Target Design, Fabrication and Integrated Diagnostic Capabilities

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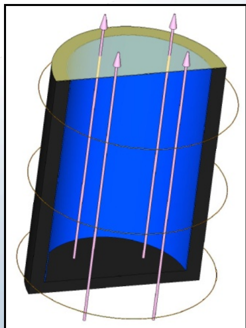
General Atomics

MagLIF Workshop

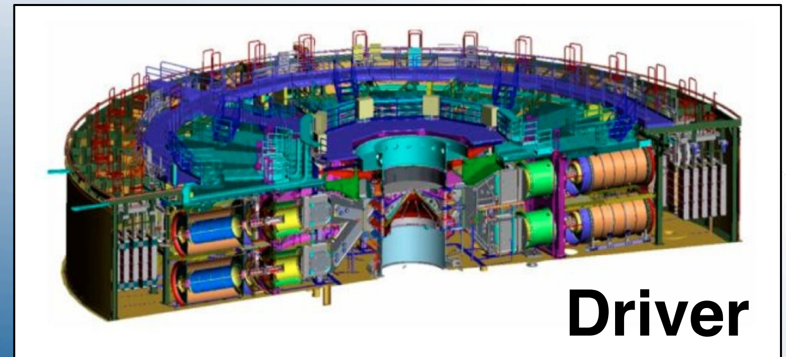
February 7th, 2012

What makes a successful experiment?

