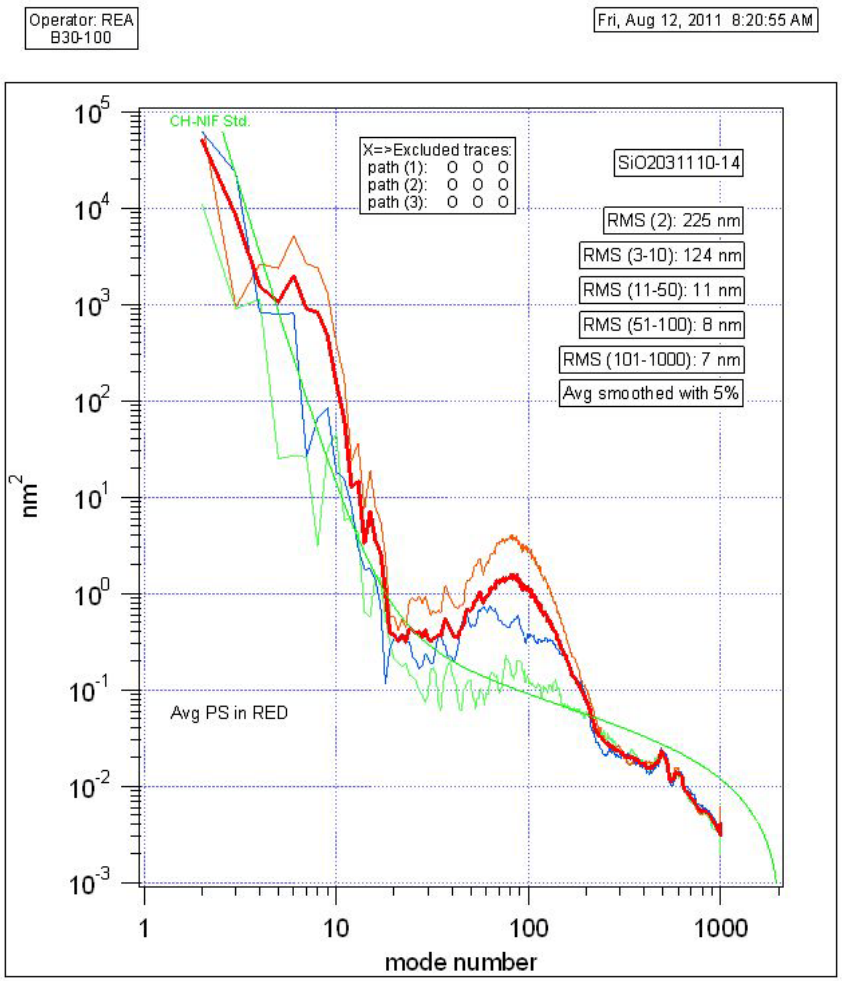
List of slide titles: - suggested flow

- SiGDP Glass capsules met program needs over last two years
- > 1.5 mm Glass Capsules only possible via SiGDP Glass Process
- Diagnostic Gases (Ar-Kr-Xe) Must be Added During the Glass Conversion Step
- Possible concerns for glass capsules include
- Common surface attributes of exploding pusher capsules not a problem
- Residual gases inside glass capsules are: H_20, CO_2 and O_2 (~ 0.1 - 0.3 atm)
- He gas retention improved by Al layer
- NIF startup experiments required precise H_2D_2 fills; RAGS experiments needed ^{124}Xe
- Mass spec technique developed to confirm fills
- Gas recovery system built to reclaim expensive fill gases
- Test of recovery system demonstrates that it works
- Trenched glass capsules were fabricated for AWE experiments at LLE
- Two methods produced glass capsules after SiGDP to glass conversion
- 30mm GDP Overcoat Fills in 2mm Deep Trench and Results in Bulge on Outer GDP Surface
- Future plans / new requests
- 2000 x 4 μm glass capsules have been demonstrated
- SiGDP Glass capsules continue to satisfy ICF community needs

Even the Optically Nice 1600x4μm Shells Have High Mid-Mode Roughness by Spheremap



