Target Fabrication and Engineering Services at General Atomics

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Outline

- **GA Overview**
- Target production for stockpile stewardship
- Recent R&D focus

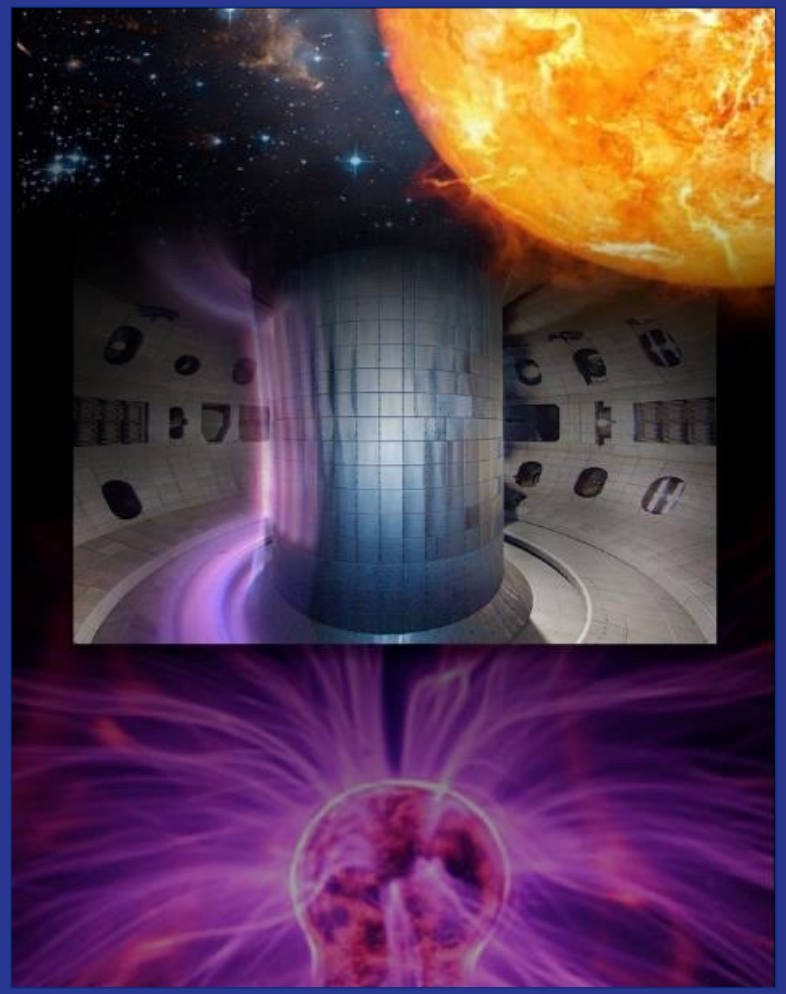
Energy Group

DIII-D Fusion Facility

ITER Components & Systems

Systems Engineering

High-Performance Computing



Magnetic Fusion Energy

Inertial Fusion Technology

Precision Materials & Components

Leading edge Diagnostics & Metrology

Stockpile Stewardship Mission

Personnel and Facilities

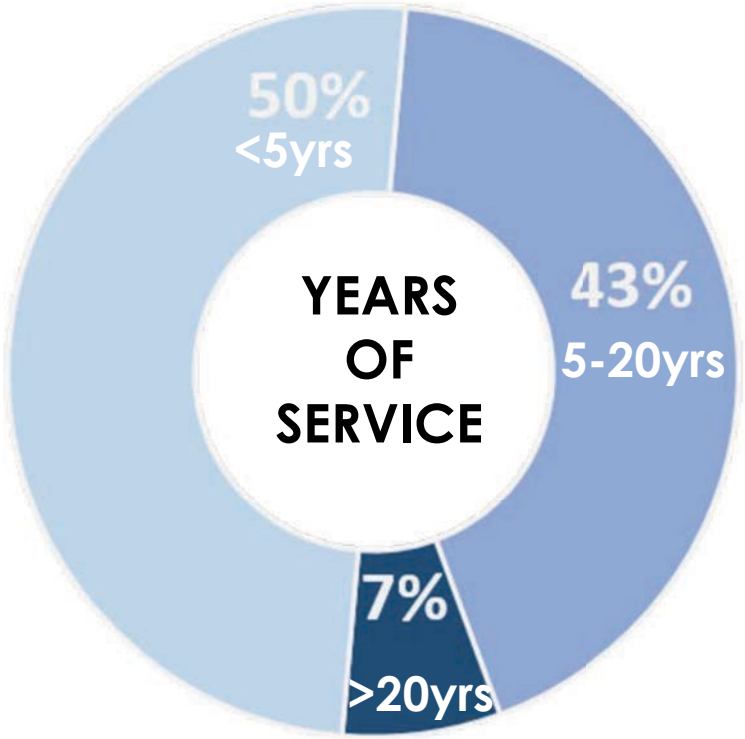
IFT Division

119

STAFF
La Jolla: 76
LLNL: 36
SNL: 7
LLE: 2

77

DEGREES EARNED
18 PhD
14 MS
33 BS/BA
12 Assoc.



Energy Group

- ~300,000 sq. ft.
- ~400 personnel
- Q Cleared: 75

ISO 9001:2015

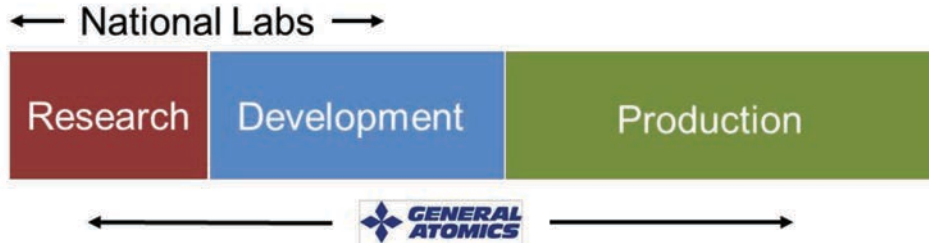
- Classified work areas
- Beryllium & uranium labs
- Class100 cleanroom

GA is a centralized target fab resource for NNSA Science-Based Stockpile Stewardship

Annually, GA provides 90% of the targets (~14,000 components), used for the nominal 2,600 experiments on NIF, Z, & Omega,

- Lower costs thru less redundancy
- Critical mass of specialized skill set
- Nexus of technical capability
- Agility to support NIF, Z, & OMEGA
- Academics participants benefit from national lab quality capabilities
- Significant private investment

Innovative multi-disciplinary materials research coupled with operations excellence



Outline

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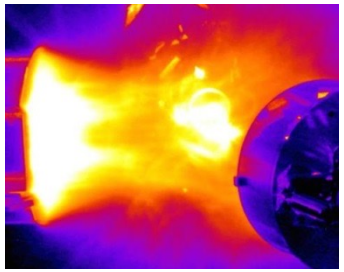
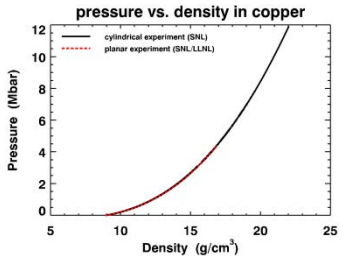
Key Research for Science-Based Stockpile Stewardship

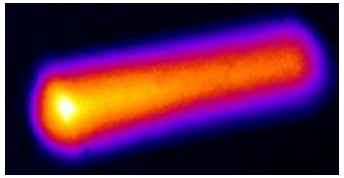
Output & Effects



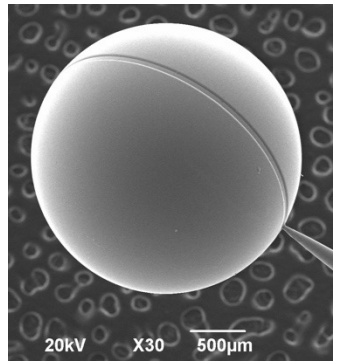
Material Properties



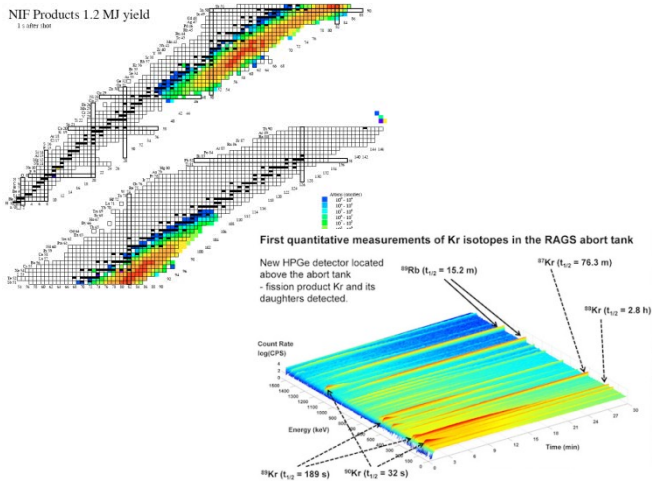
Radiation Transport



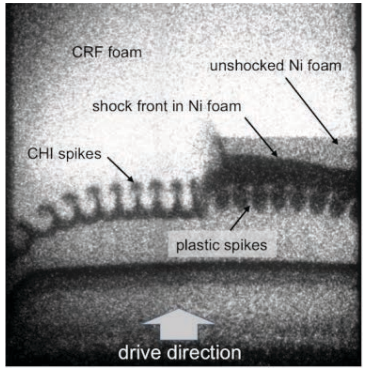
Engineering Feature



Radiochemistry



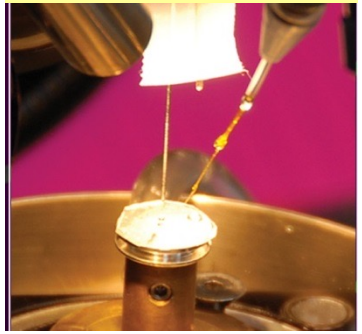
Hydrodynamics



Precision targets are at the center of each experiment that require capabilities from multiple disciplines

Various coatings

Precision assembly

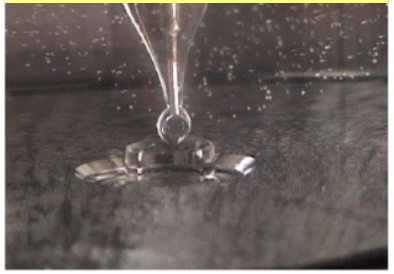


Precision Engineering & design

Diamond turning & laser machining

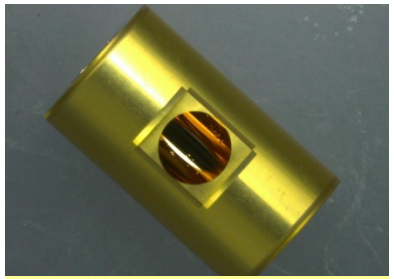
Metrology

Chemistry & Materials



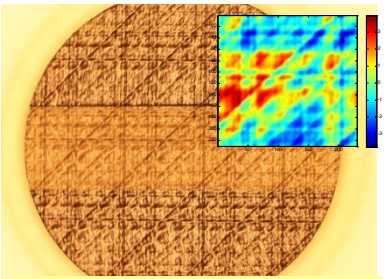
Multiple capabilities are often needed to make a single target

Capsules

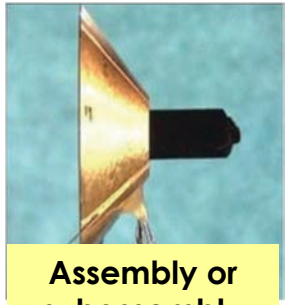


"Hohlraums"