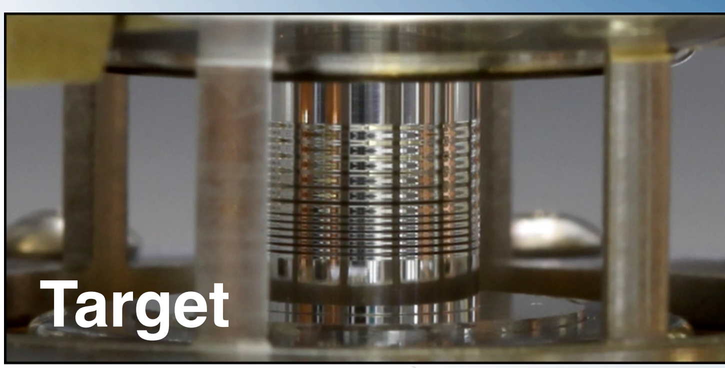
Purpose

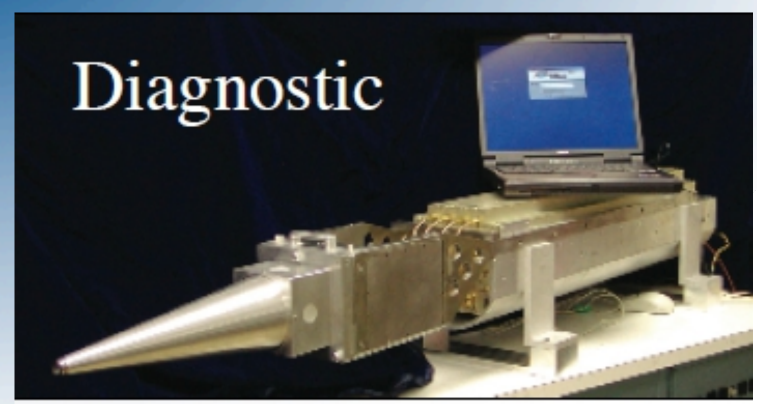


Design



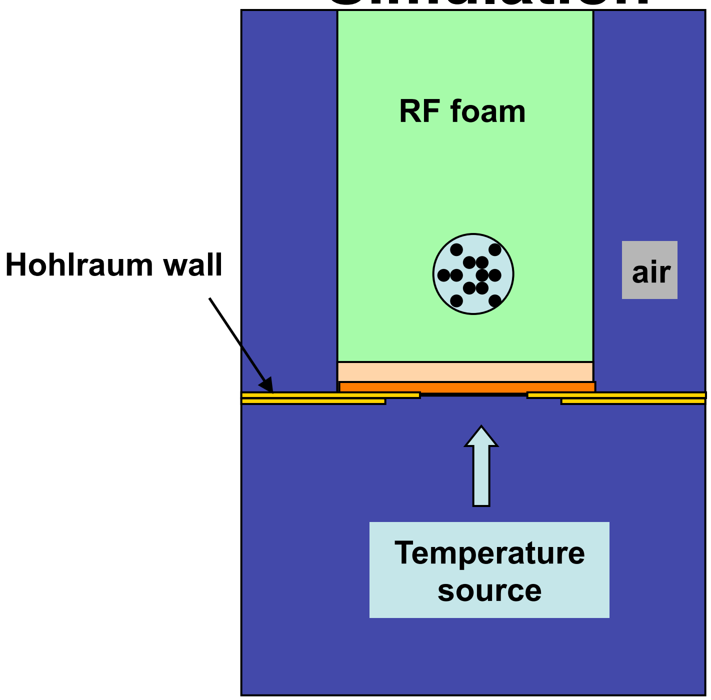
Results



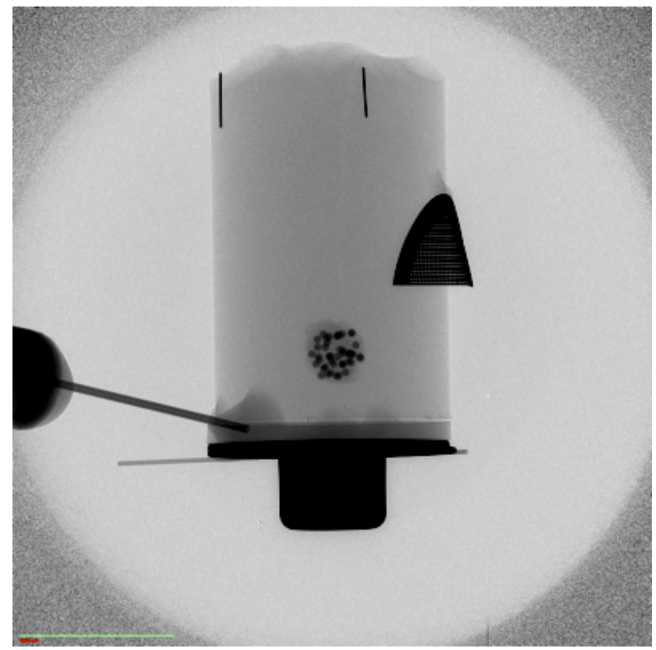


Knowledge of a real target is critical to experimental success

Simulation



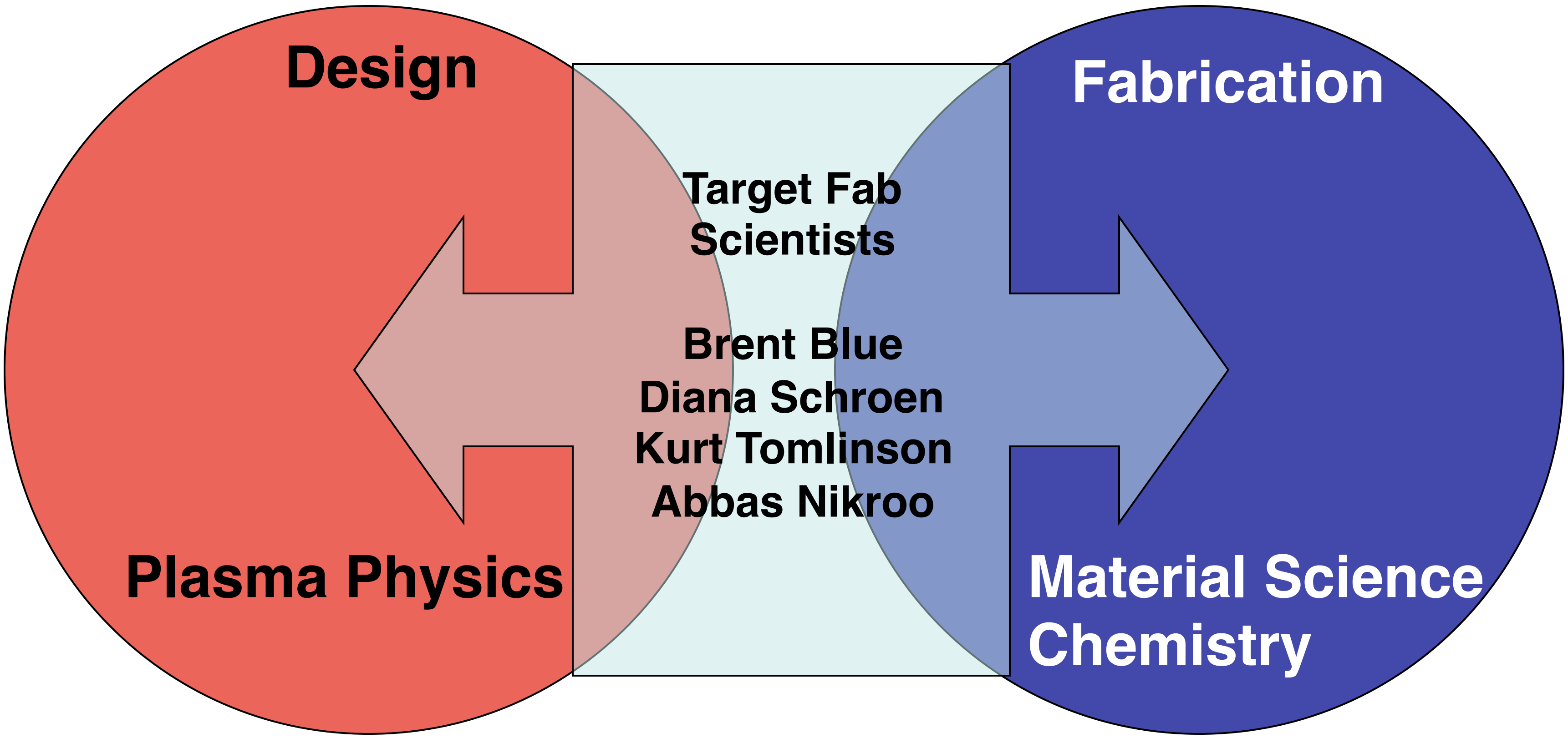
Experiment



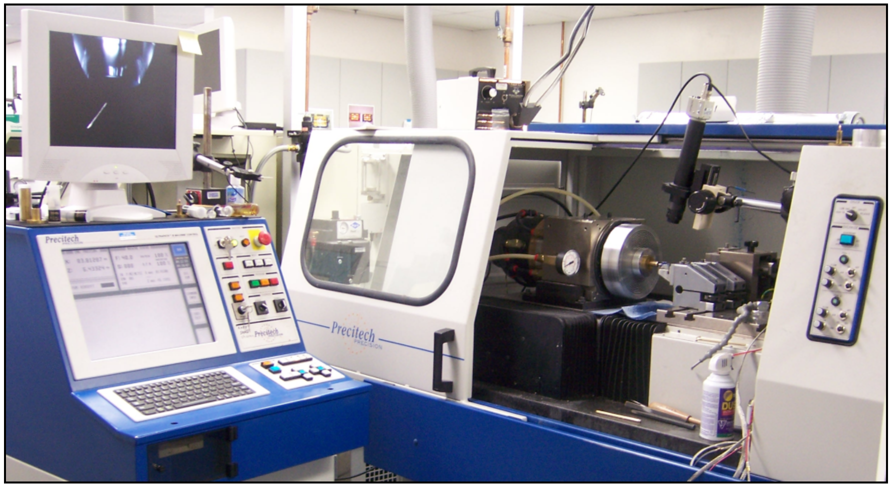
