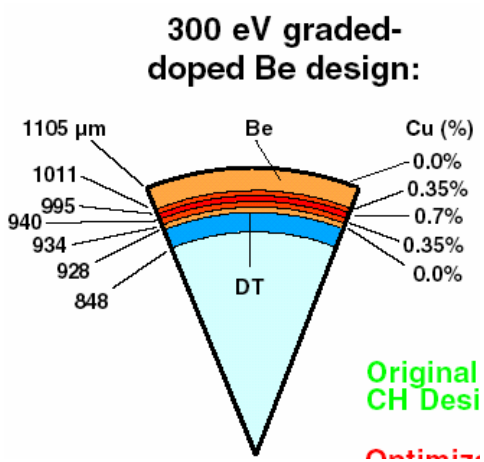
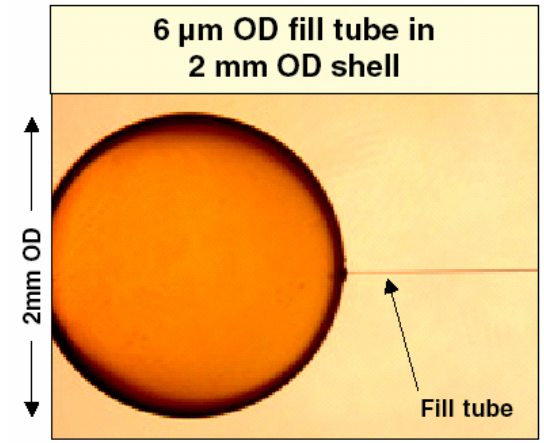
Innovation in target fabrication can reduce cost, schedule and risk of ignition and compensate for driver inflexibility





US Japan IFE Workshop

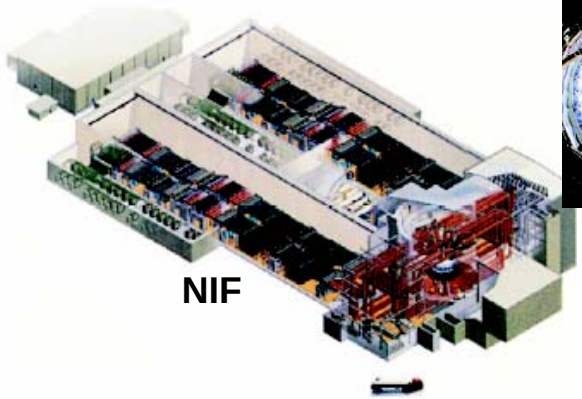
3-22-05

Joe Kilkenny

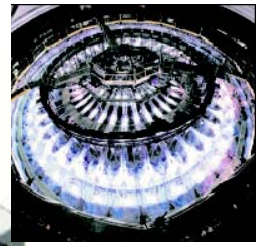
General Atomics

Success inHEDP, and Ignition requires–

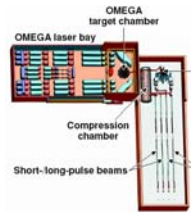
- **Drivers**
  -major investment



NIF



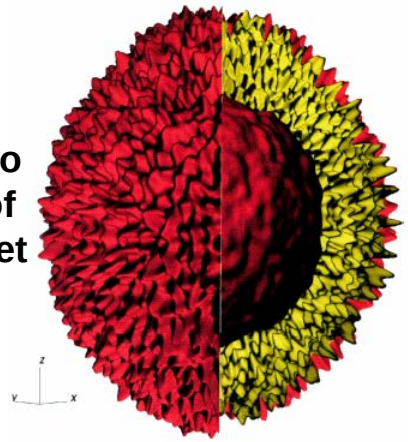
Z-R



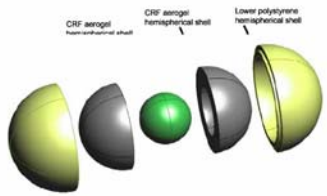
OMEGA EP
& Nike,Trident,..

- **Simulations,** ASCI
  -major investment

3D rad.-hydro Simulation of igniting target



- **Target S&T**
  -Cinderella
  ~$25M FY 04



Double shell target

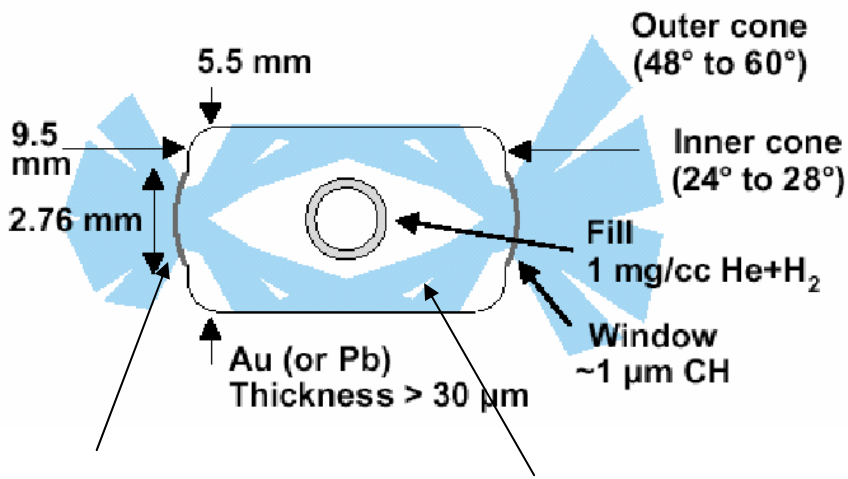
There has been inadequate investment in target fabrication S&T commensurate with its role in the SS Program

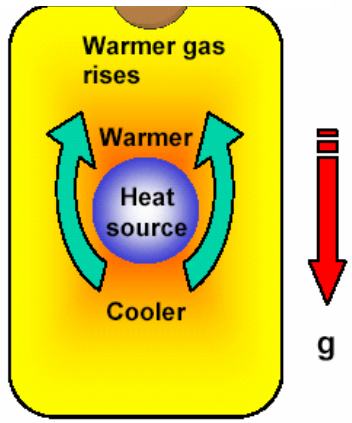
3D codes allow sophisticated 3D targets, reduce risk, cost and schedule & compensate for driver limitations

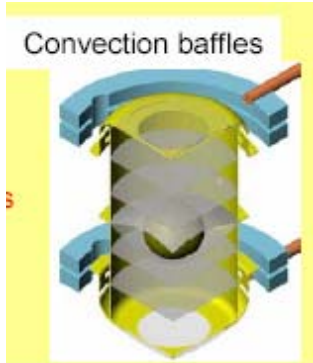
- **Hohlraums-gas fill reduces symmetry swings**
- **Cocktail hohlraum wall reduce x-ray wall loss-helps <u>all</u> drivers**
- **Graded doped ablators reduce instability,allow fill tubes& reduce cryo cost for NIF ignition target**

Innovation in target fabrication compensates for driver and facilty limitations

Innovation in target fabrication: gas fill in Hohlraums provides symmetry control- Compensates for driver inflexibility







thin(0.1μm) windows

Gas fill Reduces wall Motion BUT → Convection -- → Baffles or low ρ foams

Target fabrication challenges remain!