Aerogels



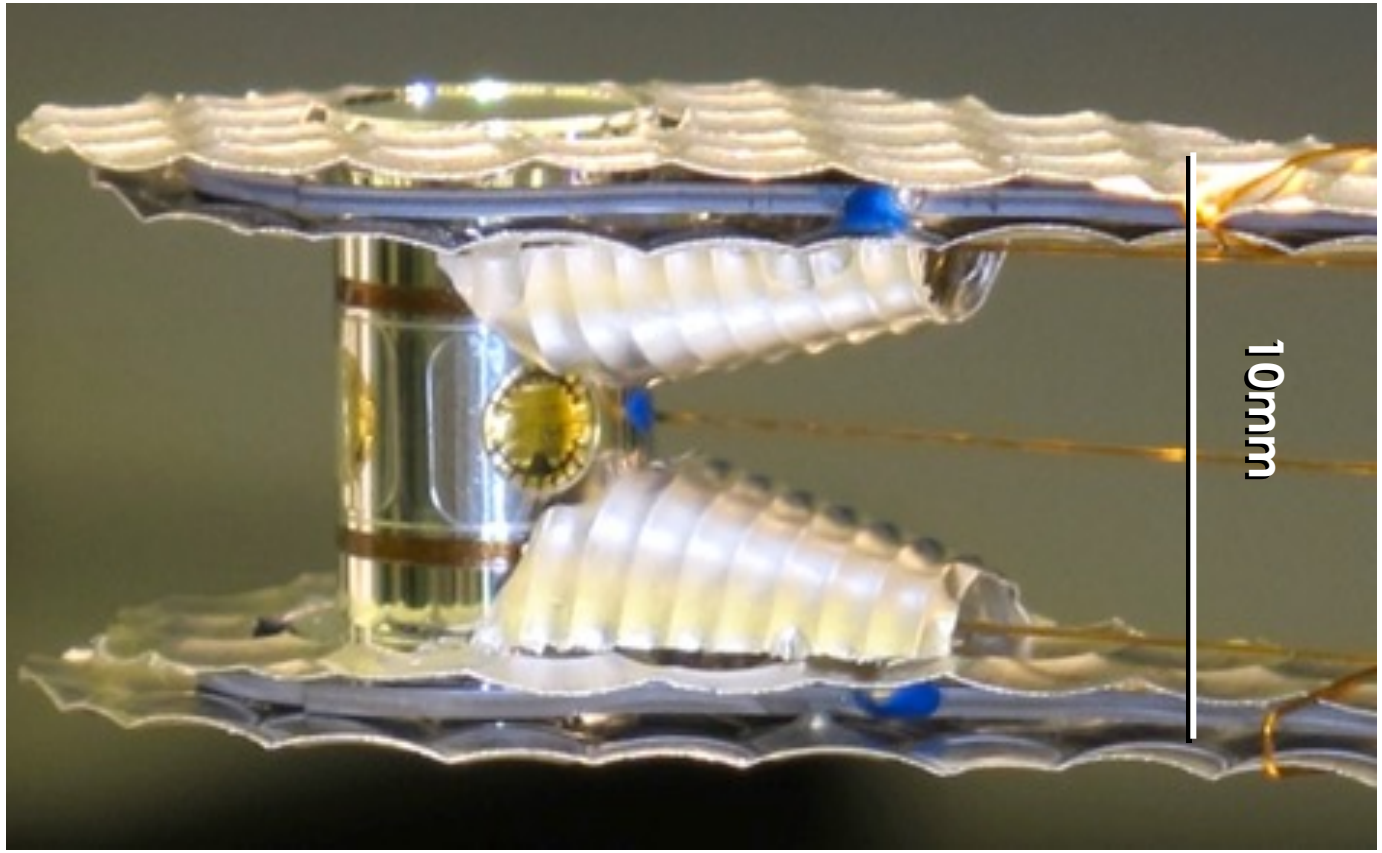
Complex Planar

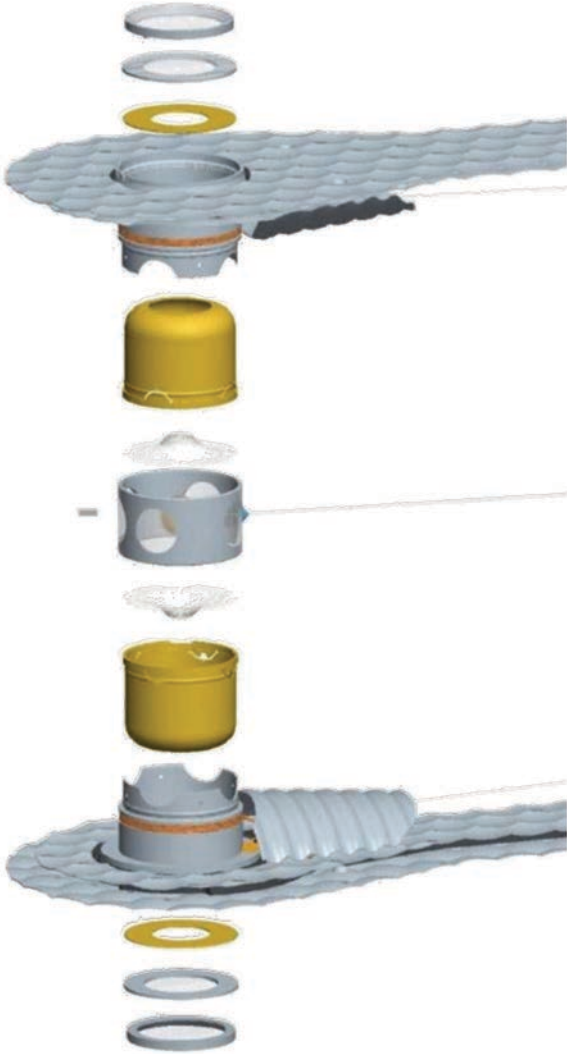


Assembly or subassembly

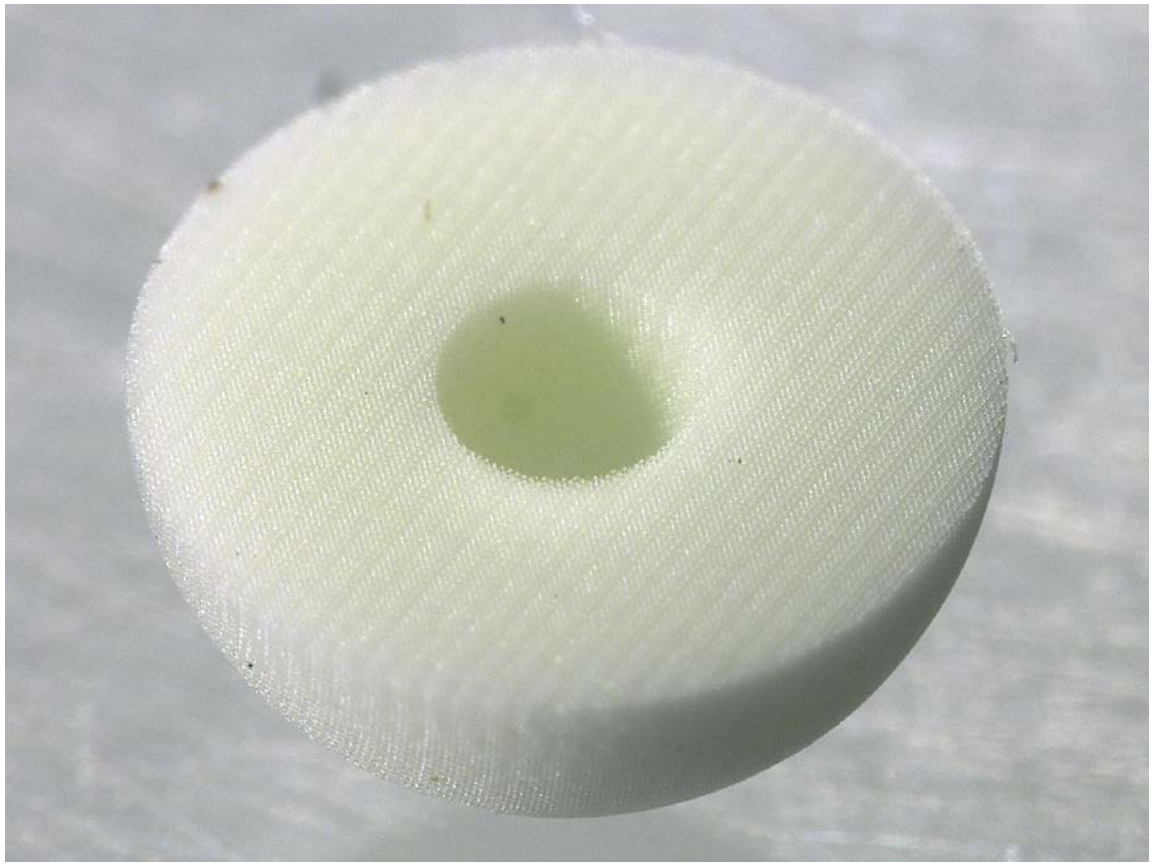
GA provides most components for high-yield science at NIF

Ignition Target

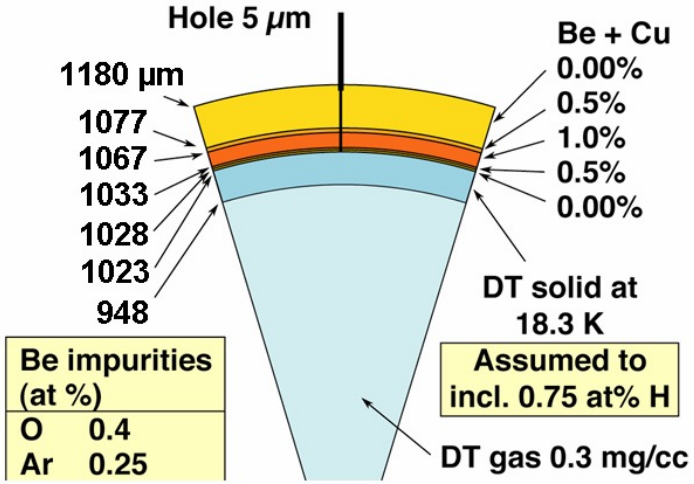




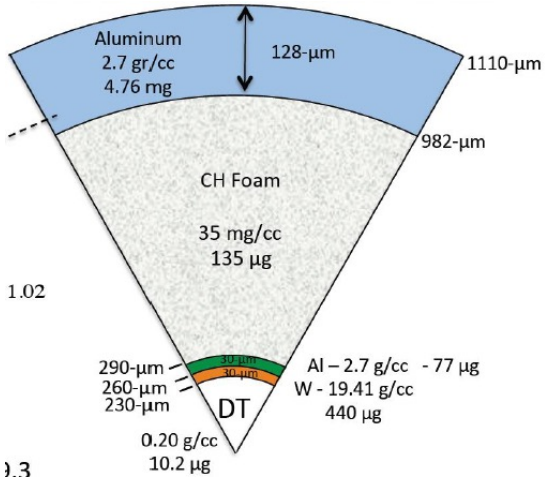
At the center of all ICF assemblies is an ablator capsule



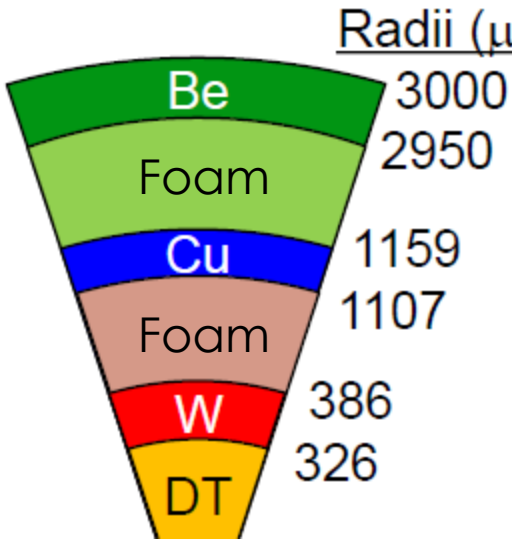
Capsule zoology: Many different materials, dopants and densities



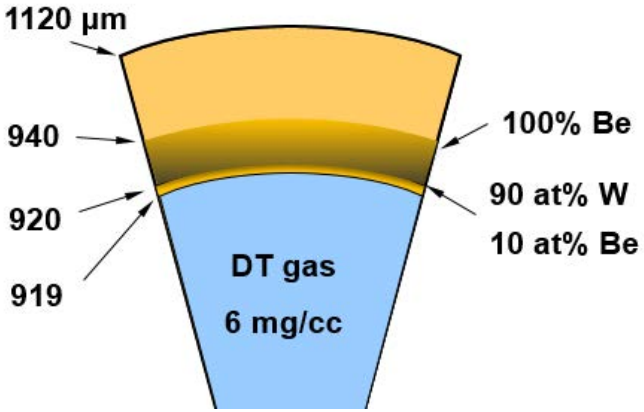
NIC



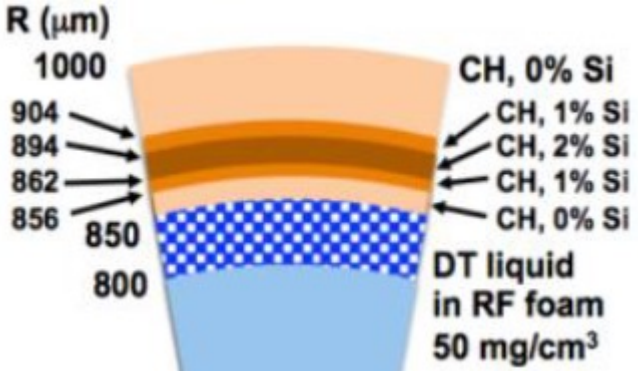
DS



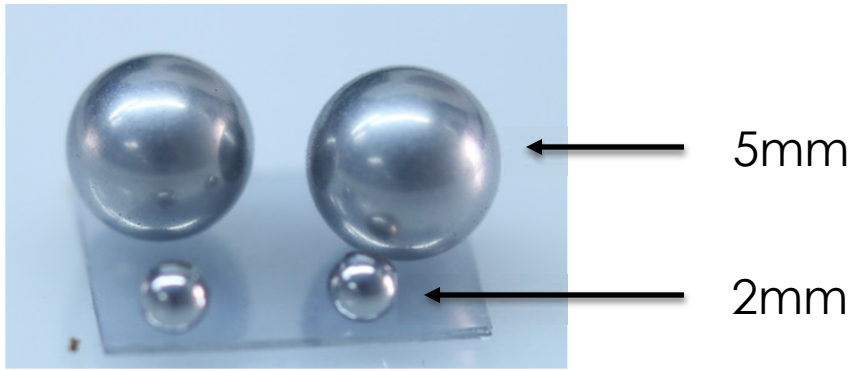
Revolver



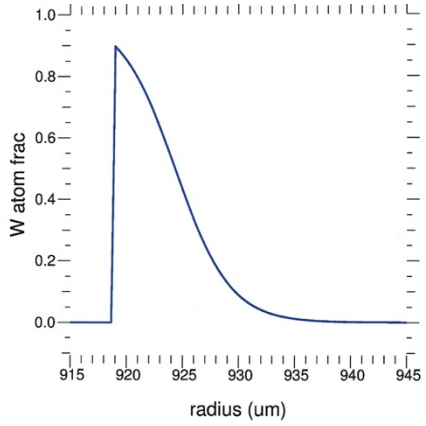
PSS



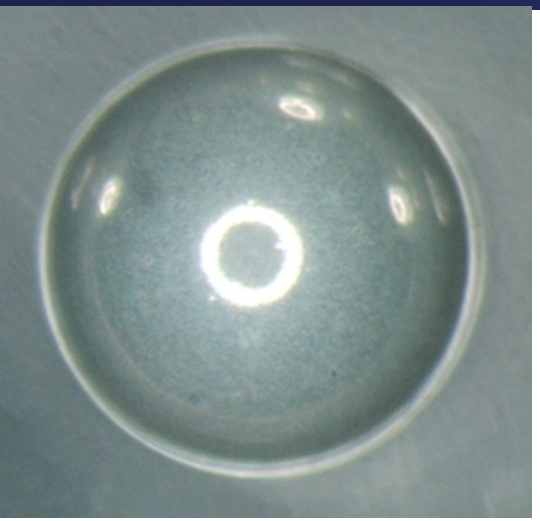
Wetted Foam



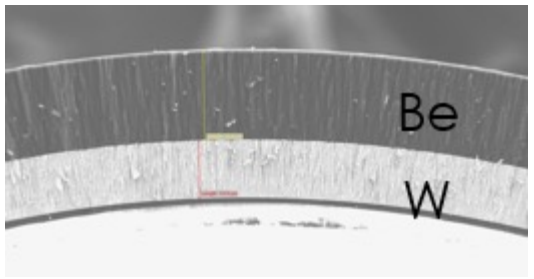
Exploding pusher



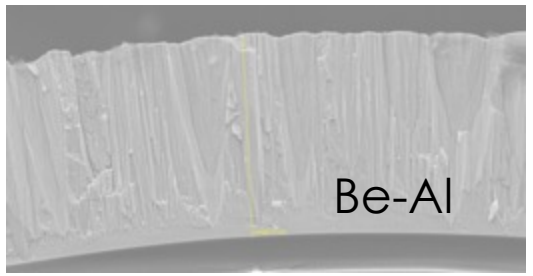
Metal alloys, grading and bilayers needed for alternative ignition paths



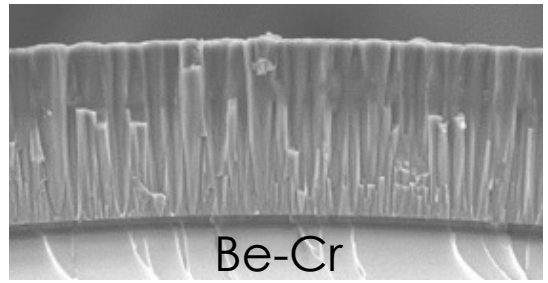
Look alike? All different!