Proper metrology is key

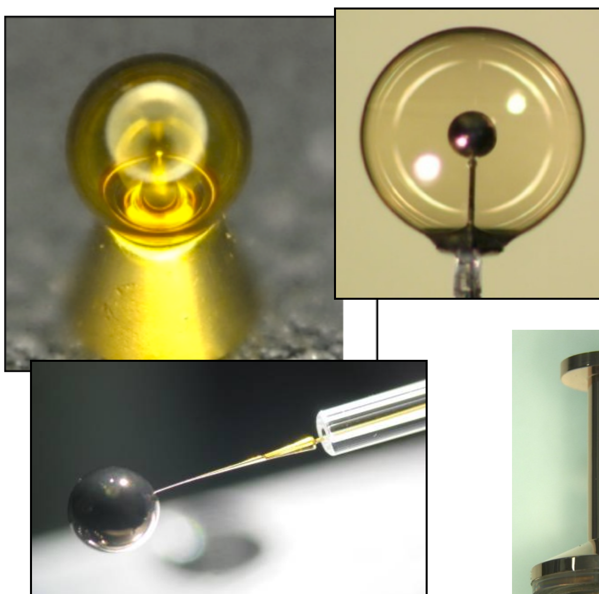
Goal: Design around manufacturing realties to achieve experimental success

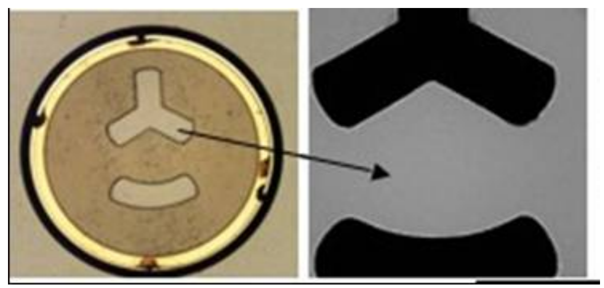
Engage target fabrication early

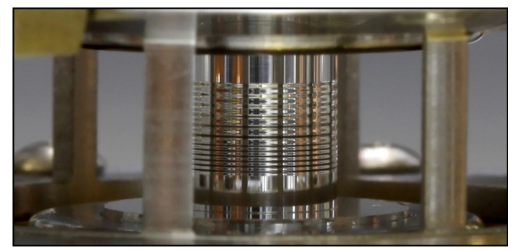


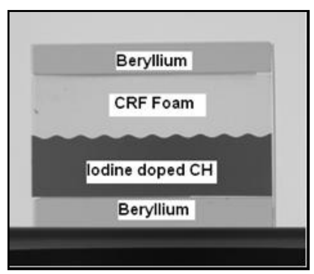
General Atomics has a broad suite of tools to fabricate targets