Target fabrication and characterization Drives target choices

•Beryllium is the best ablator-

PHYSICS OF PLASMAS VOLUME 5, NUMBER 5 MAY 1998

The development and advantages of beryllium capsules for the National Ignition Facility*

Douglas C. Wilson,[†,a)] Paul A. Bradley, Nelson M. Hoffman, Fritz J. Swenson, David P. Smitherman, Robert E. Chrien, Robert W. Margevicius, D. J. Thoma, Larry R. Foreman, James K. Hoffer, S. Robert Goldman, and Stephen E. Caldwell
Los Alamos National Laboratory, Los Alamos, New Mexico 87545

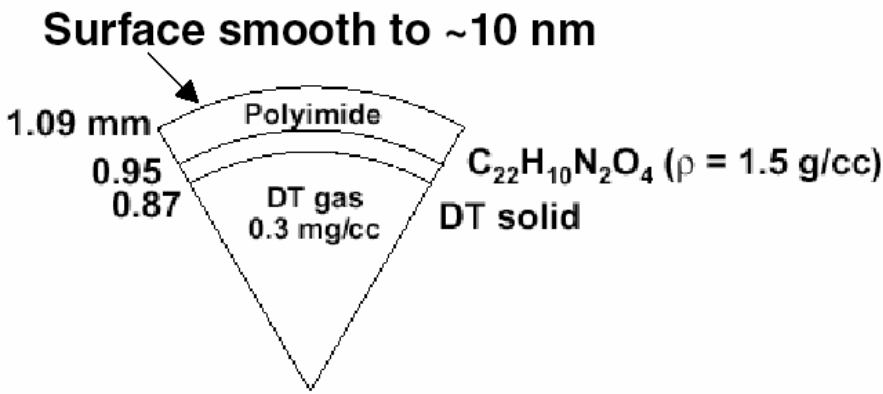
Thomas R. Dittrich, Steven W. Haan, Michael M. Marinak, Stephen M. Pollaine, and Jorge J. Sanchez
Lawrence Livermore National Laboratory, Livermore, California 94551

- But Be has fabrication and characterization issues:
  - surface finish
  - filling
  - no augmented beta layering
  - characterization difficult- opaque

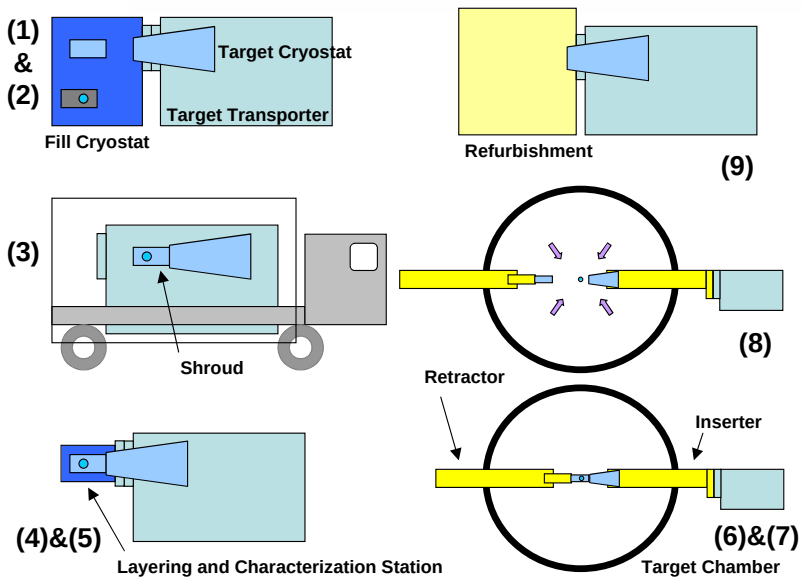
The first choice NIF ignition target was diffusion filled plastic with fewer target fab. issues

The NIF baseline target was plastic diffusion filled

•Baseline target-diffusion fill
- Physics issues
  - -surface finish
  - -augmented β layering
  - -Optical characterization