Bi-layers



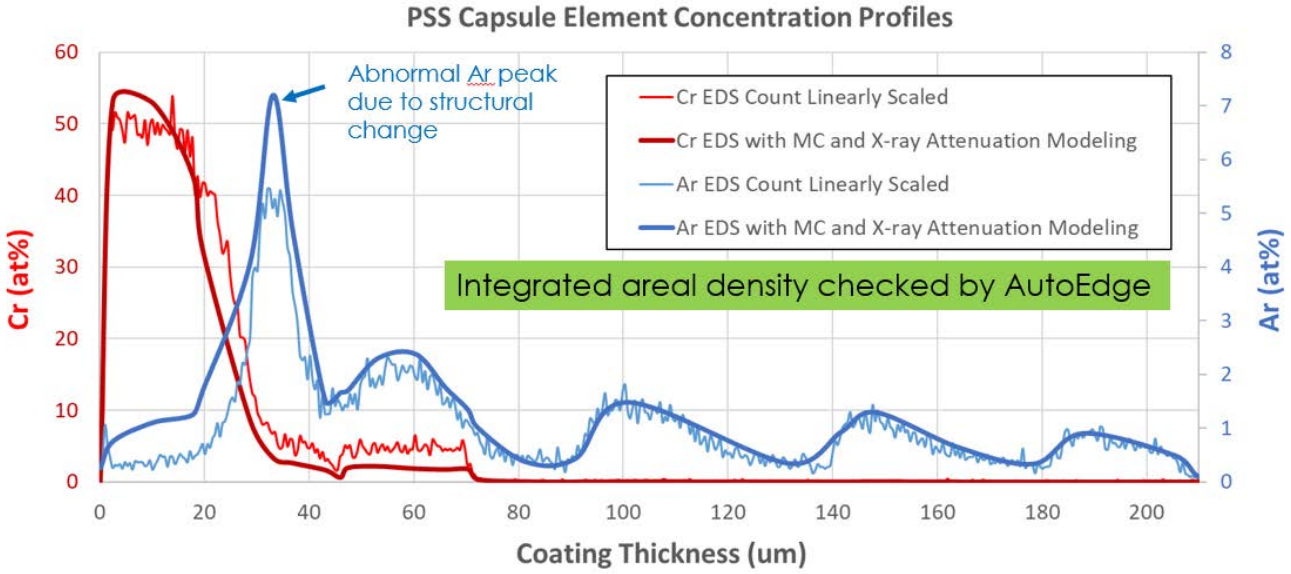
Uniform alloy



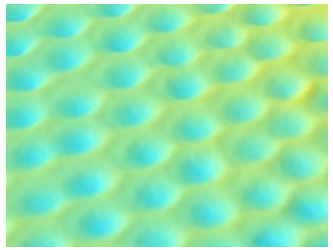
Graded alloy

Bi-layers	Uniform	Graded
W/Cr	Be-B	Cr-Be
W/Mo	Be-Al	W-Be
W/Ti	Be-Ta	W-Ti
W/Zr	Be-W	W-Cr
W/Ta	Cu-B	W-Zr

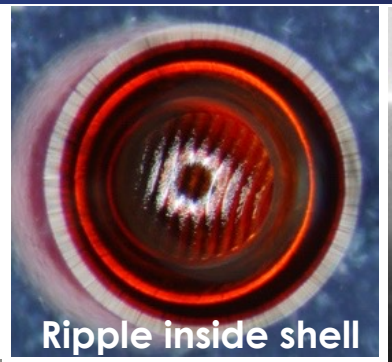
Structural modification and dopant profile measurement

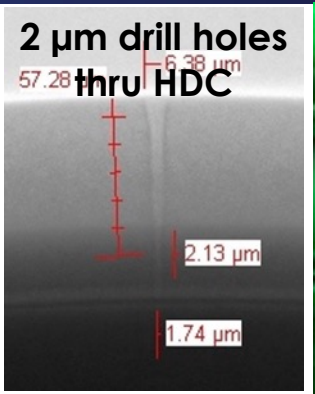


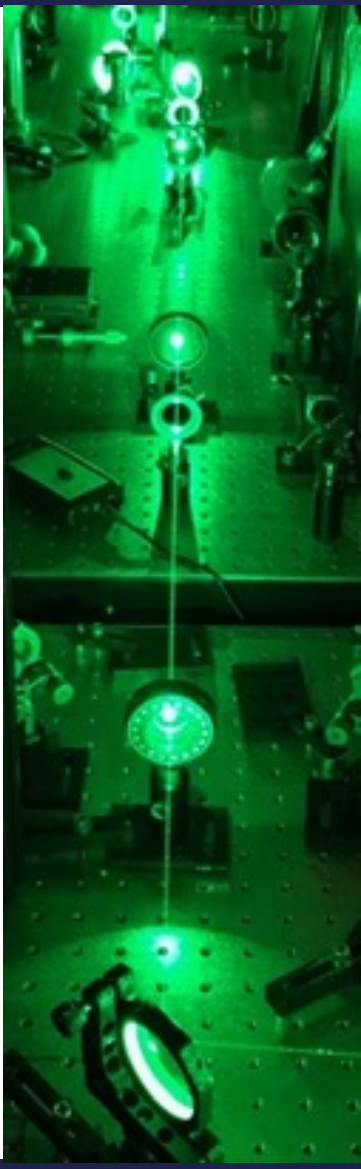
Bulk synthesis, combined w. micro- or laser machining, produce new possibilities

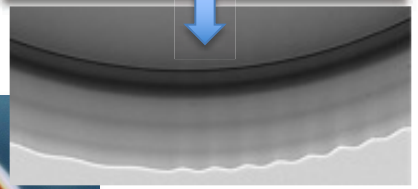


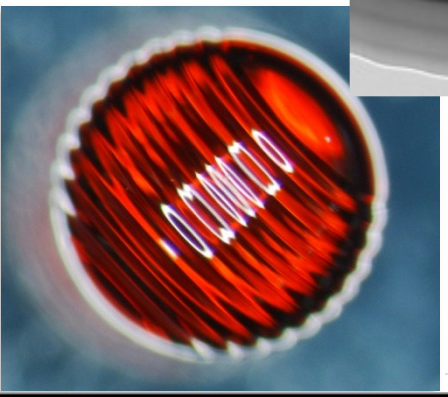
Dimpled pattern

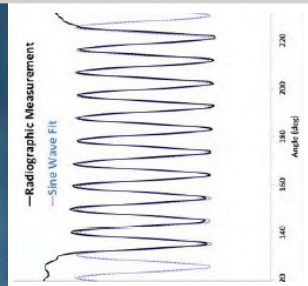


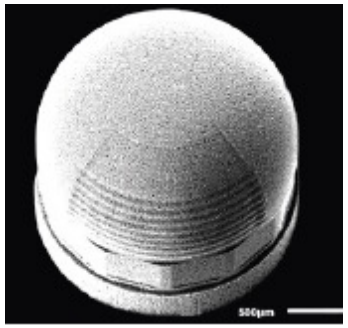




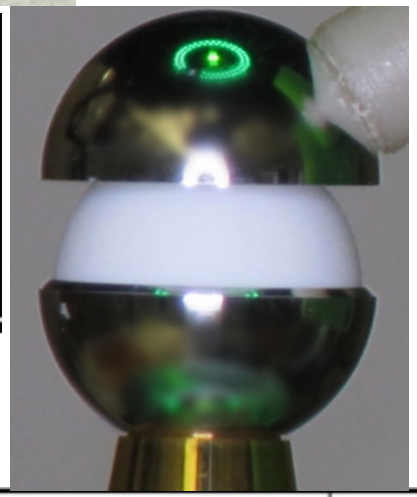




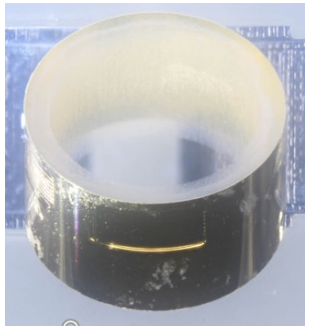




1 g/cc Cu foam

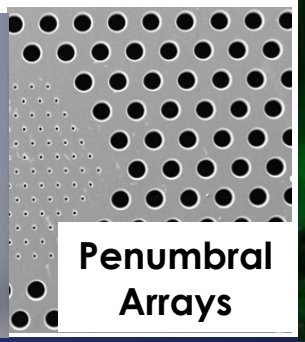


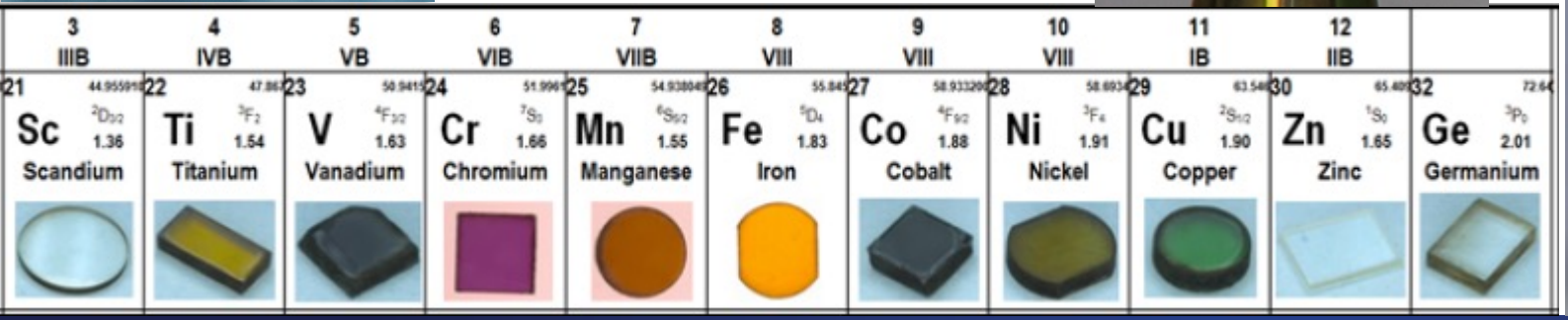
Laser-cut hemis



Laser-cut foam liner

ABEX capsule





IFT

Bulk-produced metal-doped plastics

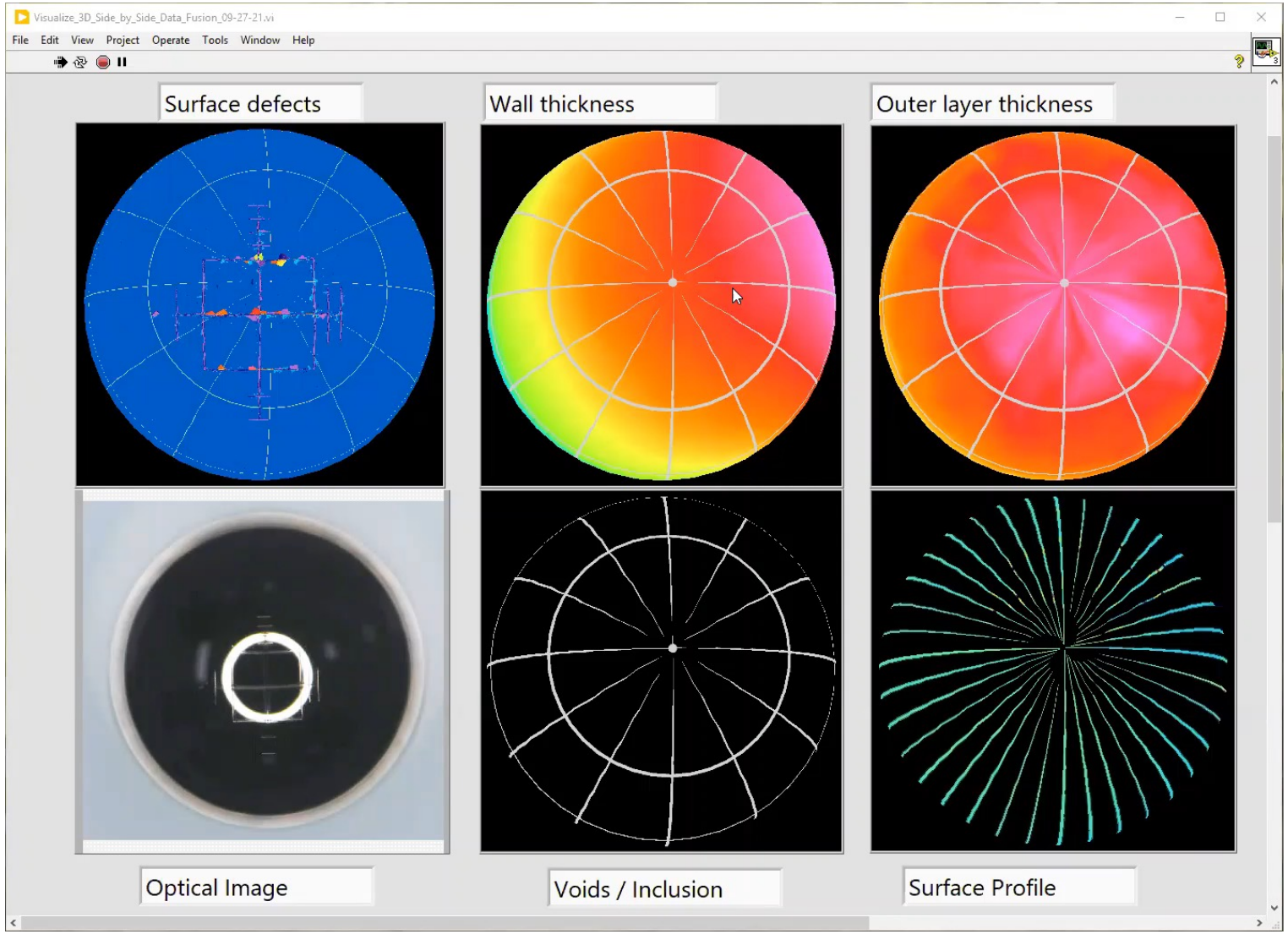
GENERAL ATOMICS

Capsule Metrology Vision: From single instrument to data fusion

From five instruments:

- Interference Microscope => Surface defects
- FTIR => Wall thickness
- Xradia => Voids
- AFM => Surface shape
- Nikon => Optical image

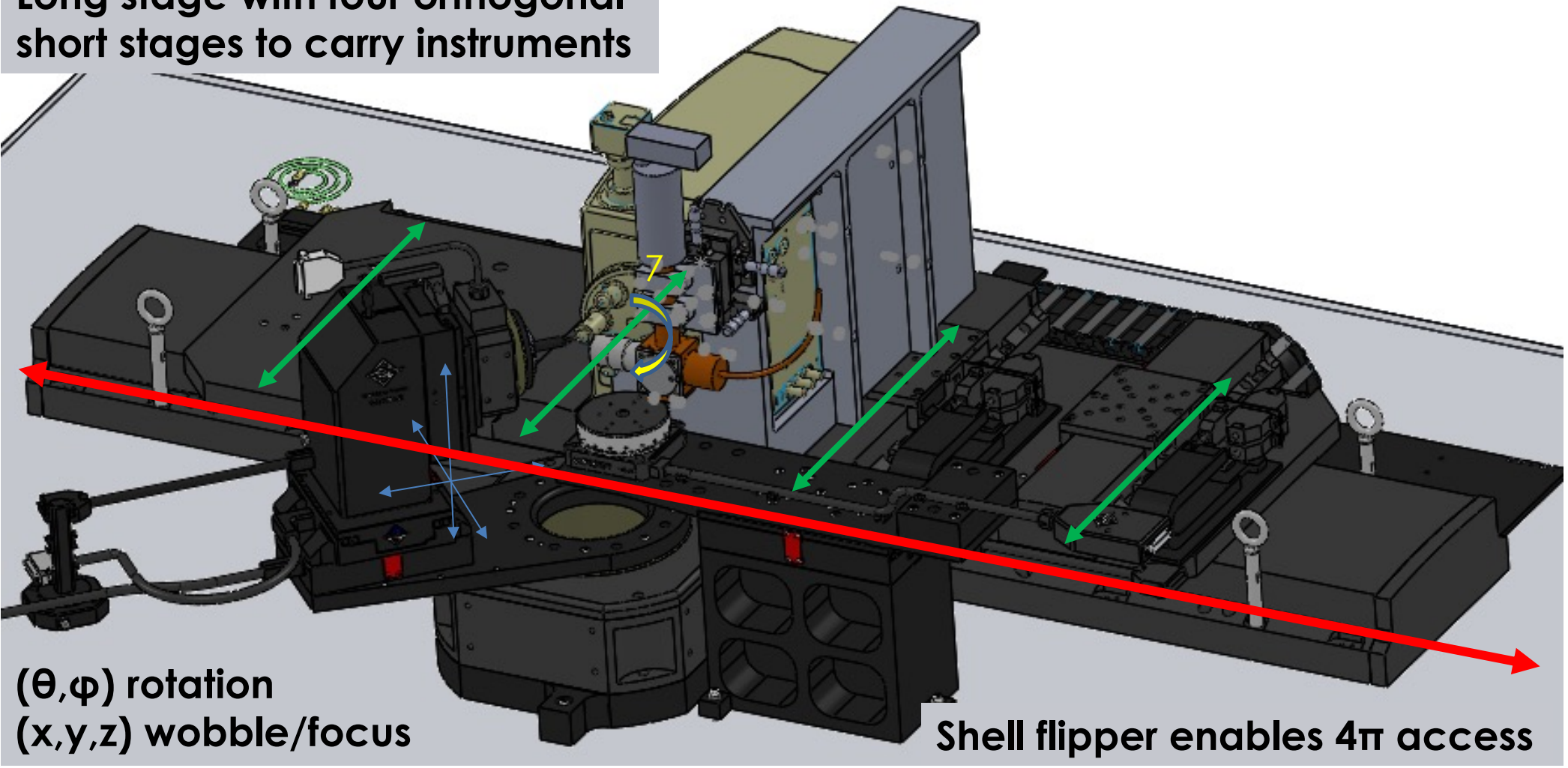
The same coordinate system



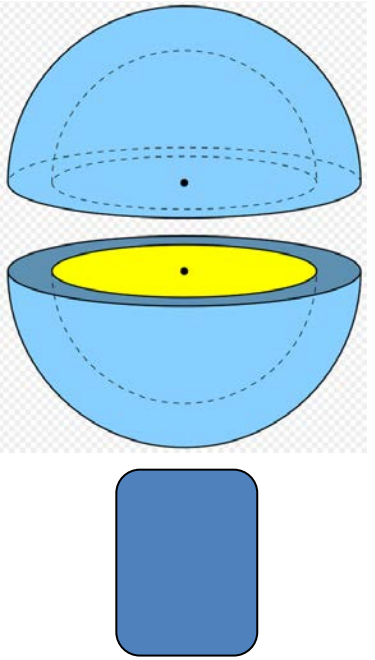
The "4Pi" example

Conceptualizing a 4Pi "aircraft carrier" with many instruments: Sharing common (θ, φ) is critical to benchmarking & efficiency