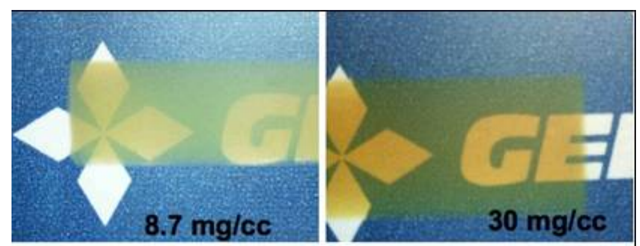






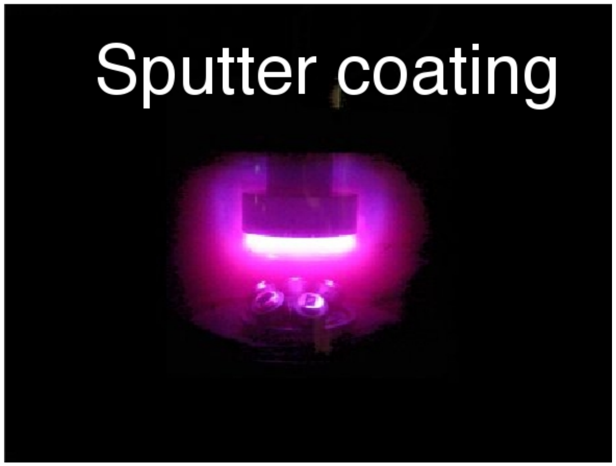






Many elements and compounds can be coated onto targets

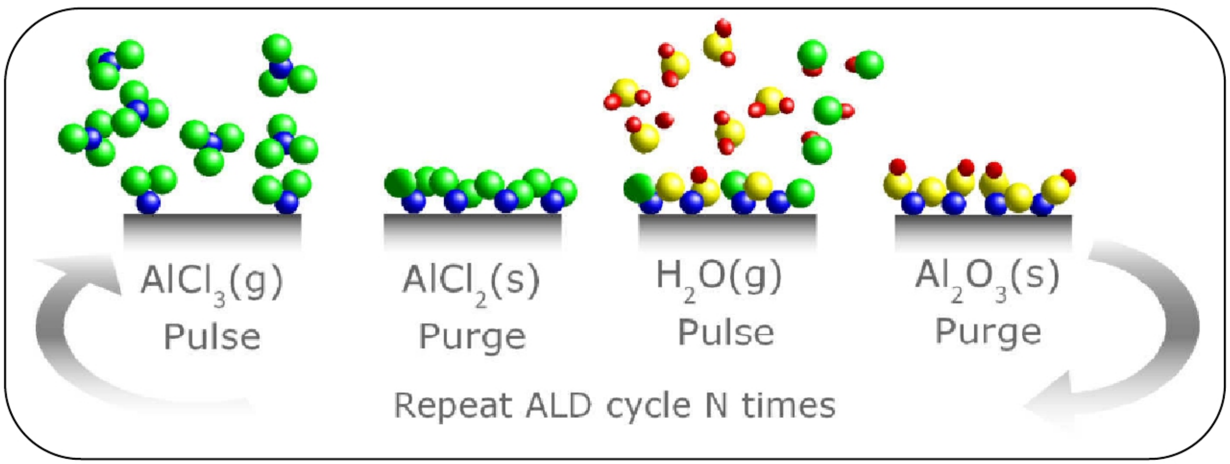
Aluminum
Boron
Boron Carbide
Boron Nitride
Carbon
Chromium
Copper
Dysprosium
Gadolinium
Gold Boron
Iridium
Iron
Manganese
Molybdenum
Neodymium
Nickel
Scandium
Silicon
Silver
Silicon Dioxide
Tantalum
Tellurium
Tin
Titanium
Titanium Dioxide
Tungsten
Vanadium
Zinc



Electroplating

Gold
Copper

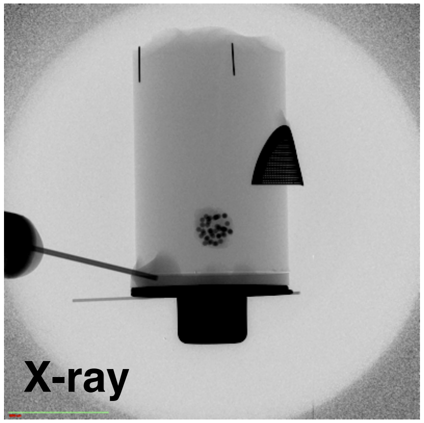
Atomic Layer Deposition (ALD)

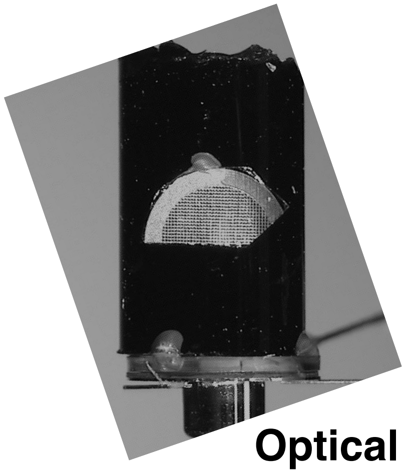


Metrology: the final critical fabrication step

Group B — **Clumpy Aluminum Oxide Ball Target**

No.	Specification	Value	Specification Tolerance ±	B1	B2	B3	B4	B5	B6	Meas. Error±	Note
1	Foam Density (mg/cc)	300	30	296	296	296	296	294	294	4	Batch average: Measured on 2 witness pieces of foam for each batch
2	Z Distance from center of ball to drive face (um)	900	200	980	1117	1159	1113	976.3	885.32	10	Measured by radiography
3	Distance of ball center from axis of foam (um)	0	500	346	269	178	82	384.45	254.75	20	Measured by radiography
5	Diameter of Foam Cylinder (mm)	3.9	0.2	3.92	3.84	3.91	3.88	3.69	3.69	0.02	
6	Minimum Length of Foam Cylinder (mm)	5	1	6.0	6.1	5.7	5.8	5.9	5.4	0.1	Length must be >4000um, foam may have rough edge on the end of the foam (but drive face will be smooth)
7	Maximum deviation from Flatness (um)	<30									Best effort; Measured on drive side face on a sampling of targets at Alberquerque
8	Ball clump/distribution diameter (um)	1000	NA	1172	1035	1063	1062	911	903	200	
10	Number of balls in clump (#)	46	5	37	46	21	34	30	43		
11	Ball diameter (um)	130	NA	130	130	130	130	130	130		
	ball material	Ruby (Al_2O_3 + <0.05% Cr)									
	Batch ID Number			RF090616-A	RF090616-B	RF090616-C	RF090616-D	RF090430-B	RF090430-D		