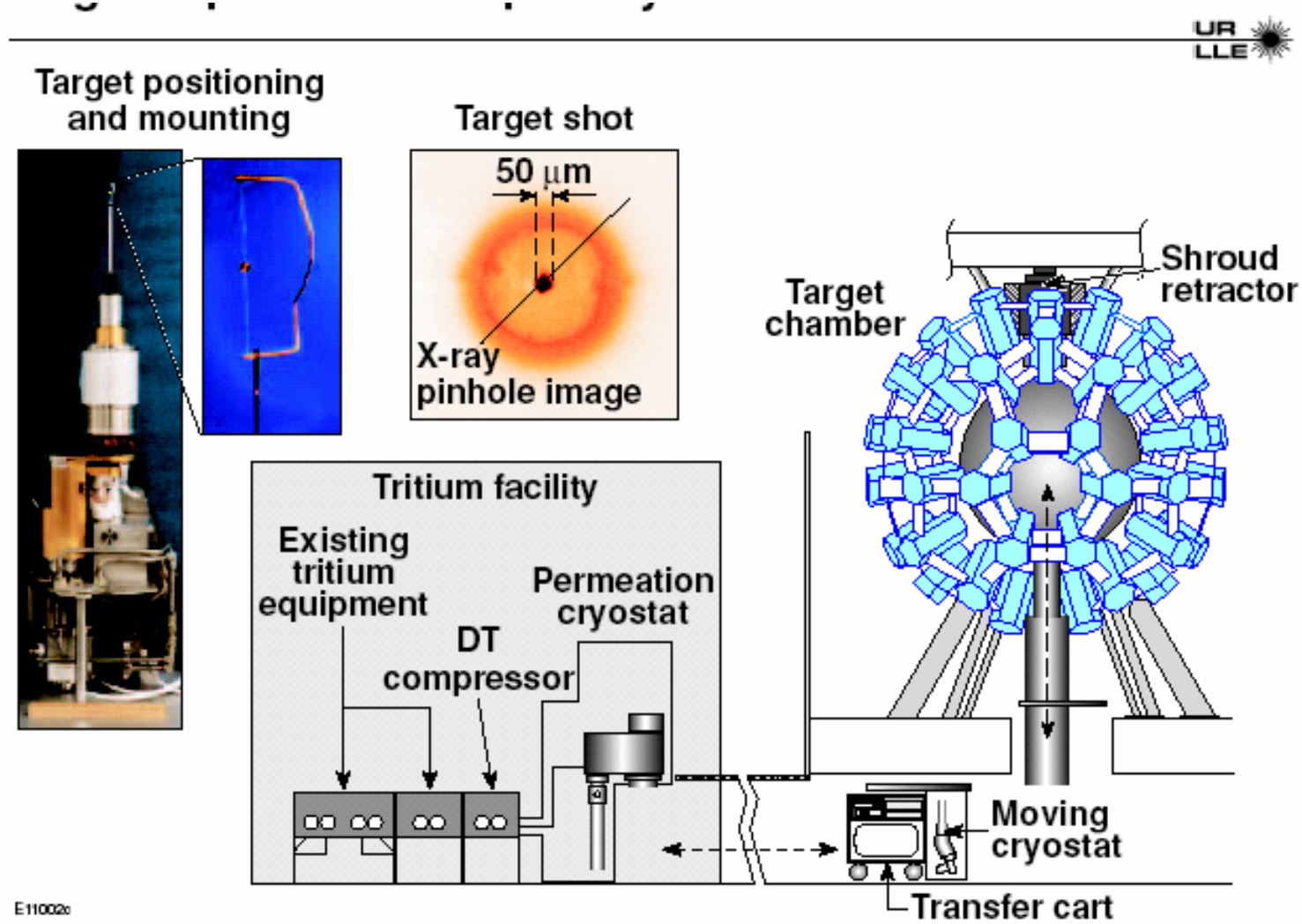
BUT



- $ and schedule issues with The NIF cryogenic target handling system because diffusion fill/cold transport

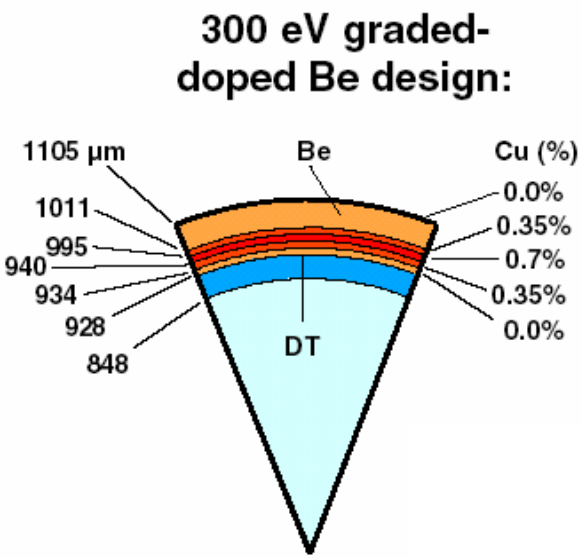
The large number of cryo. sub-systems increases complexity & cost

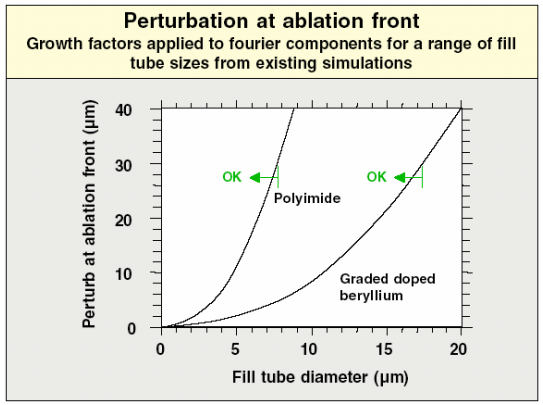
A 10 year ~ $30M GA & LLE effort was required for the OMEGA diffusion & cold fill cryo system: NIF prototype

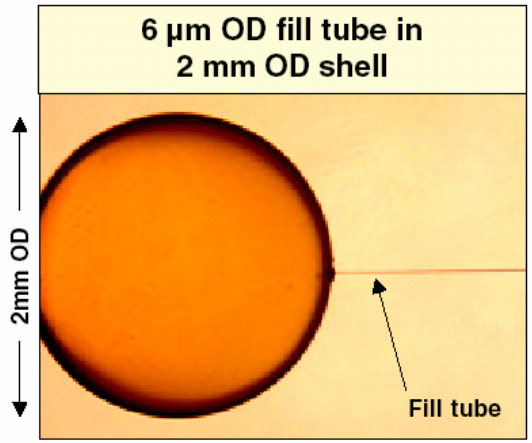


Tritium use late 2004?

Innovation in target fabrication: graded dopant Be shells less unstable & may allow a fill tube







Graded Cu dopant In Be shell → **Is less Unstable How much less?** → **A small fill tube may Not cause too large A perturbation:**

Filling in situ reduces the cost of the NIF cryo system

Dopants in the ablators are required to reduce x-ray preheat at the ablator-ice interface