Long stage with four orthogonal short stages to carry instruments

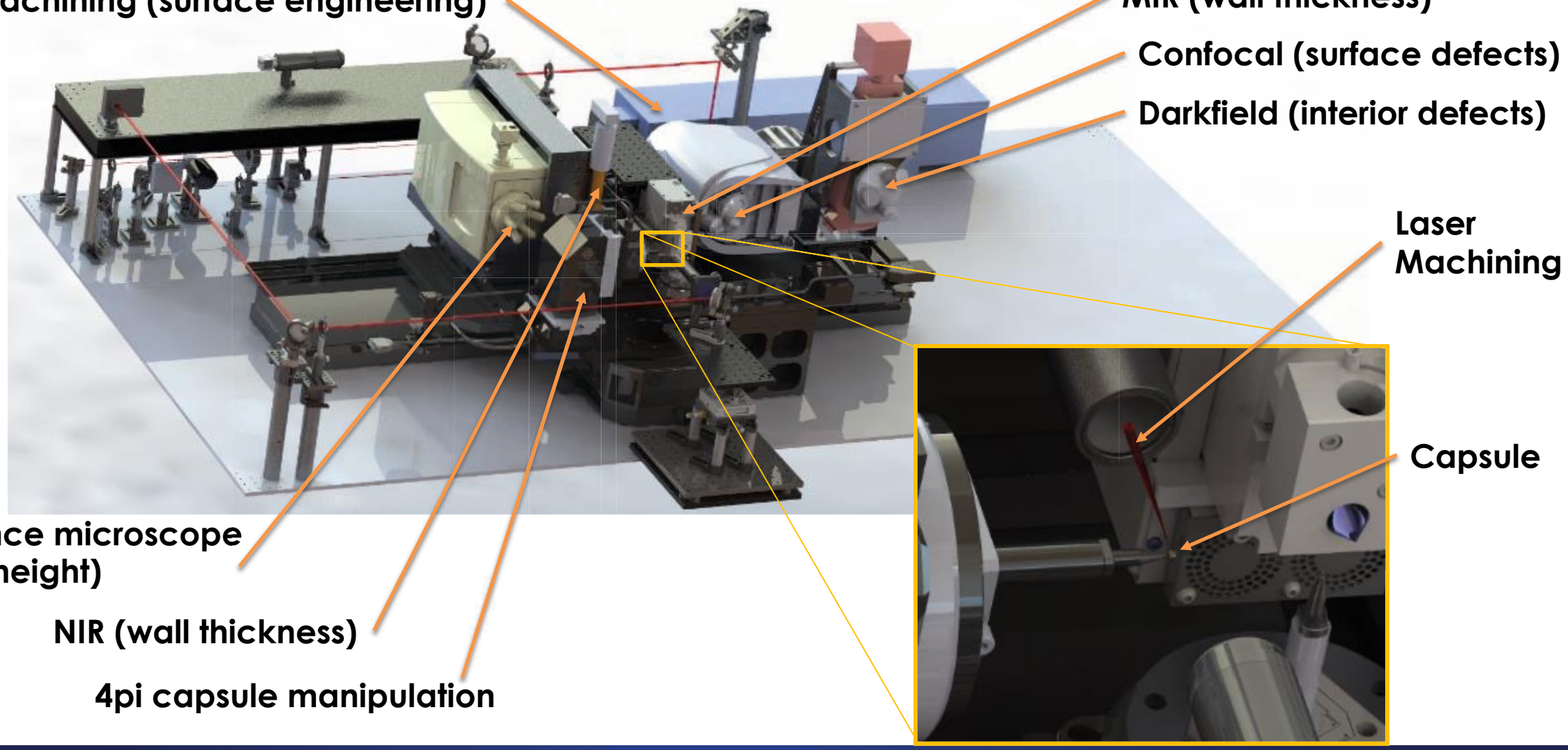


2Pi + shell flipper equals 4Pi



Vacuum chuck

Today: Full capsule data fusion and surface engineering



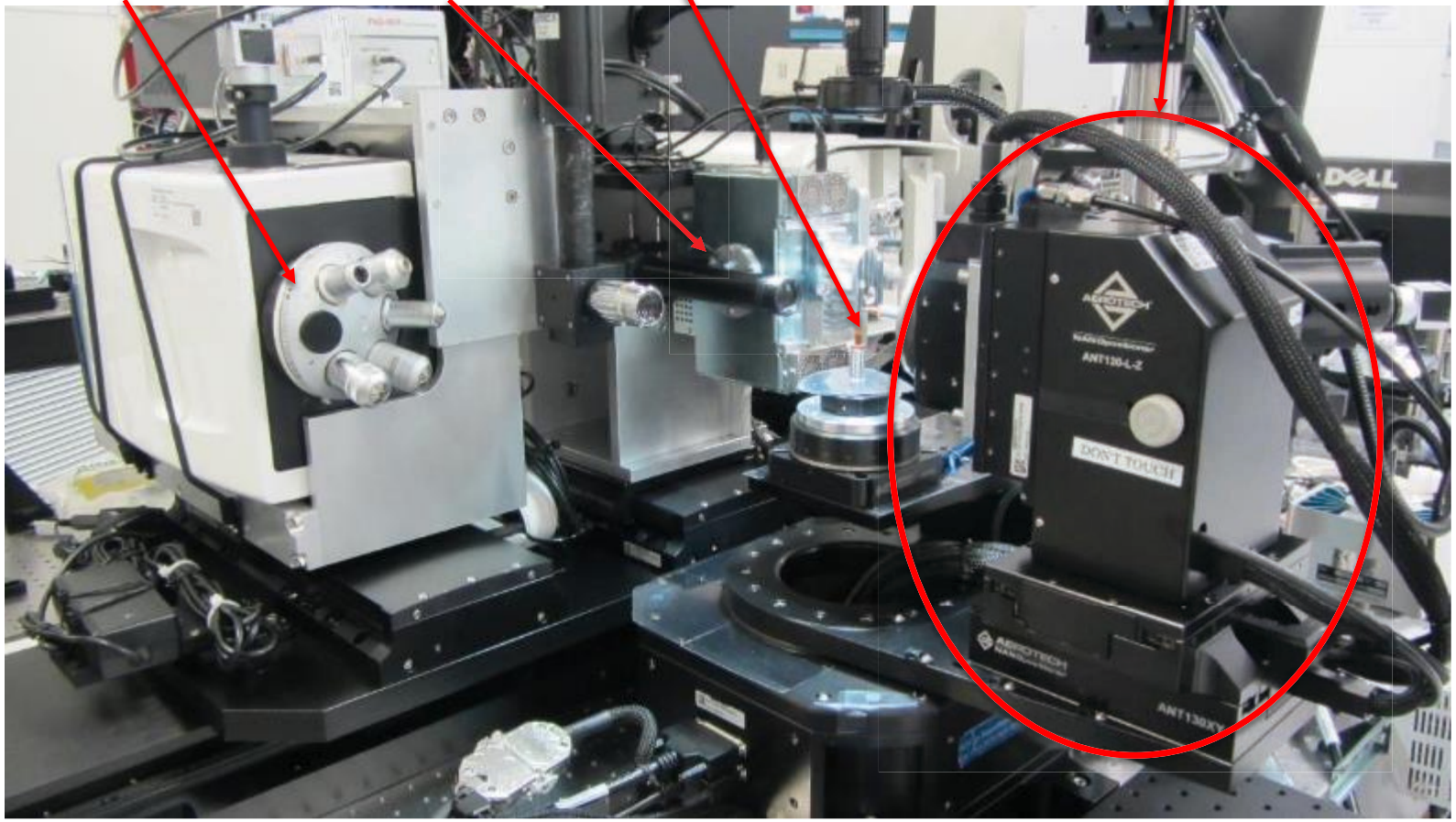
Today: Actual 4Pi hardware

Interference Microscope

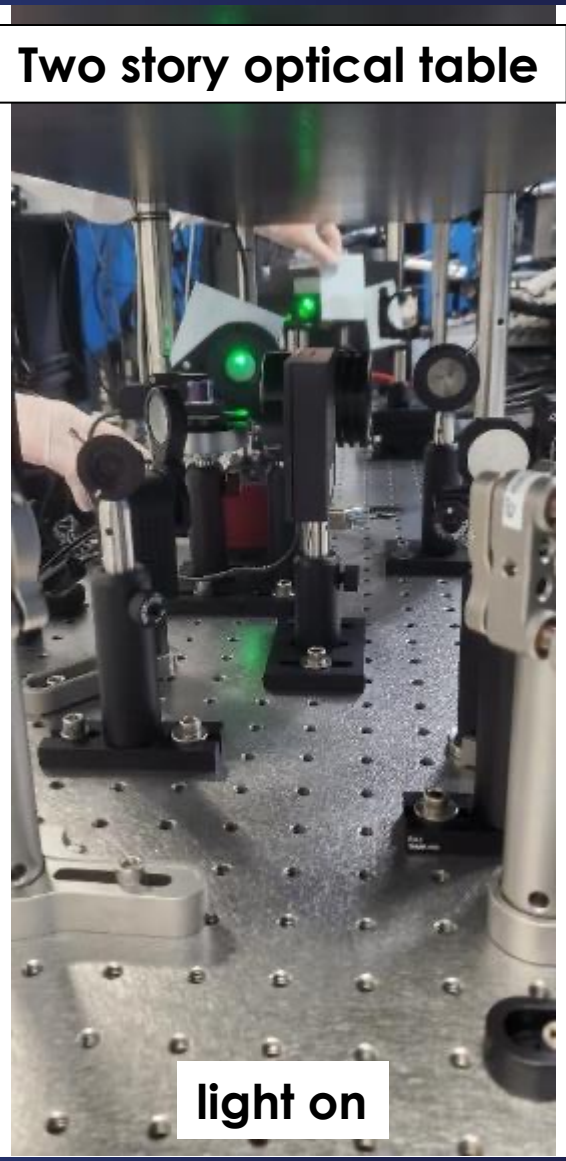
Laser Machining

Capsule

4pi capsule manipulation



Two story optical table

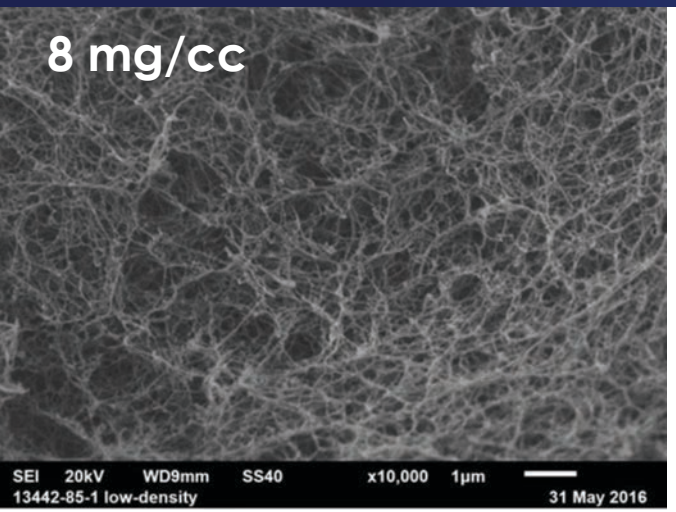


light on

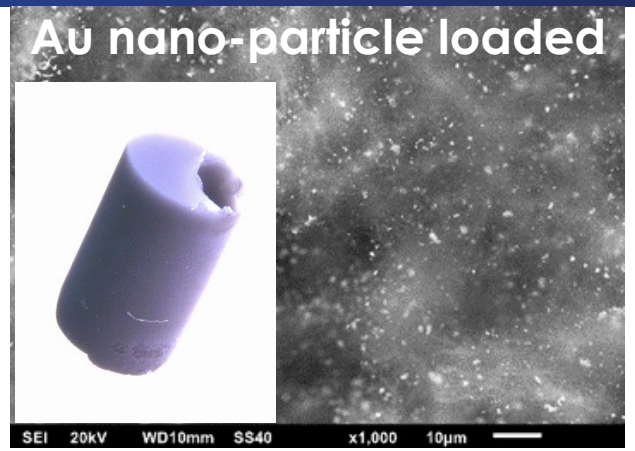
Outline

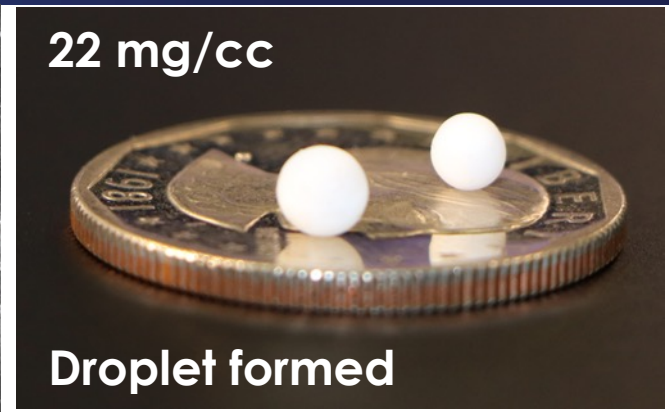
- GA Overview
- Target production for stockpile stewardship
- **Recent R&D focus**