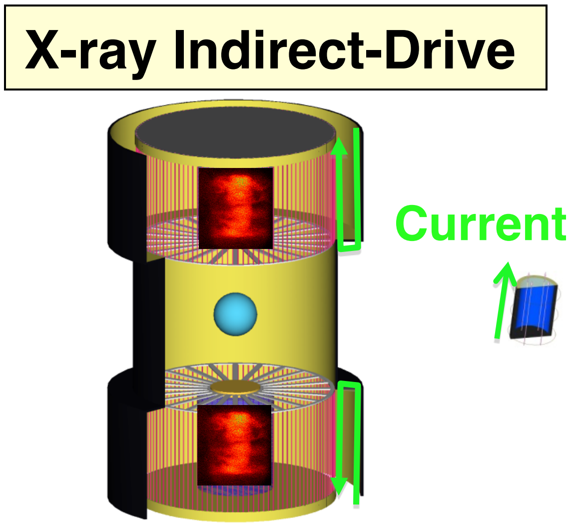
Optical

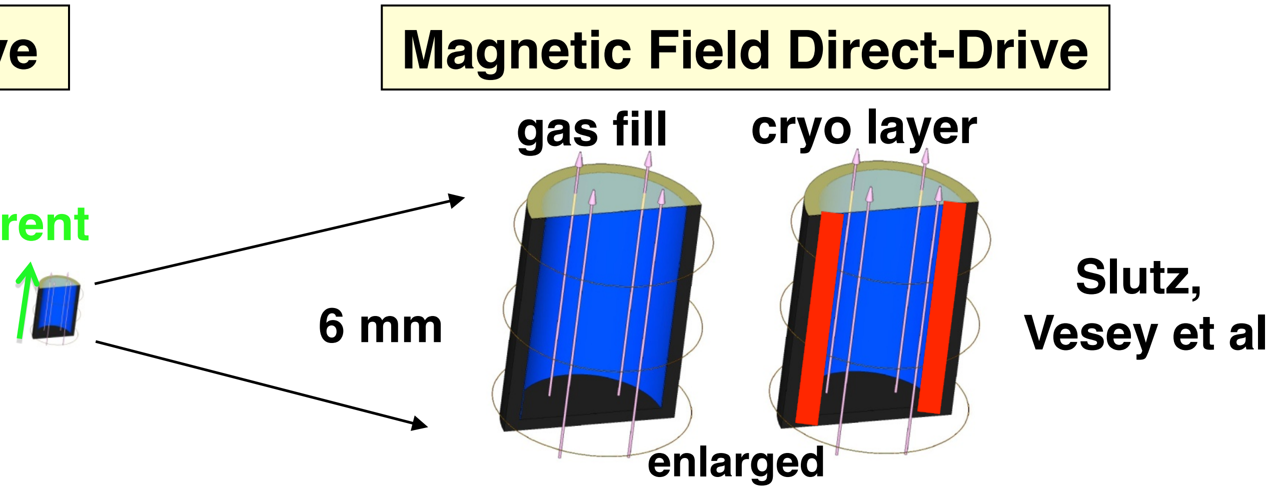
Know what you are shooting before the shot