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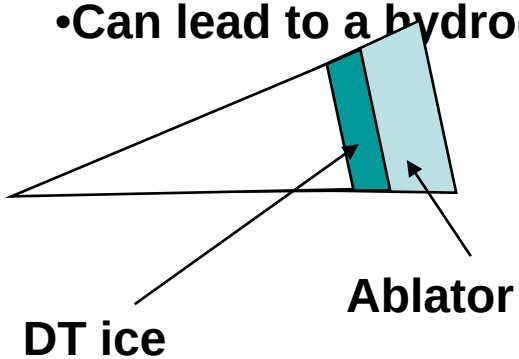
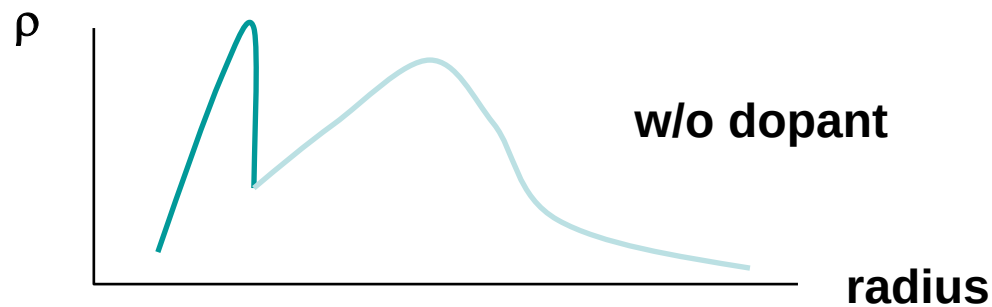
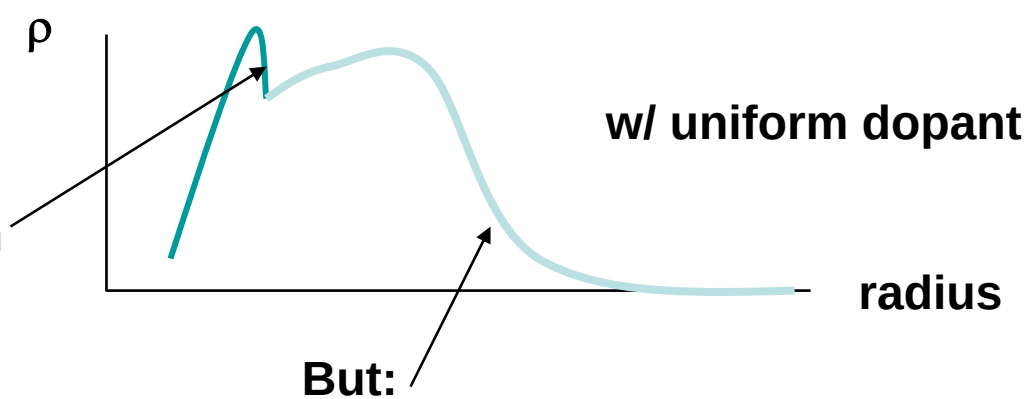
- X-ray preheat at ice-ablator interface heats absorbed by ablator not by ice
- This makes ablator less compressible than DT ice
- Can lead to a hydrodynamically unstable interface







Reducing x-ray preheat can reduce density jump (Atwood number) at interface

But:

Shorter ablation scalelength
Lower mass ablation rate

Innovations in target fabrication using Be with graded Cu dopant provide much more stability margin

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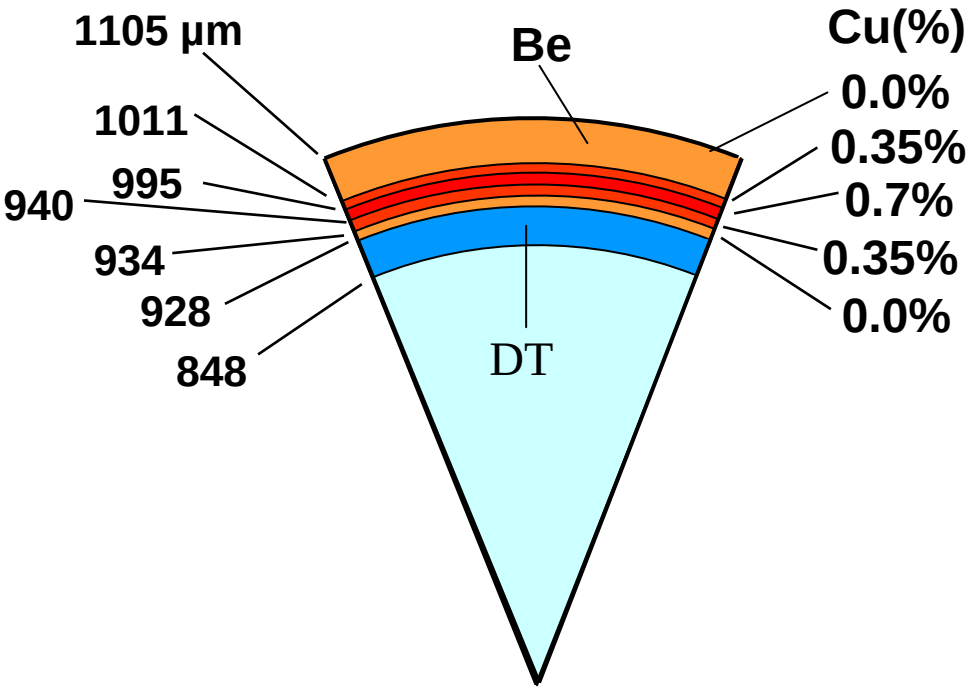
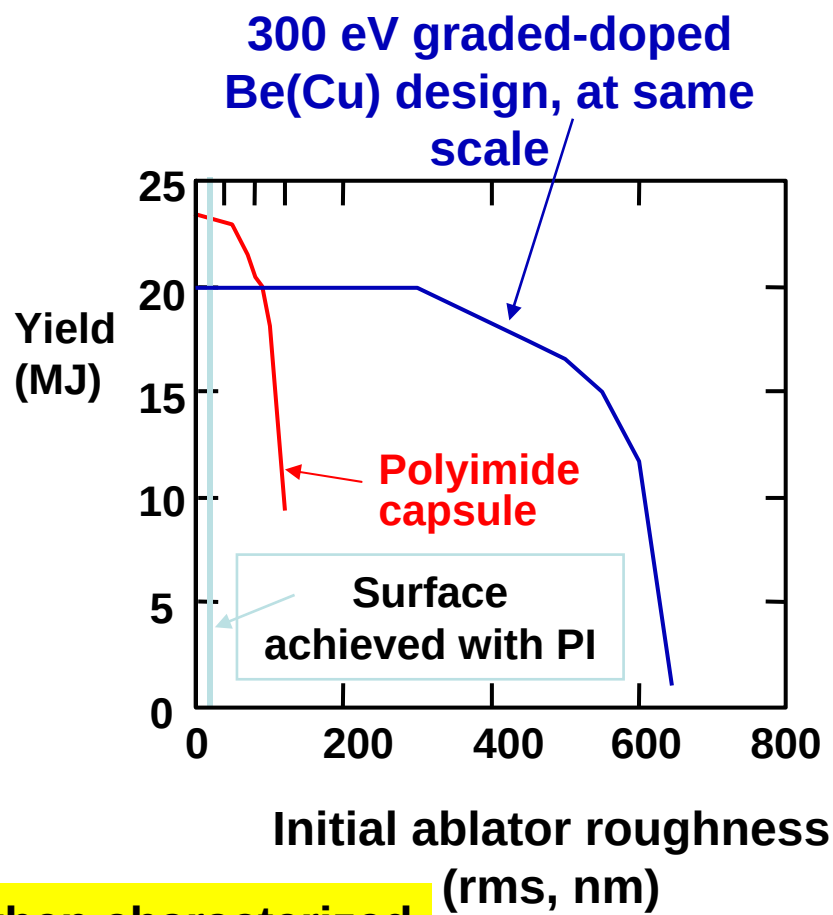
300 eV design:





But can the targets be made and then characterized To the required precise specifications?

Be and CH are both potential ablator materials for ignition capsules

Physics Issues

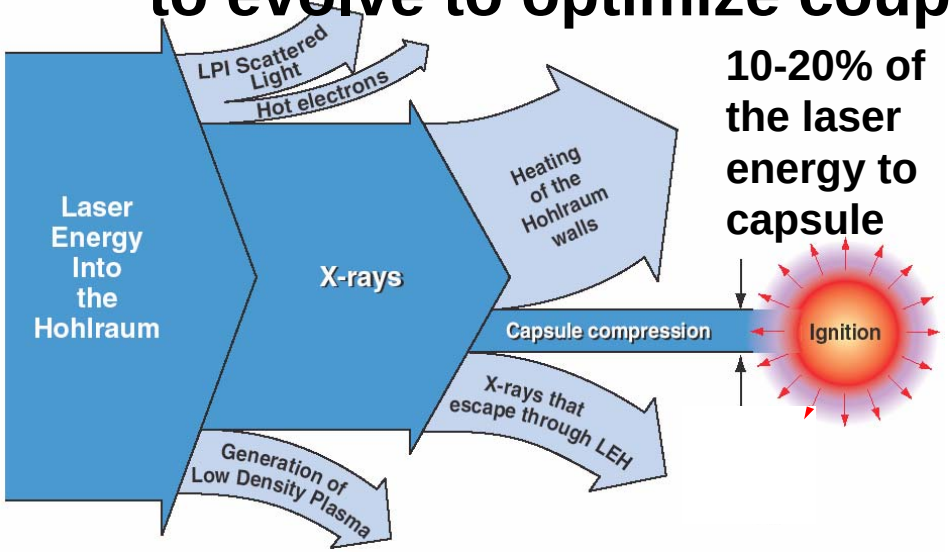
	Be	CH
Absorption Efficiency (density/opacity)	+	0
Stability	+	0
Fill tube tolerance	+	0/–
Drive temperature range	+	0/–
Morphology effects	0/–	+

Fabrication Issues

	Be	CH
Surface finish	0	+
Morphology (internal structure)	0/–	+
Fill tube/Fill hole	0/+	0/–
Dopant gradient flexibility	0/–	+
Characterization	0	0/+
Enhanced β-layering (DD and layer temp)	–	0/+
Hohlraum layering (conductivity)	0/+	0

Be capsules are preferred for physics performance but present greater fabrication challenges

The Indirect Drive Ignition point design continues to evolve to optimize coupling efficiency