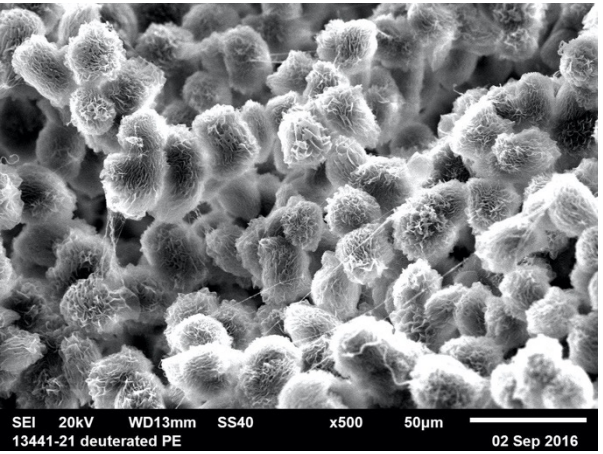
Class-leading GACH / GACD foams combine low density with small cell size



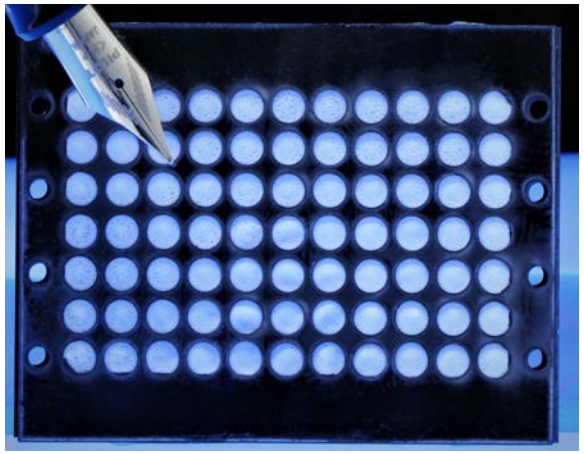
- 1:1 C/H ratio
- 1 to 250 mg/cc
- Pore size <1 µm
- Bulk or sphere
- Nano-doping







CH_2 and CD_2 foams also available



Rep-rated target arrays

Nano-particle dopant choices

Aerogels made or in progress (nanoparticle doped CH)

Supplies on hand. Experiments planned

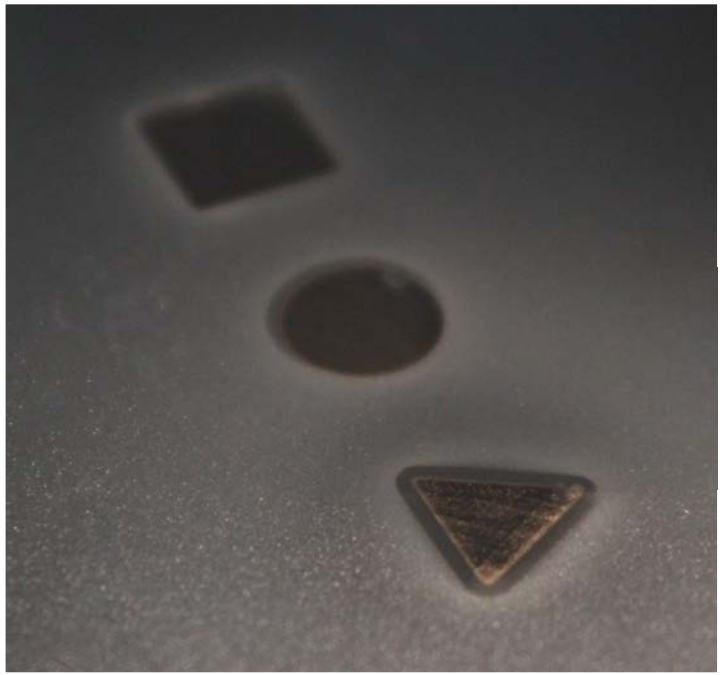
Nanopowders commercially available

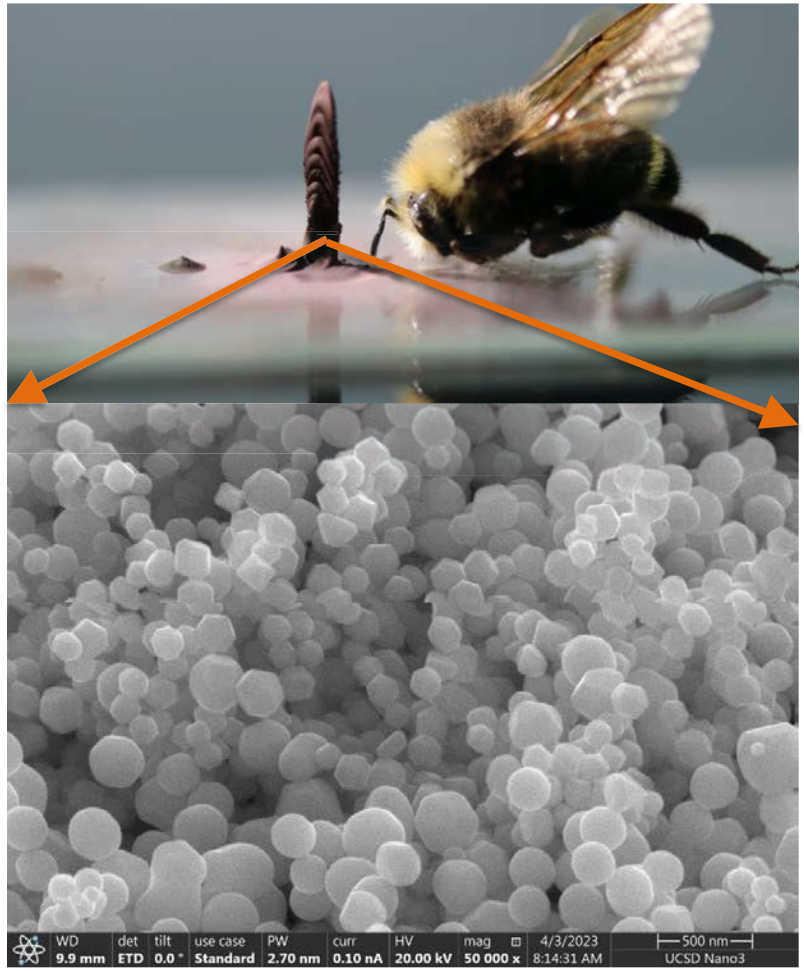
Aerogel via GACHX polymer series (non nanoparticle)

1																	18
1 H 1.008	2											13	14	15	16	17	2 He 4.0026
3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.630	33 As 74.922	34 Se 78.97	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.95	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71 *	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 #	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

* Lanthanide series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
# Actinide series	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

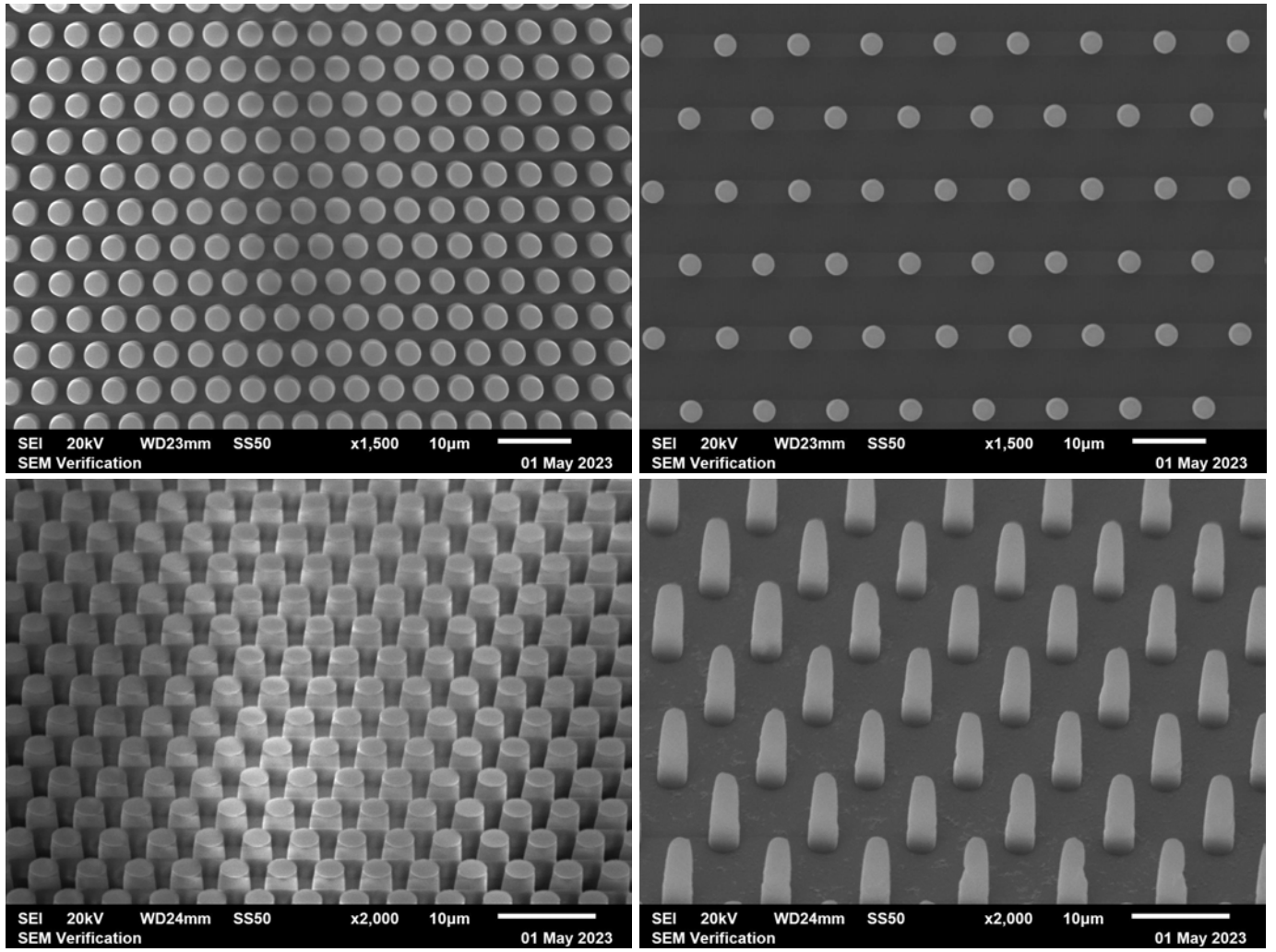
Pure-metal-foam printing capabilities are being developed



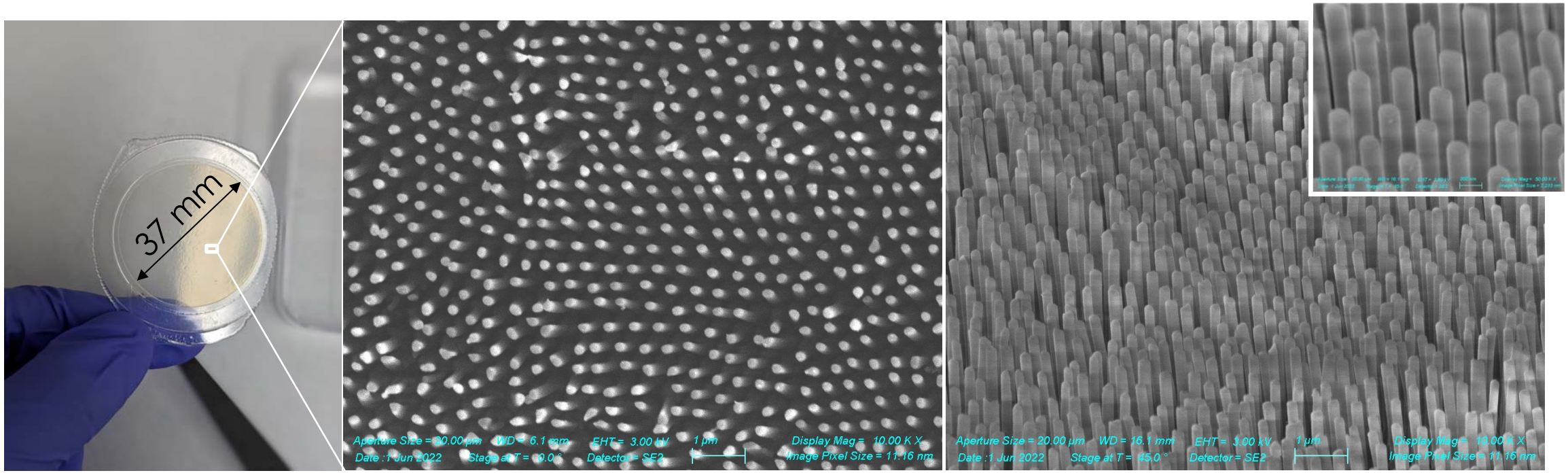


Copper and tungsten have been demonstrated, but most sputterable metals are possible.

Polystyrene nanowire targets in deuterated form or with embedded nanoparticles have been demonstrated

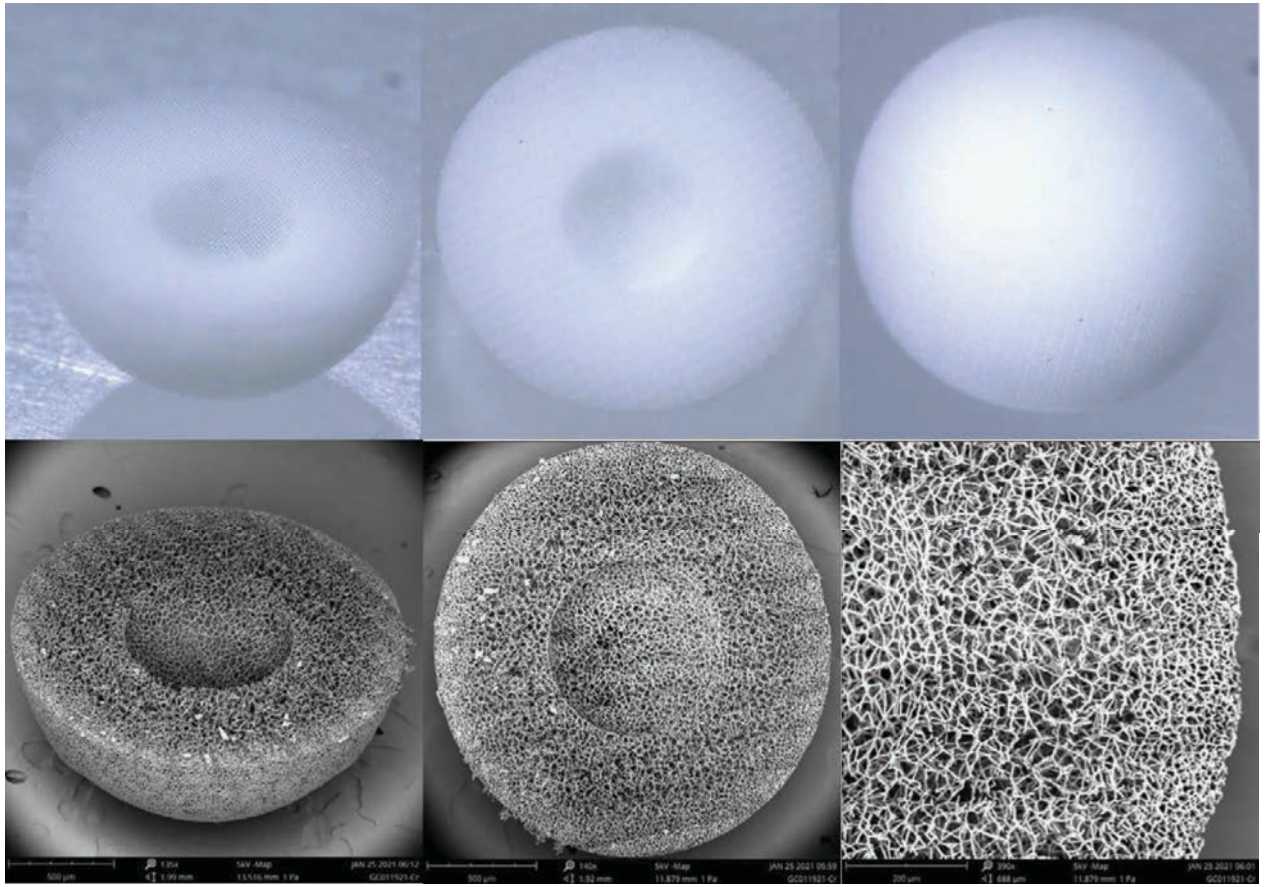


Polystyrene nanowire targets in deuterated form or with embedded nanoparticles have been demonstrated