Target destroyed

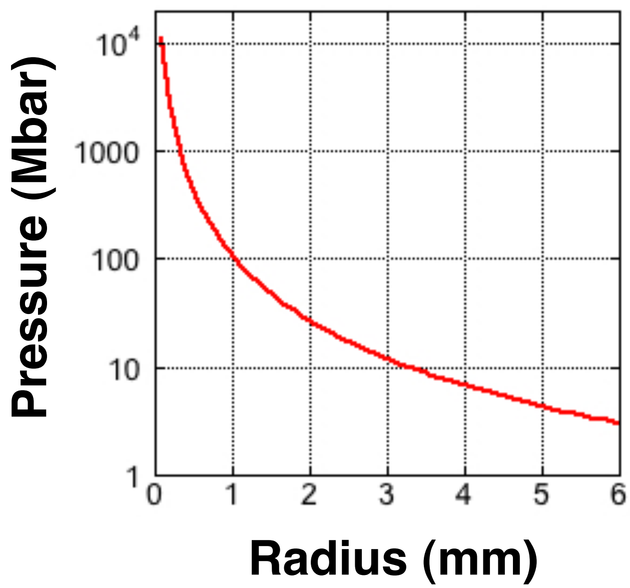
Can't go back

Z ICF Targets have advanced significantly in the last few years

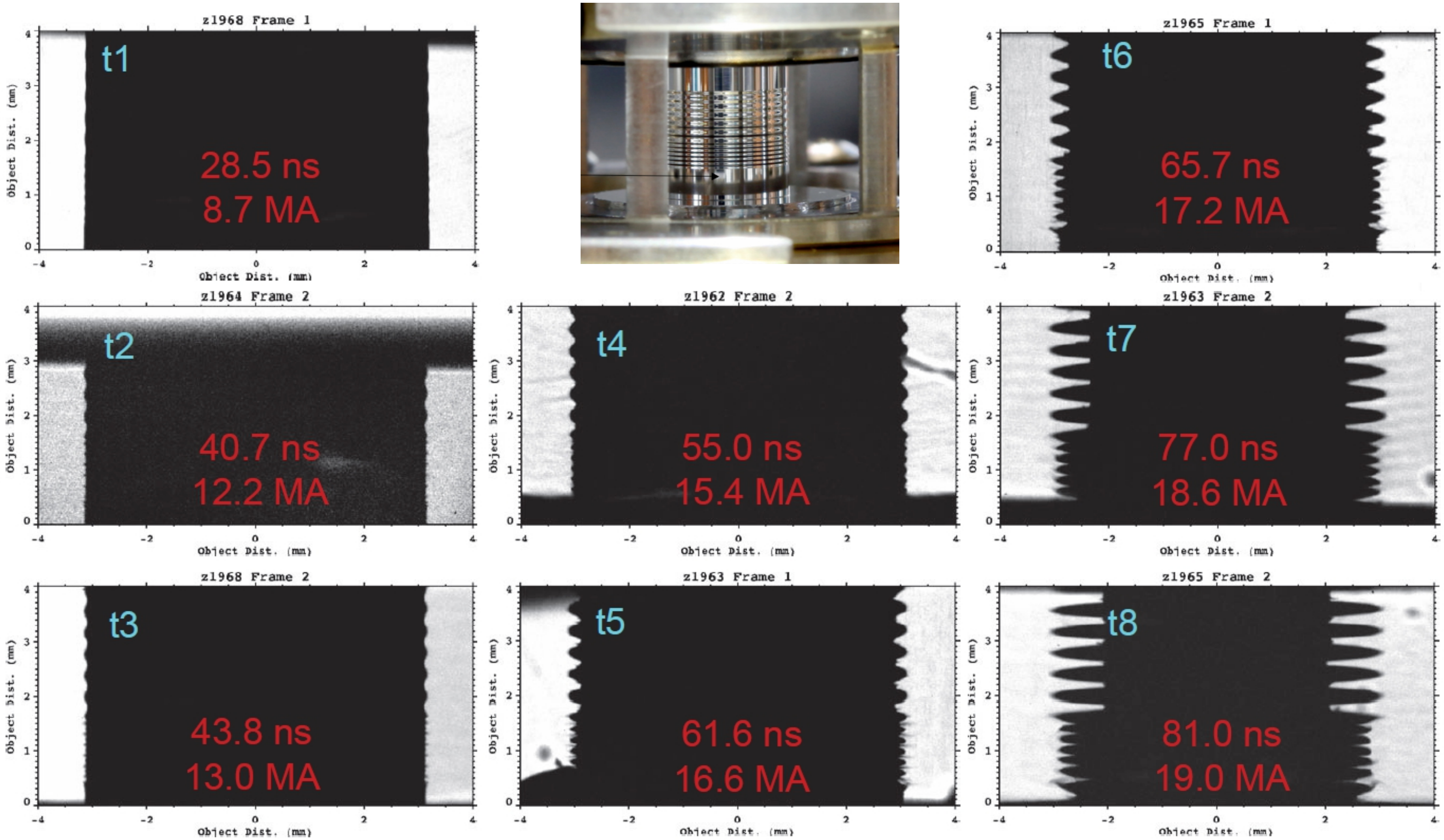




- Compact targets, easier and lower cost to fabricate
- Lower inductance hence higher coupling of current
- Higher coupling efficiency to fuel with direct driver, hence higher energy delivered, higher possible fusion yields

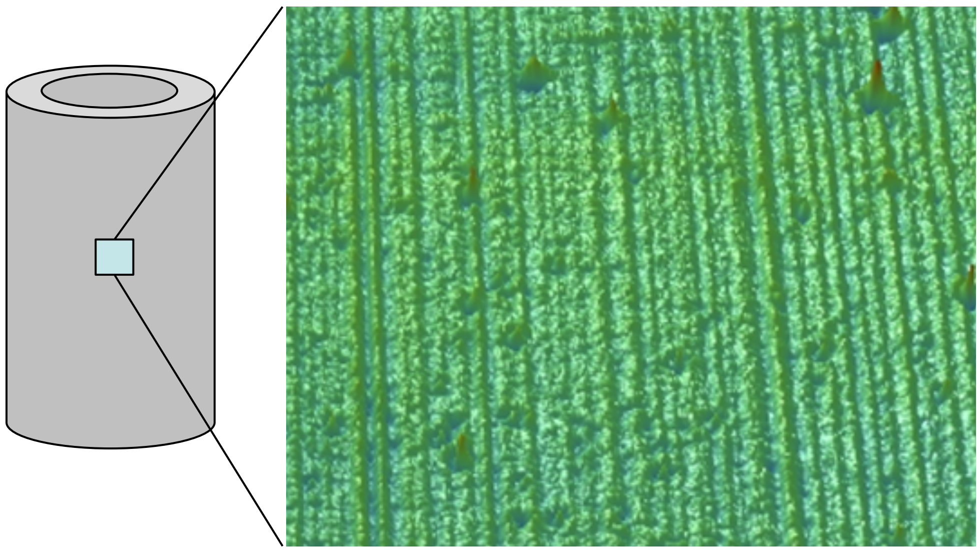


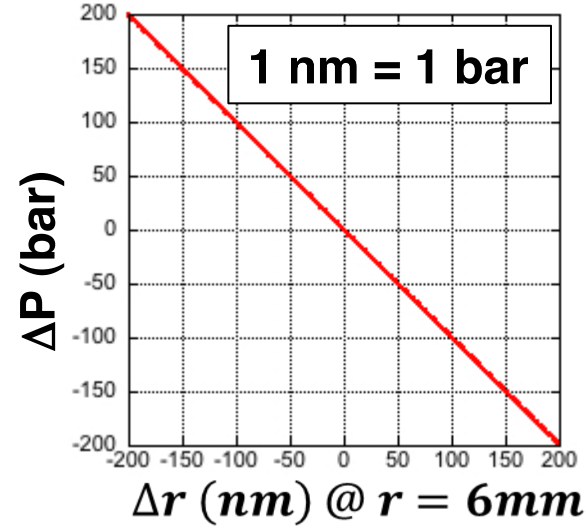
Suppressing the magneto-Rayleigh-Taylor instability is crucial for a stable implosion