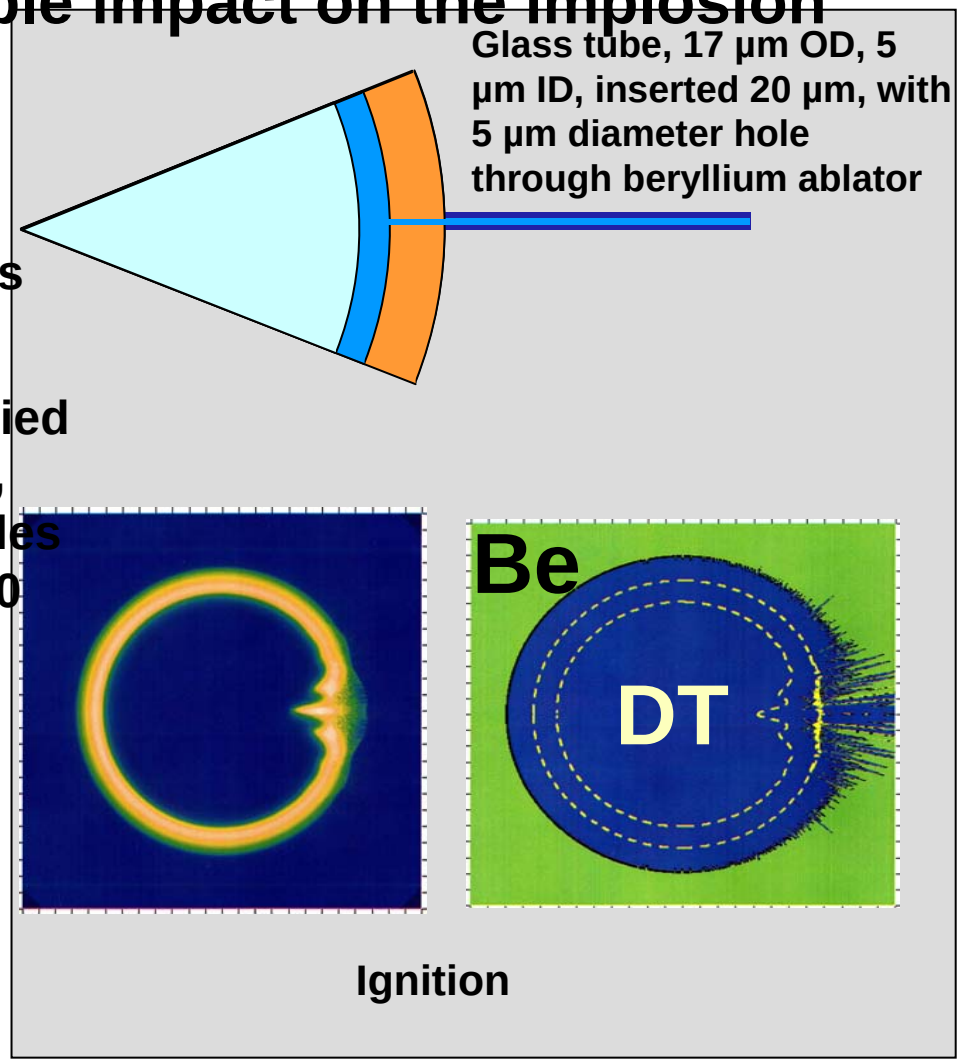
10-20% of the laser energy to capsule

	Au with CH Capsule	Au with Be Capsule	Cocktails - Be Capsule	Cocktails, LEH shields - Be Capsule
Laser light (MJ)	1.45	1.2	1.0	0.85
Absorbed Xrays	1.30	1.08	0.9	0.77
Wall loss	1.10	0.92	.765	0.655
Hole loss	0.68	0.58	0.425	0.295
Capsule	0.28	0.20	0.20	0.220
Efficiency (%)	0.14	0.14	0.14	0.14
	9.7%	11.7%	14%	16.5%

Simulations indicate that a 10-20 µm diameter tube will have an acceptable impact on the implosion

- Graded doped 200 kJ Be(Cu) capsule
- Calculation ignites and burns with near 1D yields
- Graded doped Be capsules are best but simulations carried out with uniformly doped Be, and graded doped CH capsules all give near 1D yields with 10 micron diameter tubes.

Update with point design scale info



New capsule provides new opportunities but also presents major fabrication challenges

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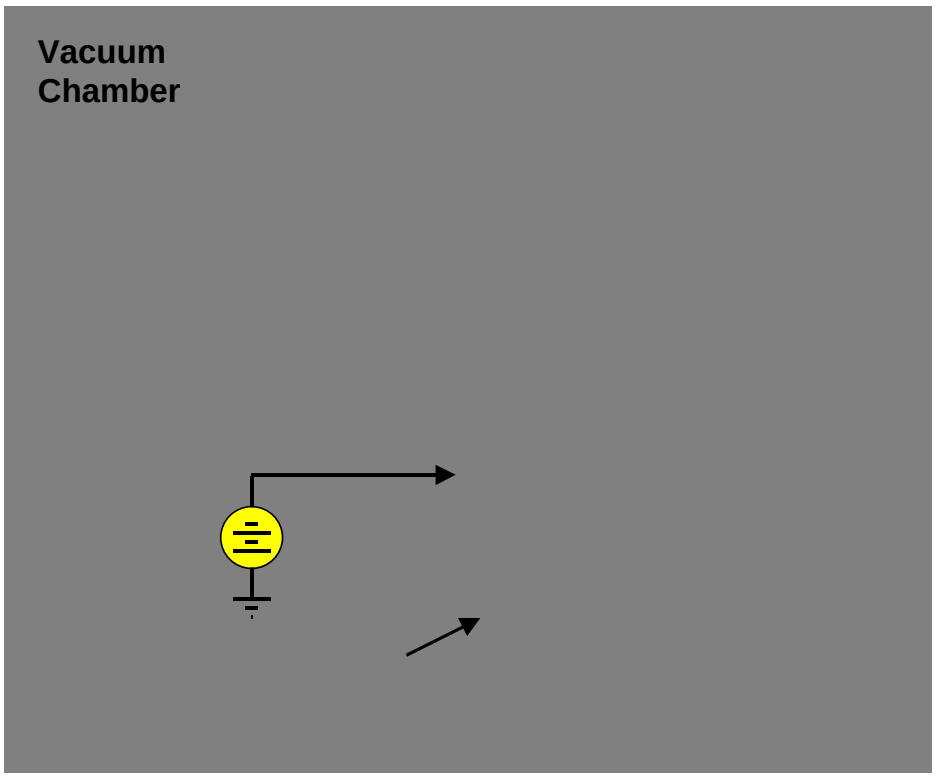
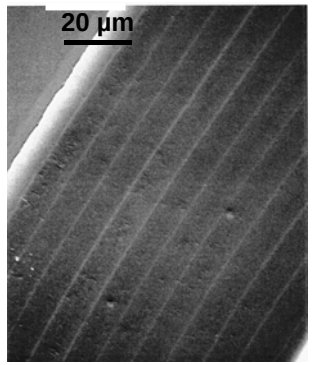
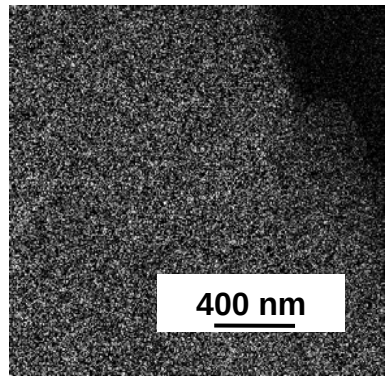
Cu-doped Be capsules are made by sputter deposition onto CH mandrels in a bounce pan

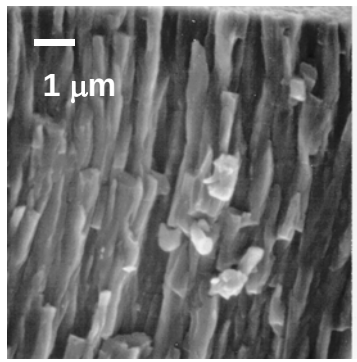


Cross-section of 100 μm thick shell

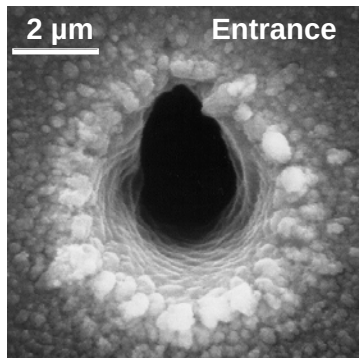


Uniform copper Distribution by TEM





Sub-micron grains



Tiny holes have been laser drilled for filling

We can attach ~ 6 µm fill tubes to capsules but with too large a perturbation so far