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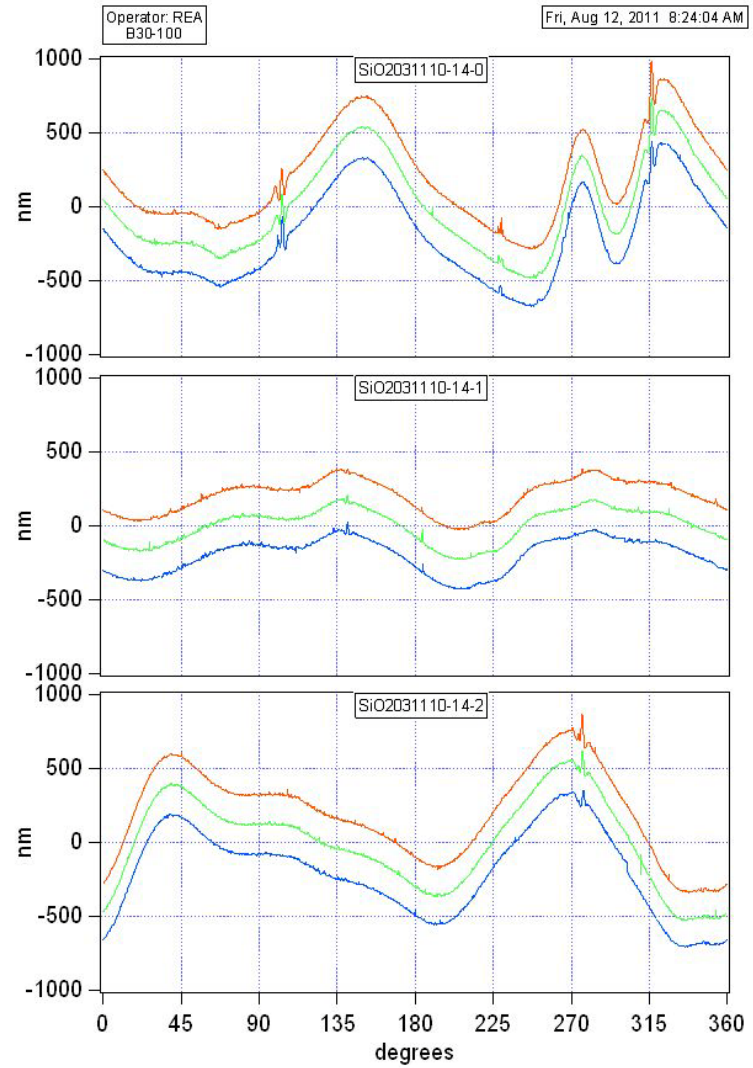
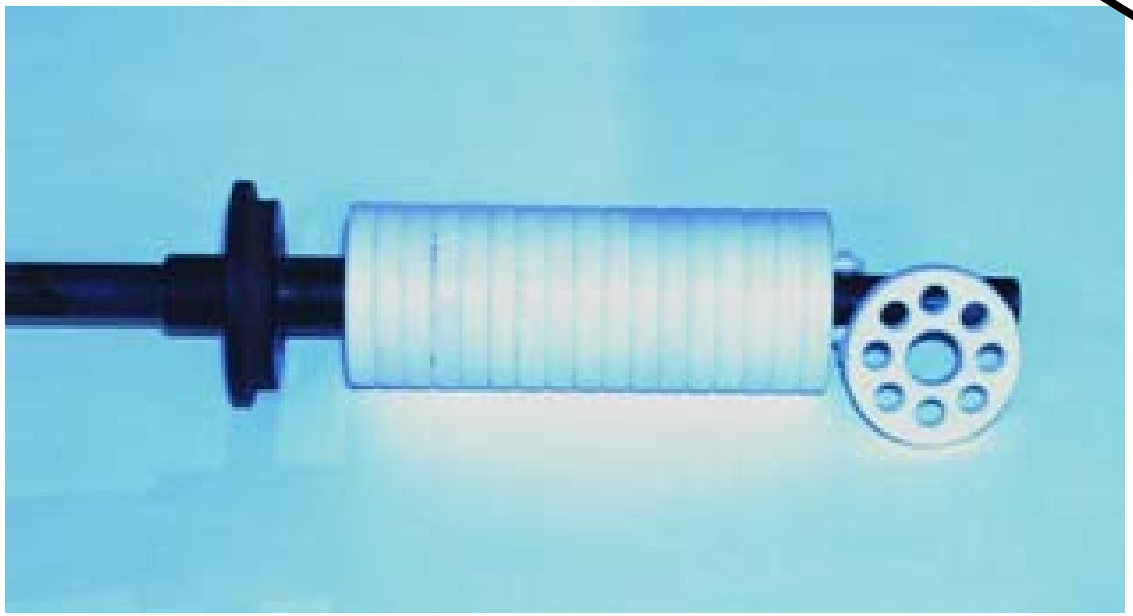
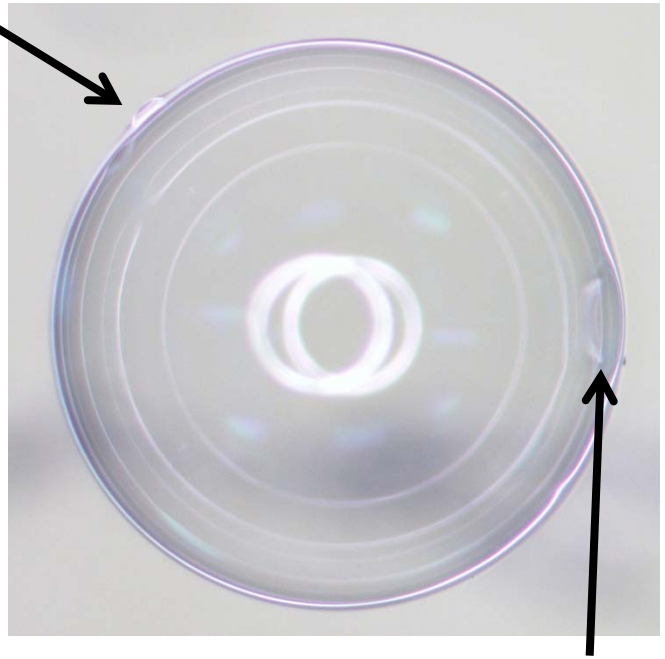
B30-100
Fri, Aug 12, 2011 8:20:55 AM
CH-NIF Std.
X=>Excluded traces:
path (1): O O O
path (2): O O O
path (3): O O O
SiO2031110-14
RMS (2): 225 nm
RMS (3-10): 124 nm
RMS (11-50): 11 nm
RMS (51-100): 8 nm
RMS (101-1000): 7 nm
Avg smoothed with 5%
Avg PS in RED
nm2
mode number


Operator: REA
B30-100
Fri, Aug 12, 2011 8:24:04 AM
SiO2031110-14-0
SiO2031110-14-1
SiO2031110-14-2
nm
degrees

Shell Rotation System Helps to Reduce Pimples and Holes During Conversion to Glass





Note: While occurrence of pimples has been nearly eliminated, dimples (dents) and wrinkles still common.