GENERAL ATOMICS

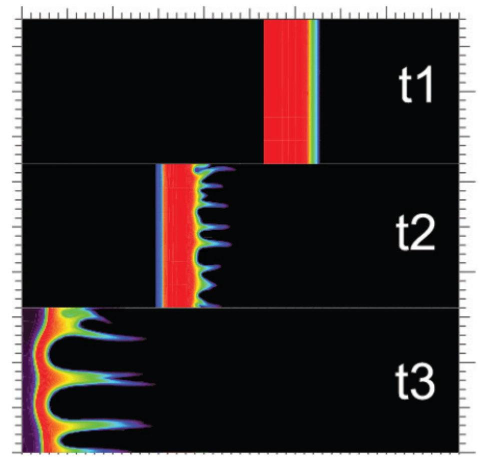
Surface roughness can seed the MRT instability





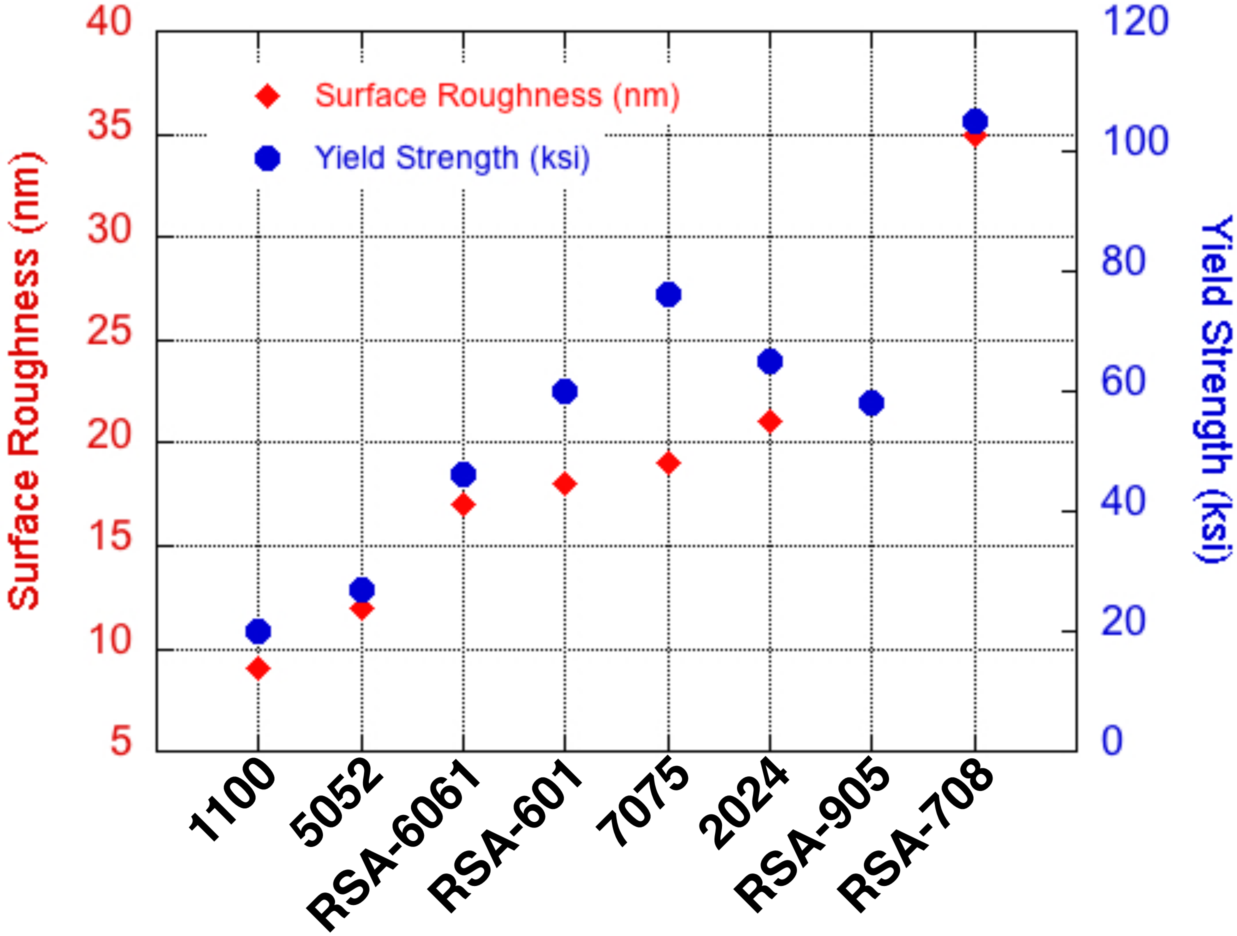
- **All materials have an inherent surface roughness**