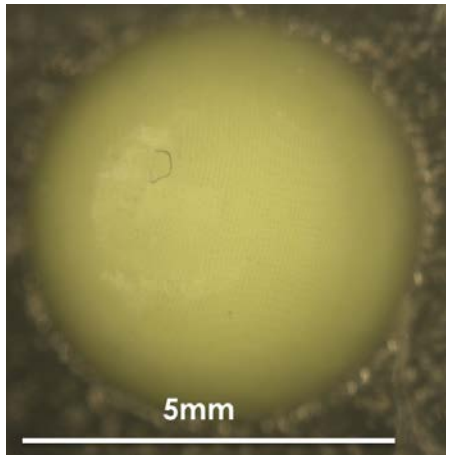
2PP fabrication of foam shells shows promise for wetted-foam IFE designs

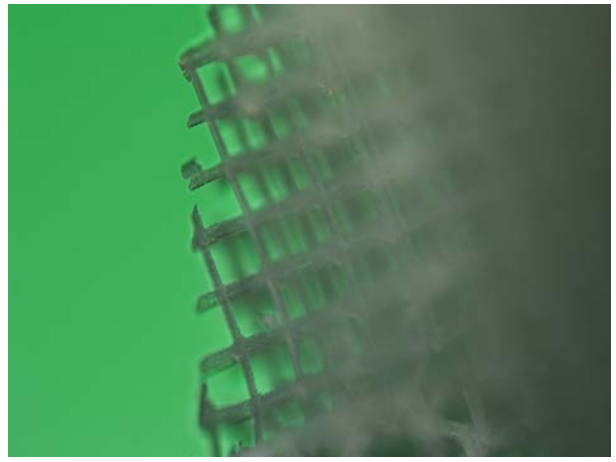
CHO polymer, BCC lattice

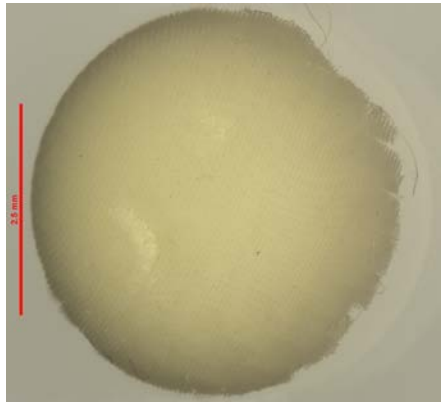


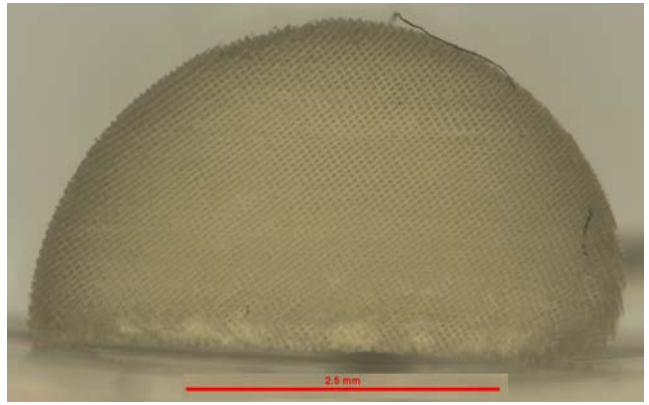
CHO polymer, Stochastic gradient lattice

Deuterated polymer



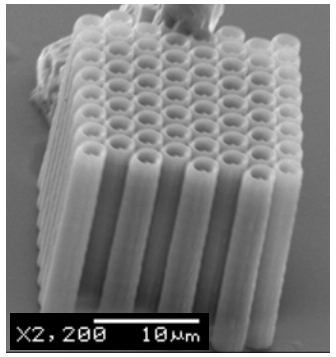




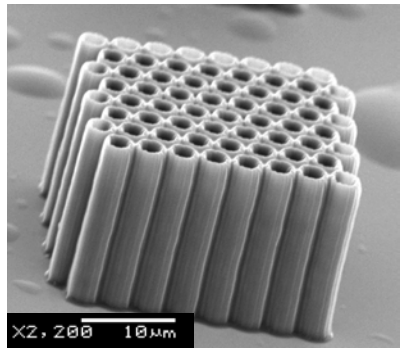


Low oxygen deuterated polymer (needs more R&D)

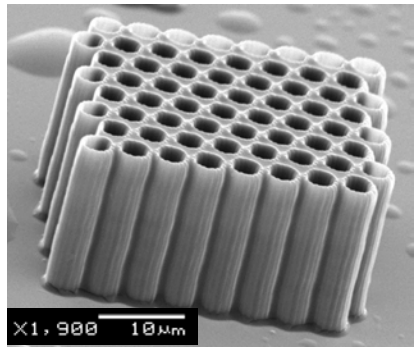
2PP techniques are being developed for radiation source development



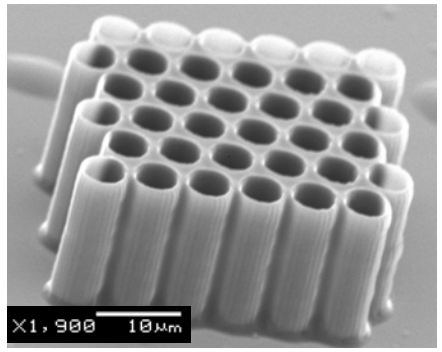
1 µm ID, 20 µm Tall



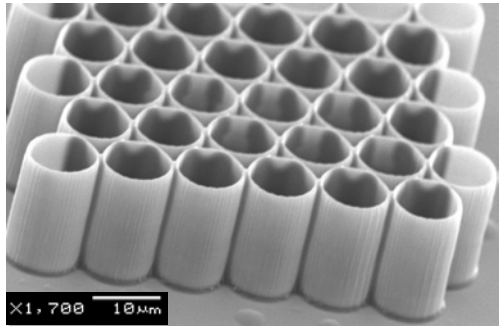
2µm ID, 20 µm Tall



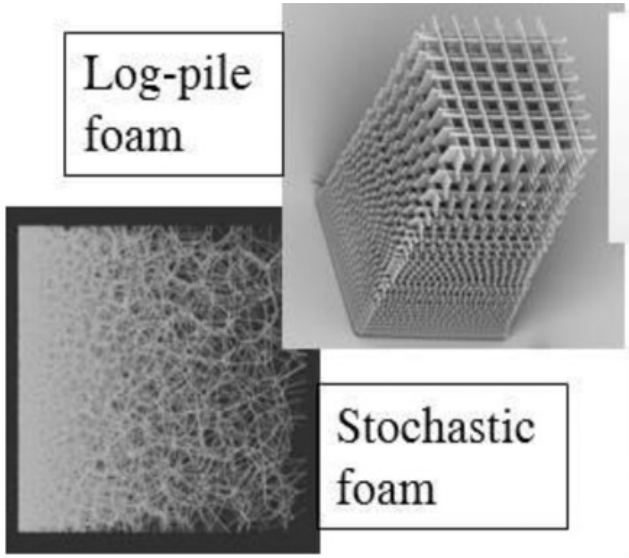
3µm ID, 20 µm Tall

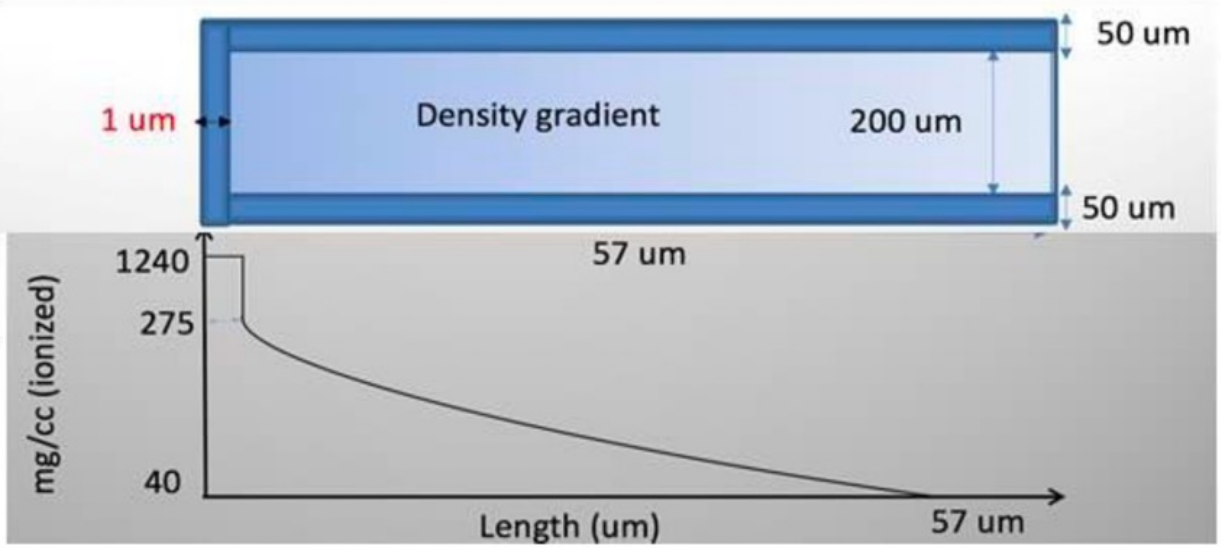


5µm ID, 20 µm Tall

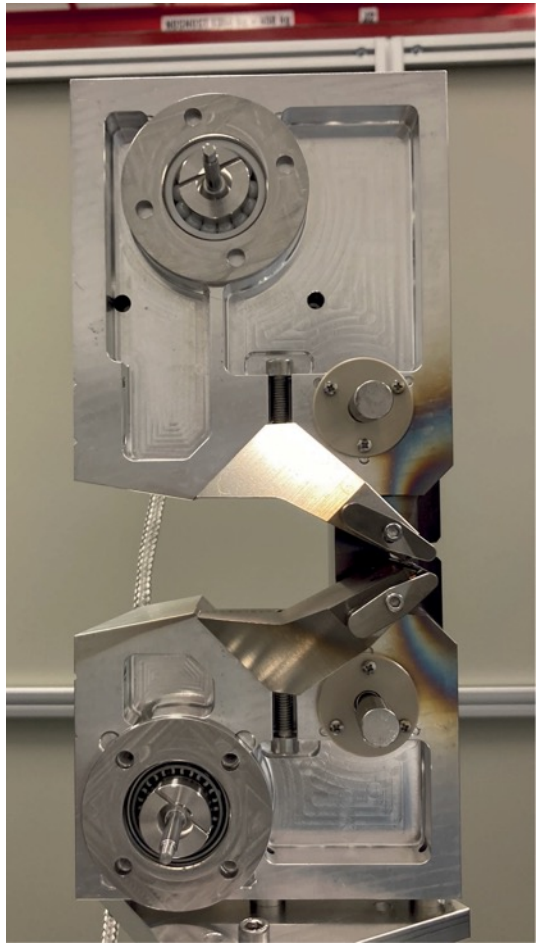


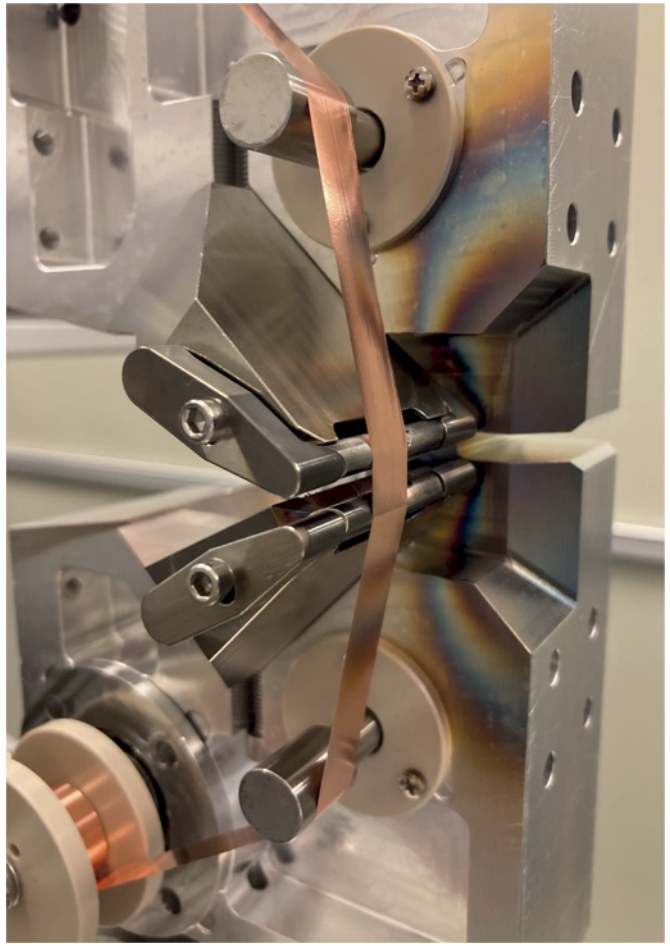
10 µm ID, 20 µm Tall

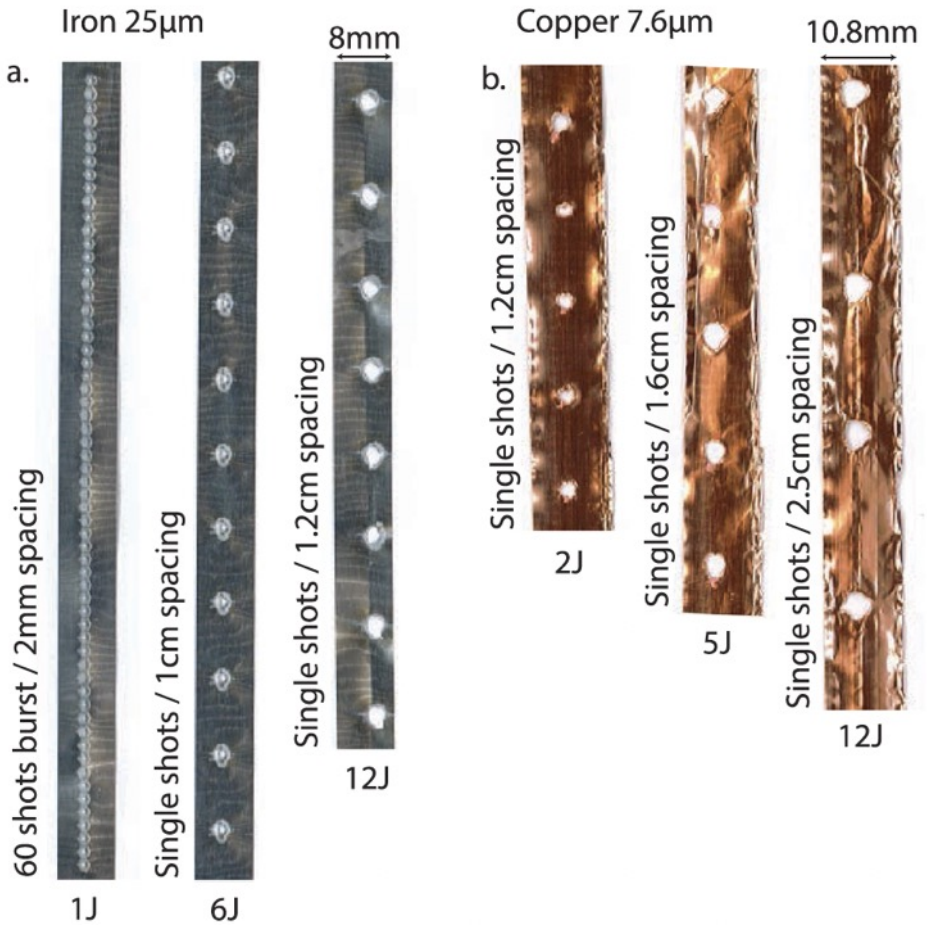




We are presently collaborating with ELI-Beamlines to develop complex target deployment using a tape-drive system