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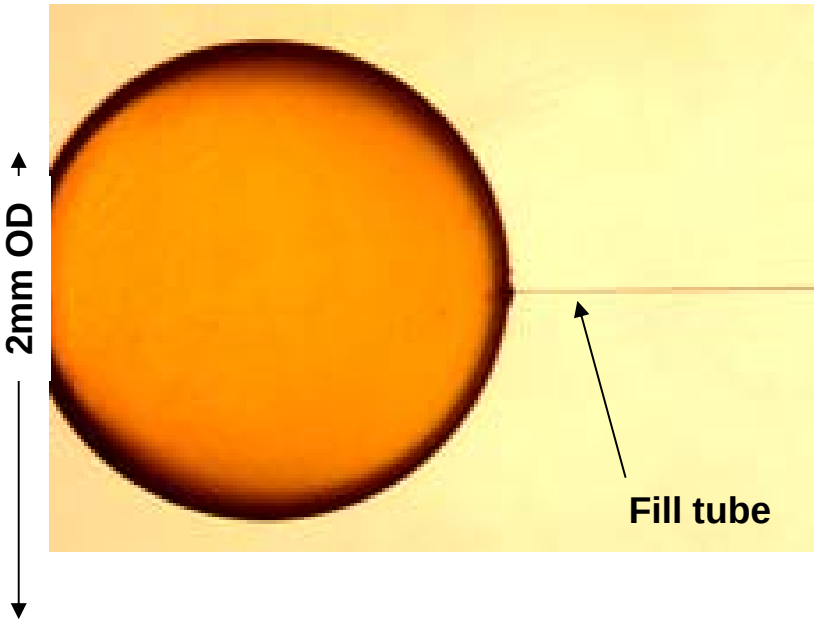
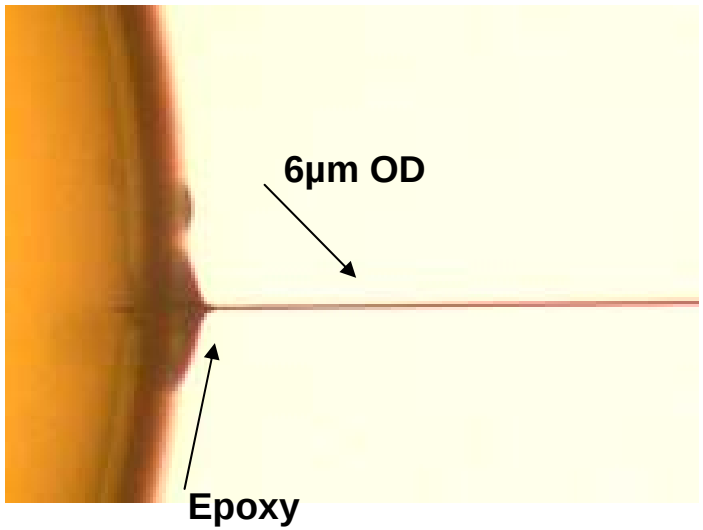
6µm OD fill tube, 2mm OD shell

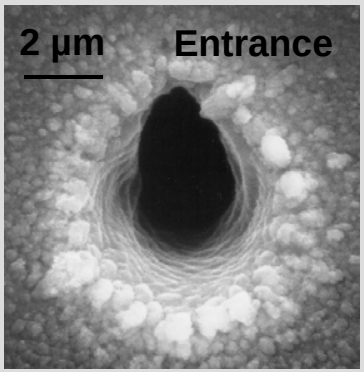


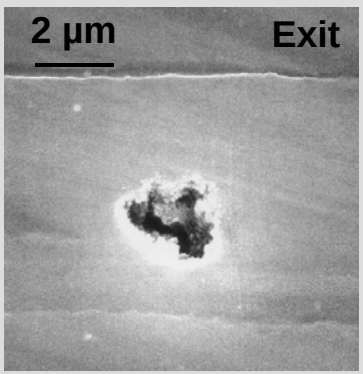


Target fabrication issues : too large a perturbation by the glue

Key fabrication capabilities for fill-tubes are being developed and demonstrated

Laser Drilling in Be

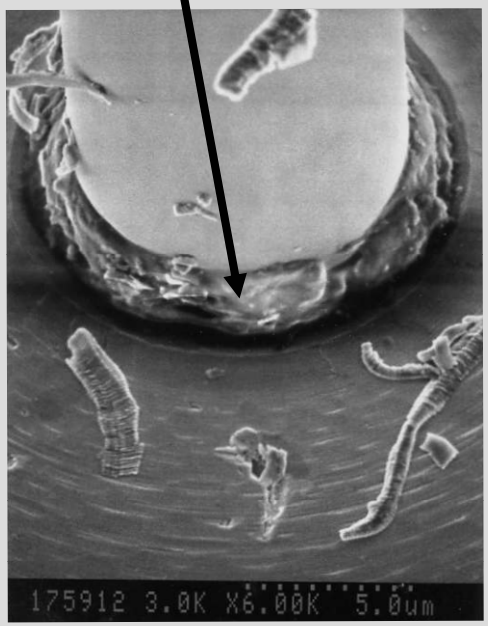


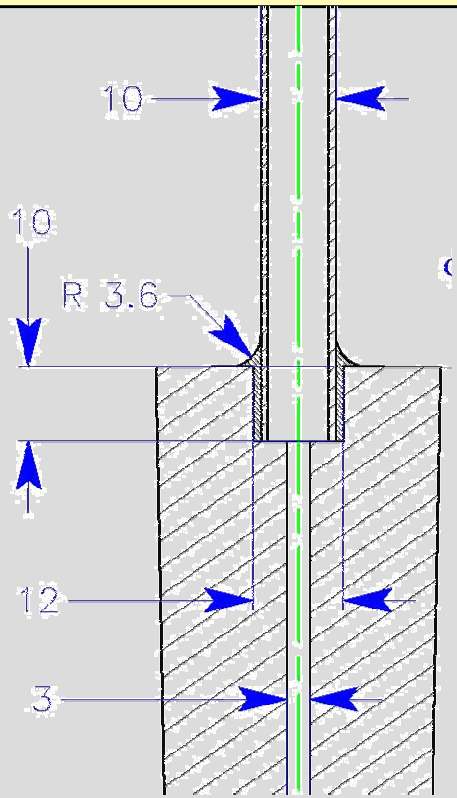


Laser: Ti:sapphire
405 nm, <1 µJ, 120 fs, 3.5 kHz
drilling time: ~40 sec

10 µm Glass Tube in Al Flat

The glue layer is ~ 1µm thick



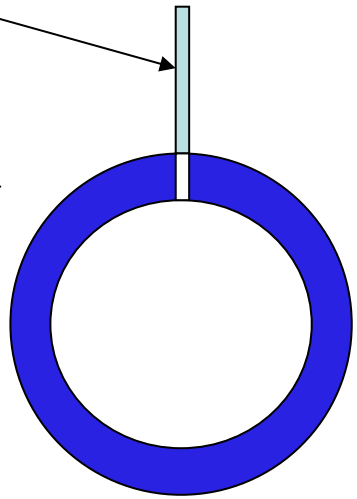


The 2010 ignition plan has risk mitigation options for the key features of the point design target