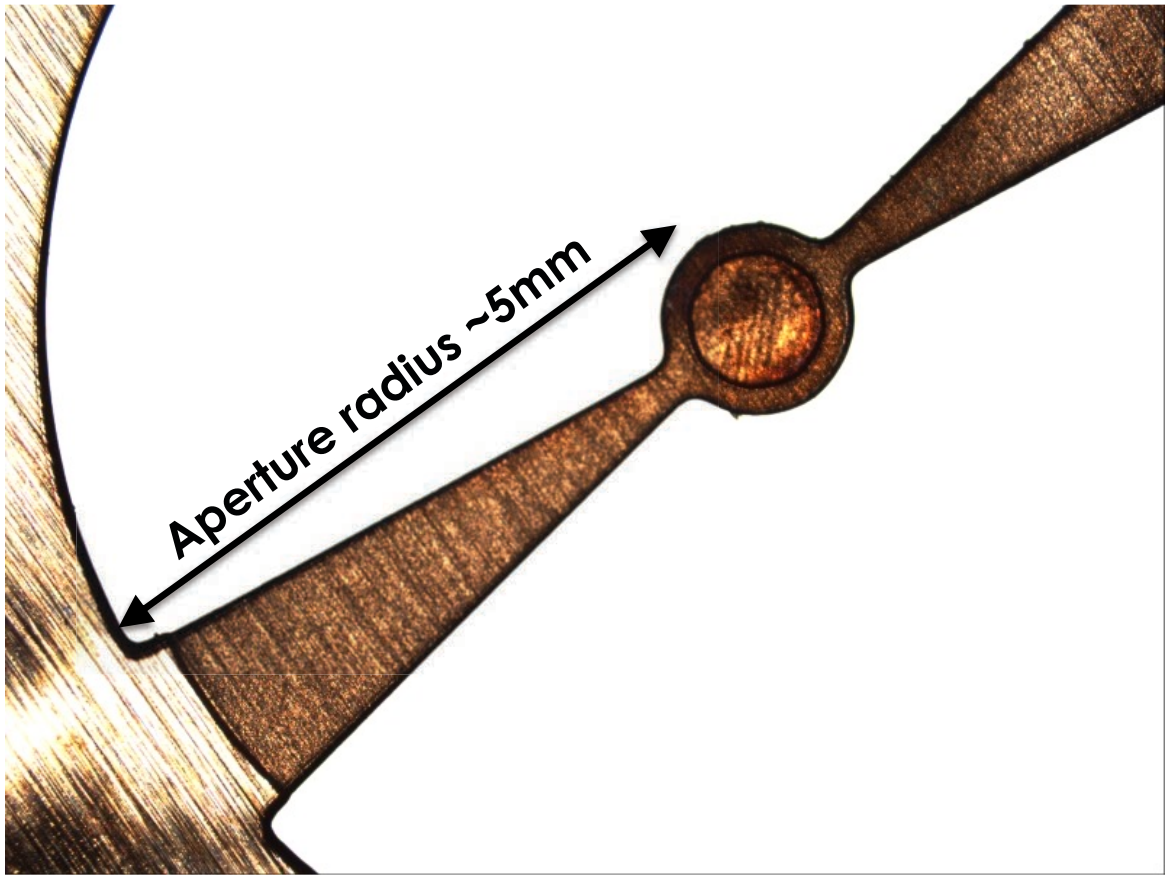


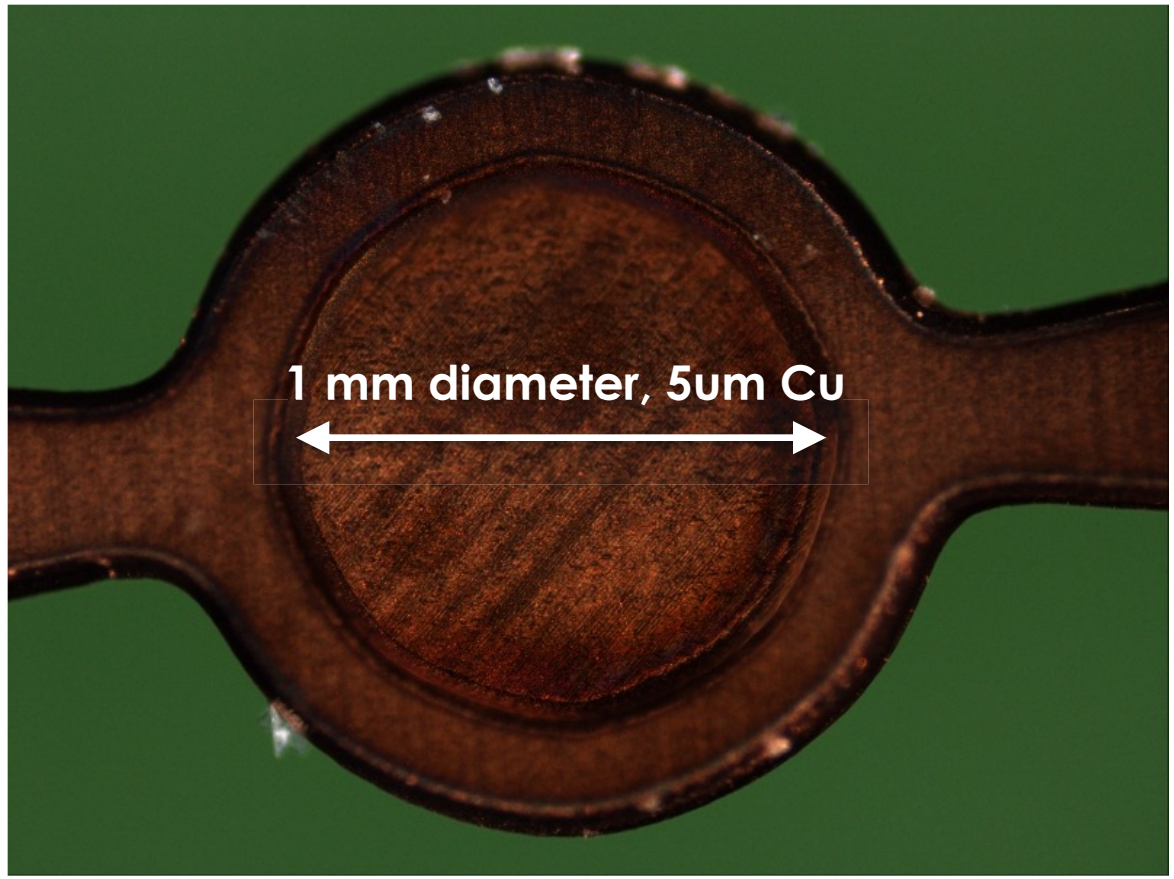


Replica system for testing and development will be available in 2023

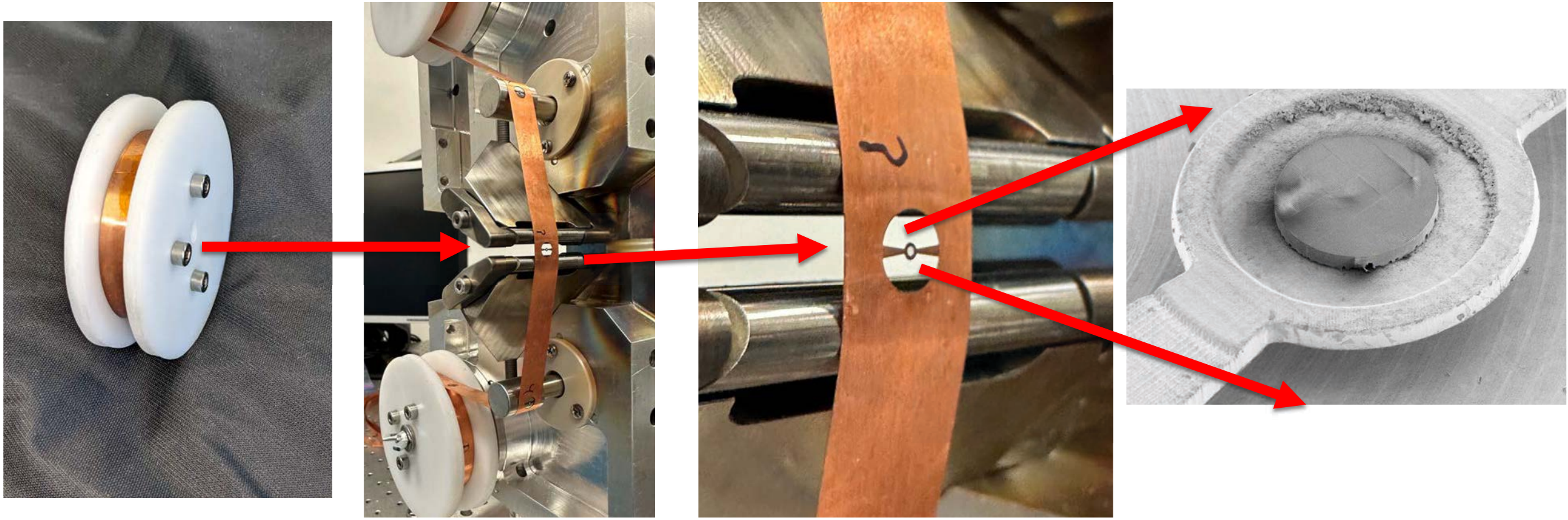
*Condamine, RSI 92 (2021)

Apertured targets significantly reduce target mass for rep-rated HED experiments



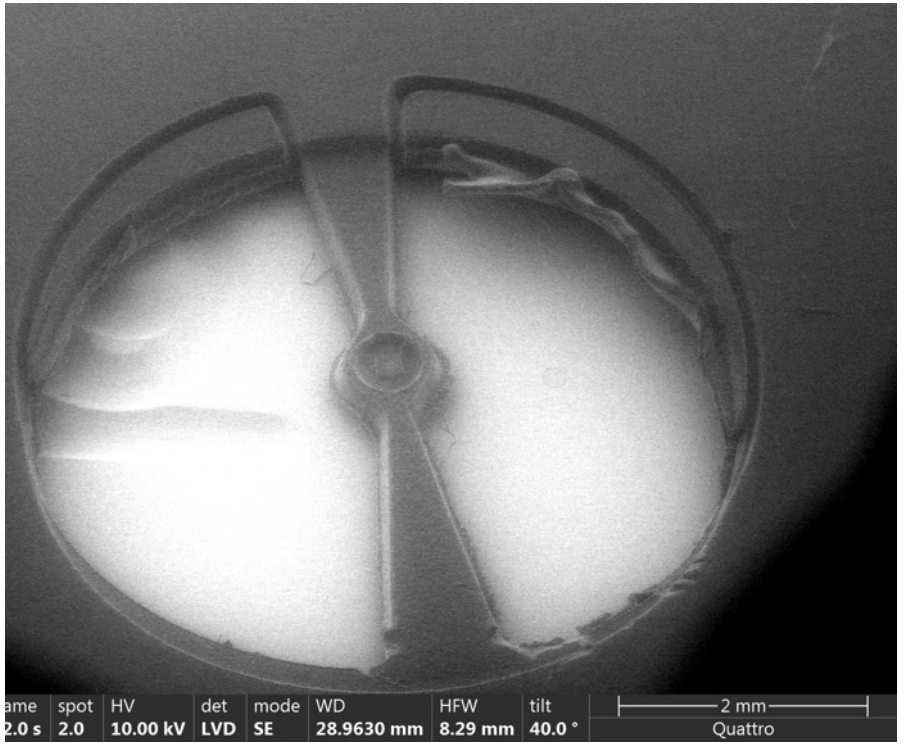


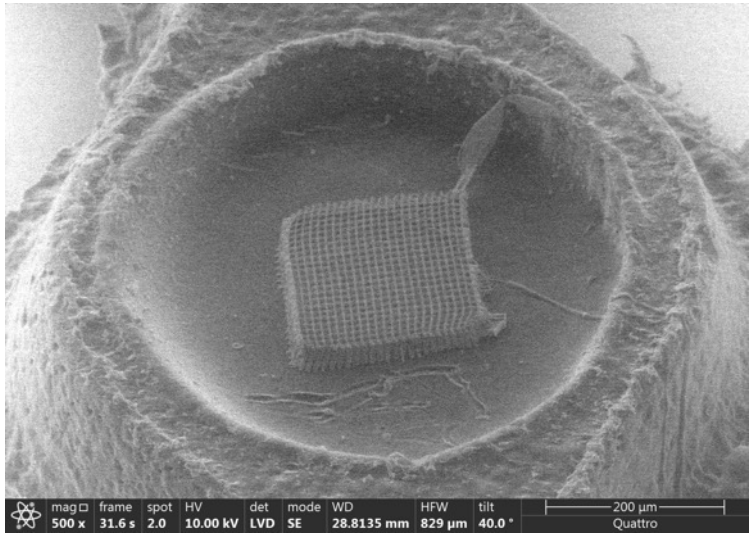
GA aperture-tape holds complex and rigid 3D structures, mitigates ablation debris, and can be flexed, rolled, and transported

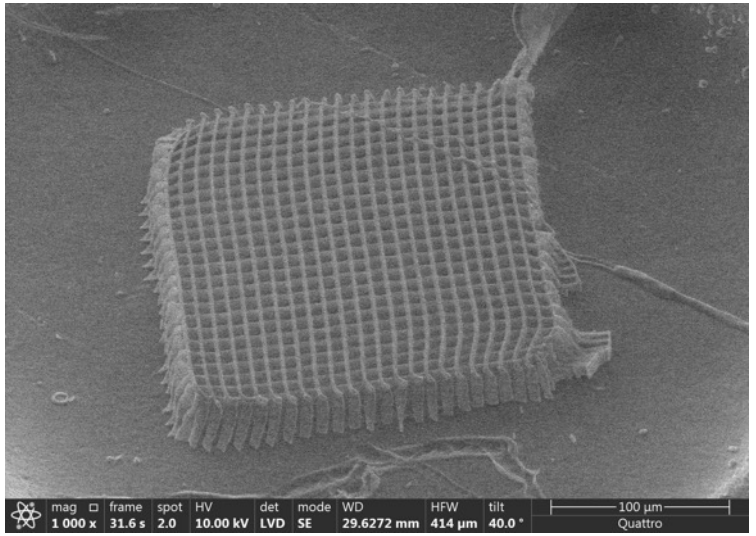


First demonstration shots using L4n executed in November 2022

We have demonstrated the ability to print 2PP structures on ~30um-thick plastic ribbon for rep-rated HED experiments

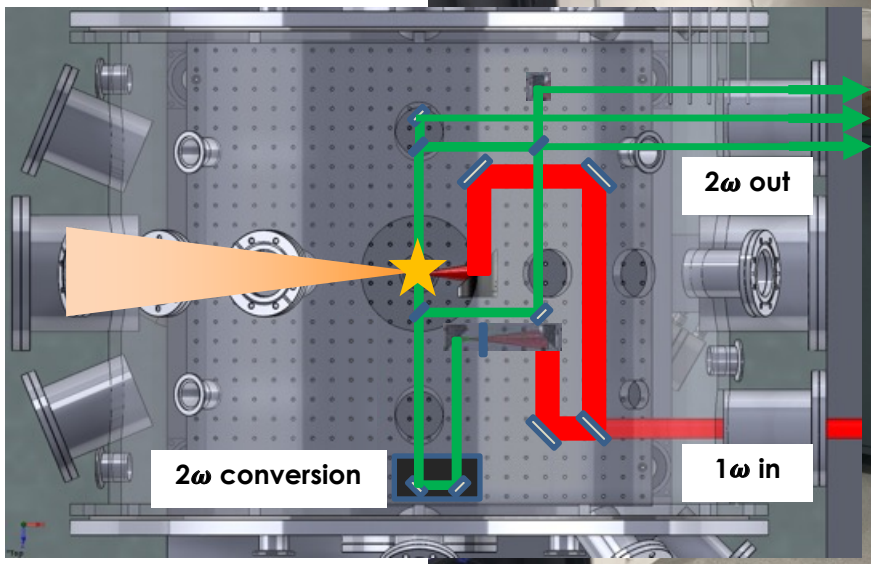






Commissioning of the General Atomics Laboratory for Developing Rep-rated Instrumentation and Experiments with Lasers (GALADRIEL)

Our goal is to develop technologies necessary to utilize rep-rated (~0.1-10Hz) capabilities of present and next-generation High-Energy-Density science facilities located in the US and abroad.

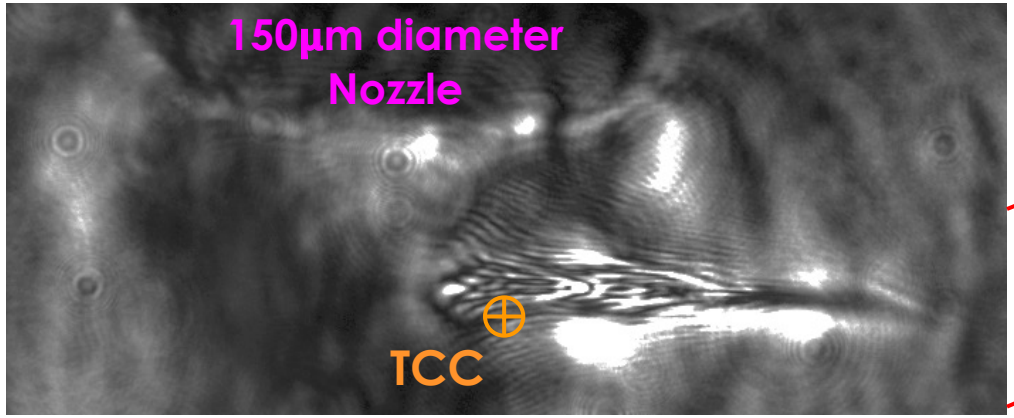


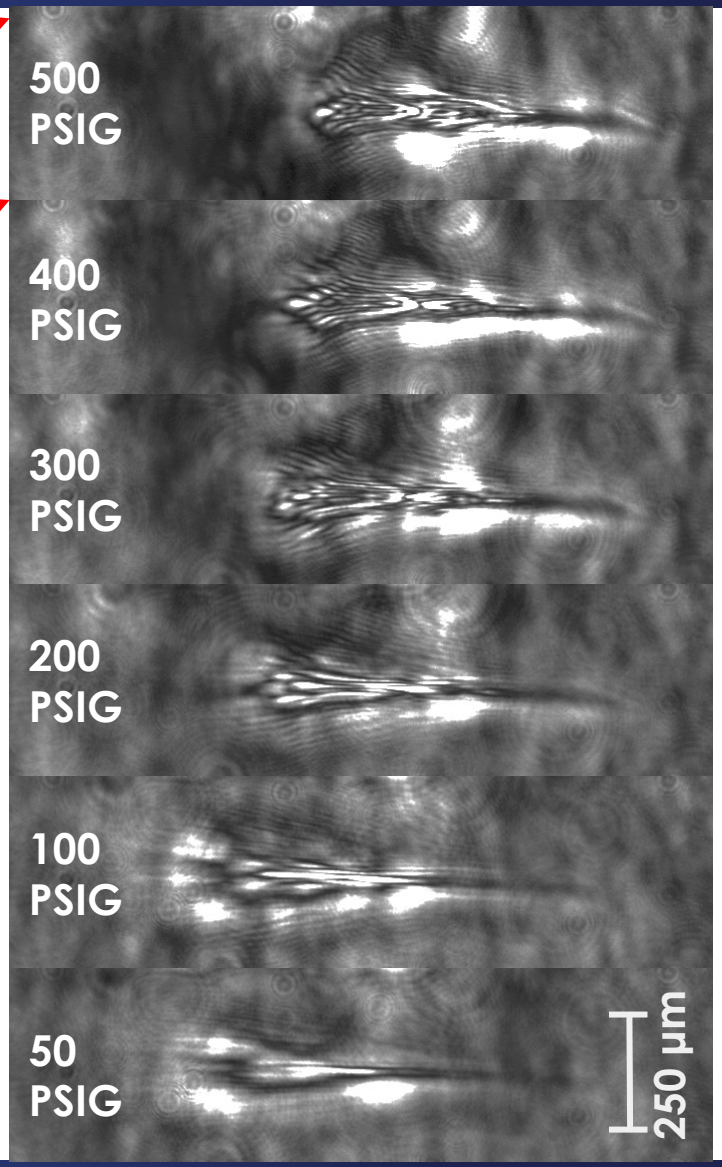
GALADRIEL

Commissioning Timeline

- Jan 2022 – Laser system install
- June 2022 – Vacuum system install
- July 2022 – Single-shot operation (gas-jet)
- May 2023 – Rep-rated operation (gas-jet)
- August 2023 – Implement tape-drive system

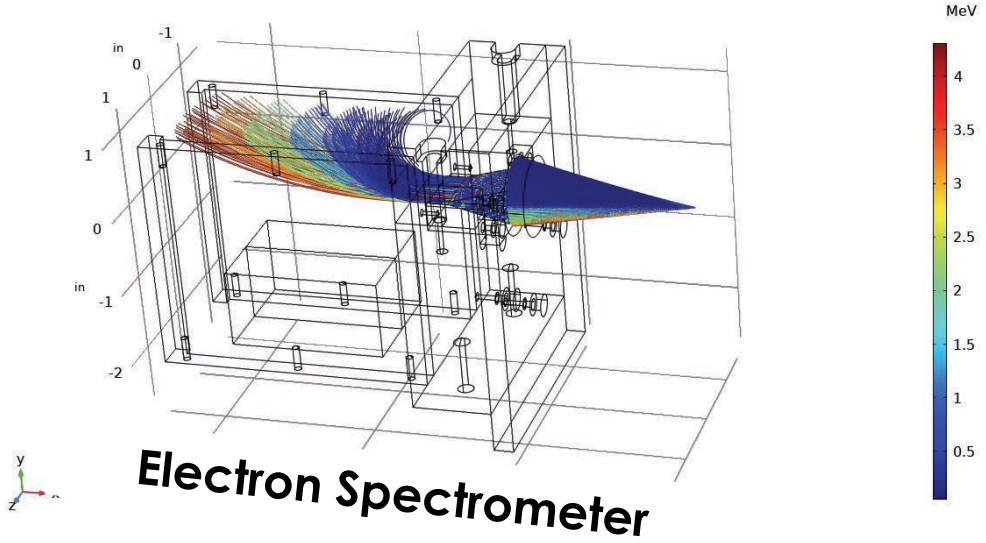
GALADRIEL commissioning experiments began in July 2022



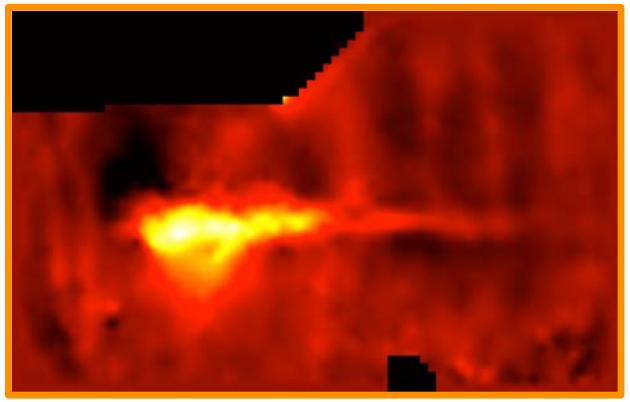


- **Pulsed gas-jet capable of 10Hz operation**
  - ~500μs valve-open time, ~40ms hold time
- **Remote control of nozzle position and gas pressure**
  - Presently using N_2 or He
- **Shadowgraphy using 400nm or 800nm probe**
  - Data show channel formation and differences in evolution after ~200ps of expansion

Rep-rated technology development on GALADRIEL



Electron Spectrometer



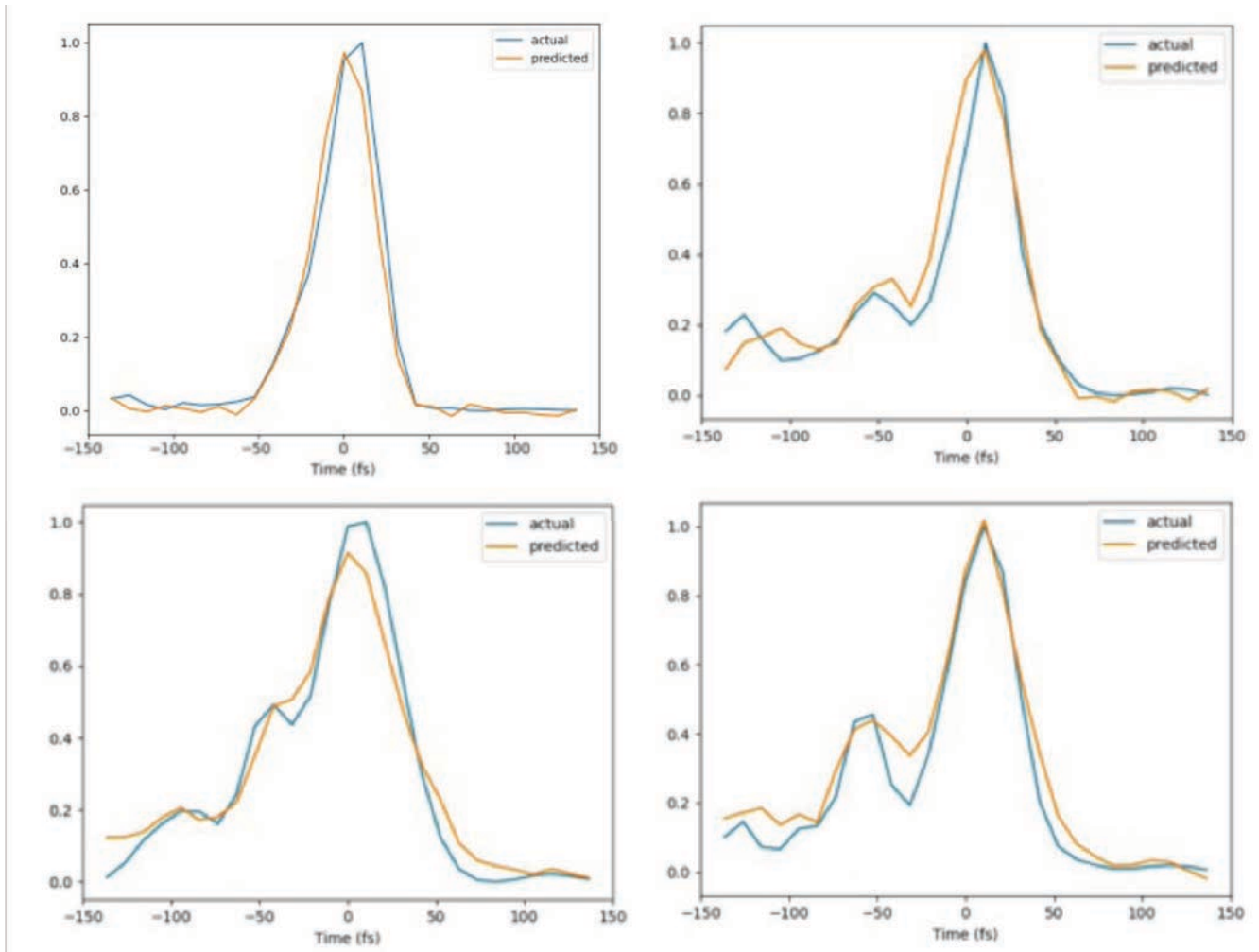
Areal Electron Density (10^{17} e^-/cm^2)

Wavefront Shift (µm)

0.70 0.35 0

10 8 6 4 2 0

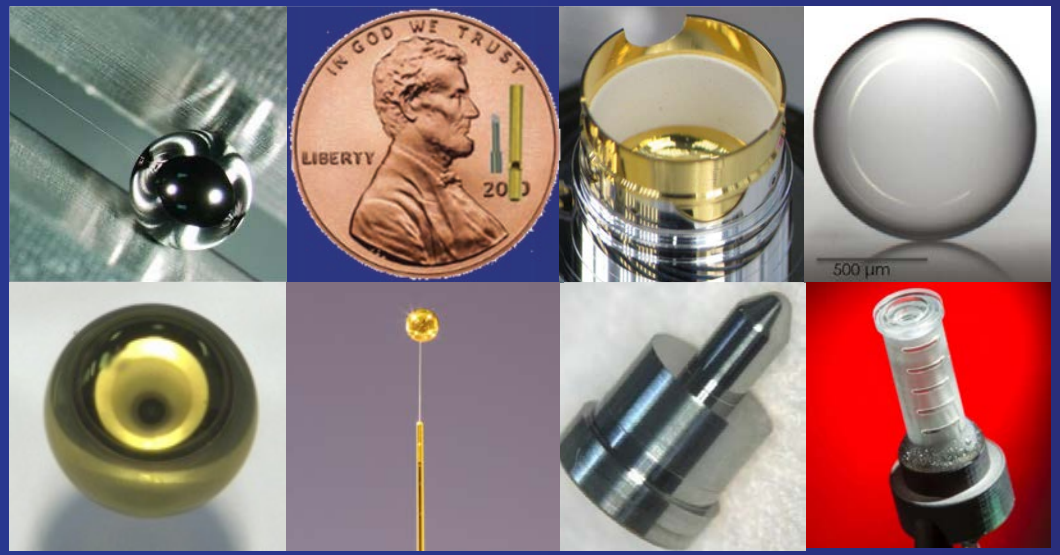
Rapid analysis of probe beam diagnostics



ML-algorithm development for compressed-pulse shaping

Target Fabrication at General Atomics

Questions?



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