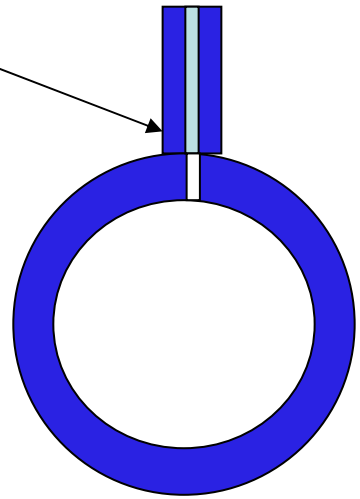
	Point Design (Risk)	Risk mitigation options	Impact of Failure
Hohlraum geometry	Includes LEH shields (Low)	No LEH shields	0.85 to 1.0 MJ (17%)
Hohlraum material	Cocktail (Low)	Au	1.0 to 1.2 MJ (20%)
Ablator Material	Be (Low/moderate)	CH	1.2 to 1.45 MJ (20%)
Hohlraum low-z fill	SiO_2 foam (for operational simplicity and flexibility) (Low/moderate)	▪He/H gas fill ▪SiO_2, Be, or Ni solid liner (with prepulse to eliminate hydro coupling)	(Scattering could increase from 10% to 30%) 1.45 to 1.7 MJ (20%)
Capsule fill method	Fill Tube (Low/moderate)	Diffusion Fill (CH)	More complex cryo system

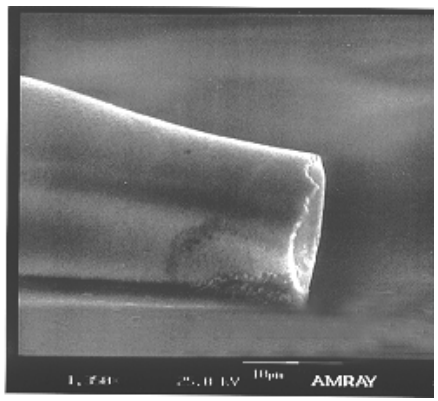
Nano technology methods can be used for monolithic fill tube manufacture

~ 5 micron mandrel grown with laser CVD on Be sphere in a laser drilled hole

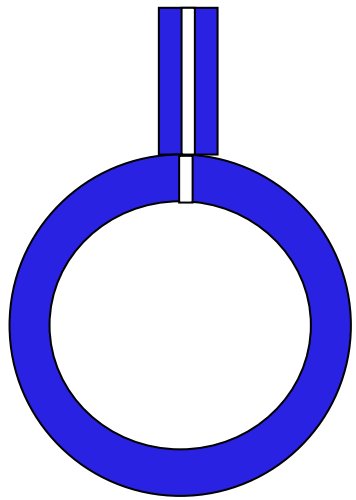


Be or Boron tube is grown off of the sphere and surrounding the mandrel also by laser CVD





6μm

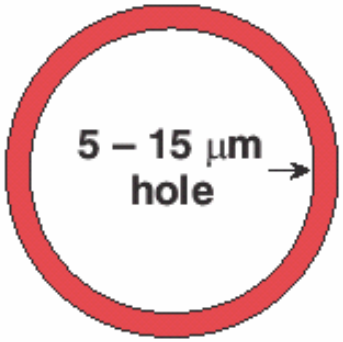


Mandrel is dissolved leaving fill tube

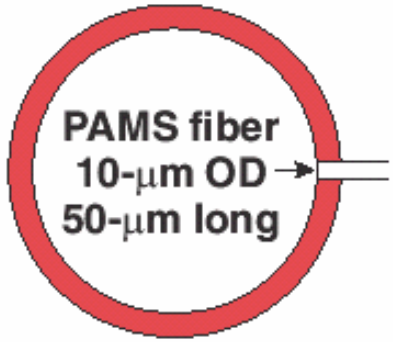
LLE and GA are investigating monolithic fabrication of fill-tube targets

UR LLE

GENERAL ATOMICS

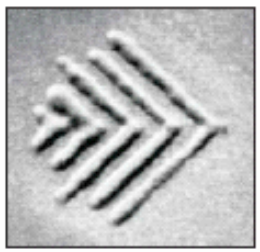


Laser hole drilled in PAMS shell (polyalphamethylstyrene)

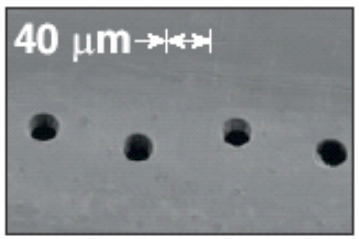


Join fiber to hole in PAMS by IR laser, PAMS glue.

GDP bounce coat integral shell/fiber for uniform wall.

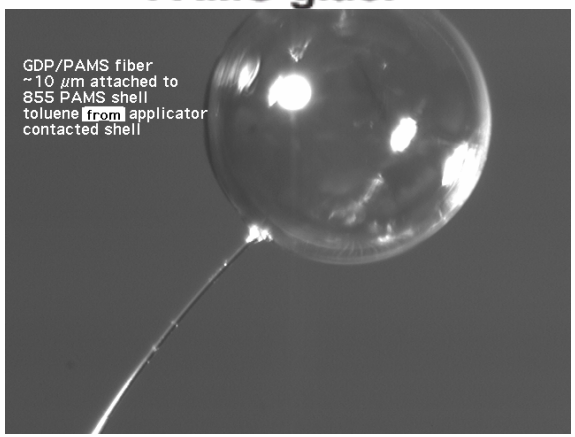


1 μm steps



25 μm holes

Exitech products



Control of joint defects during coating is key.

E12837