- **Function of material and how it was fabricated**



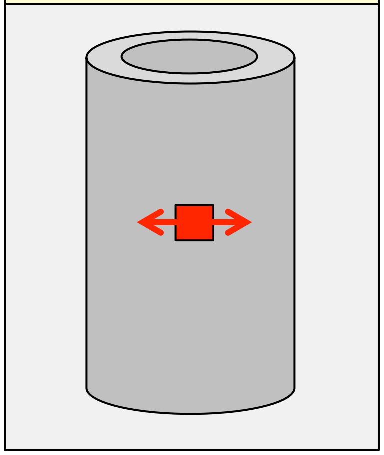
Simulated liner implosion with surface roughness

Aluminum is a candidate material for a ZFE target due to its low cost and ease of machining

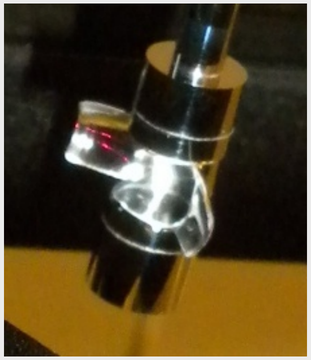


Alloys can also be selected based on elements desired for spectroscopic diagnostics

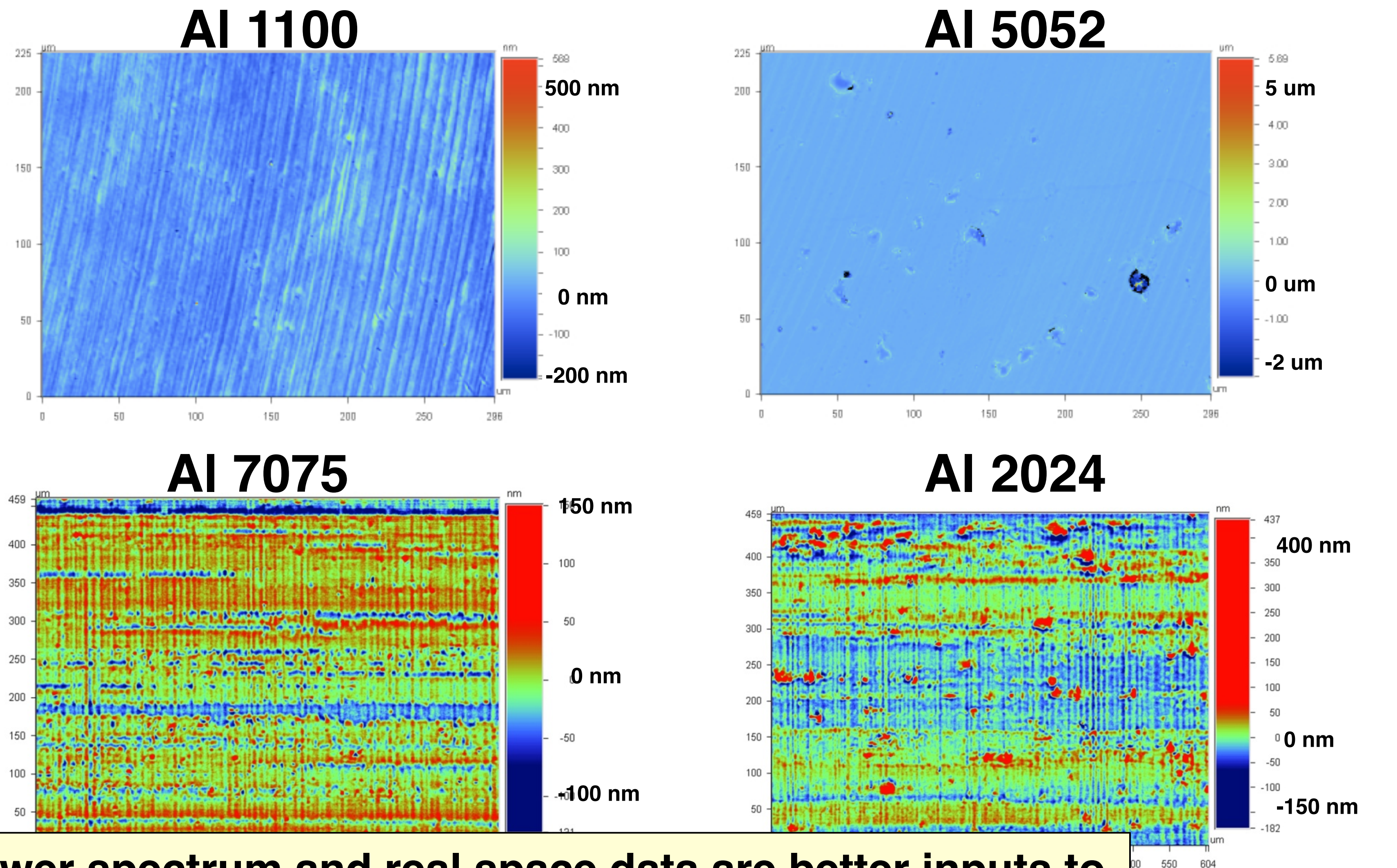
Yield strength
$\sigma_h = Pr/t < \sigma_Y$



Over Pressurized



Localized surface features are not captured by solely looking at the RMS surface roughness

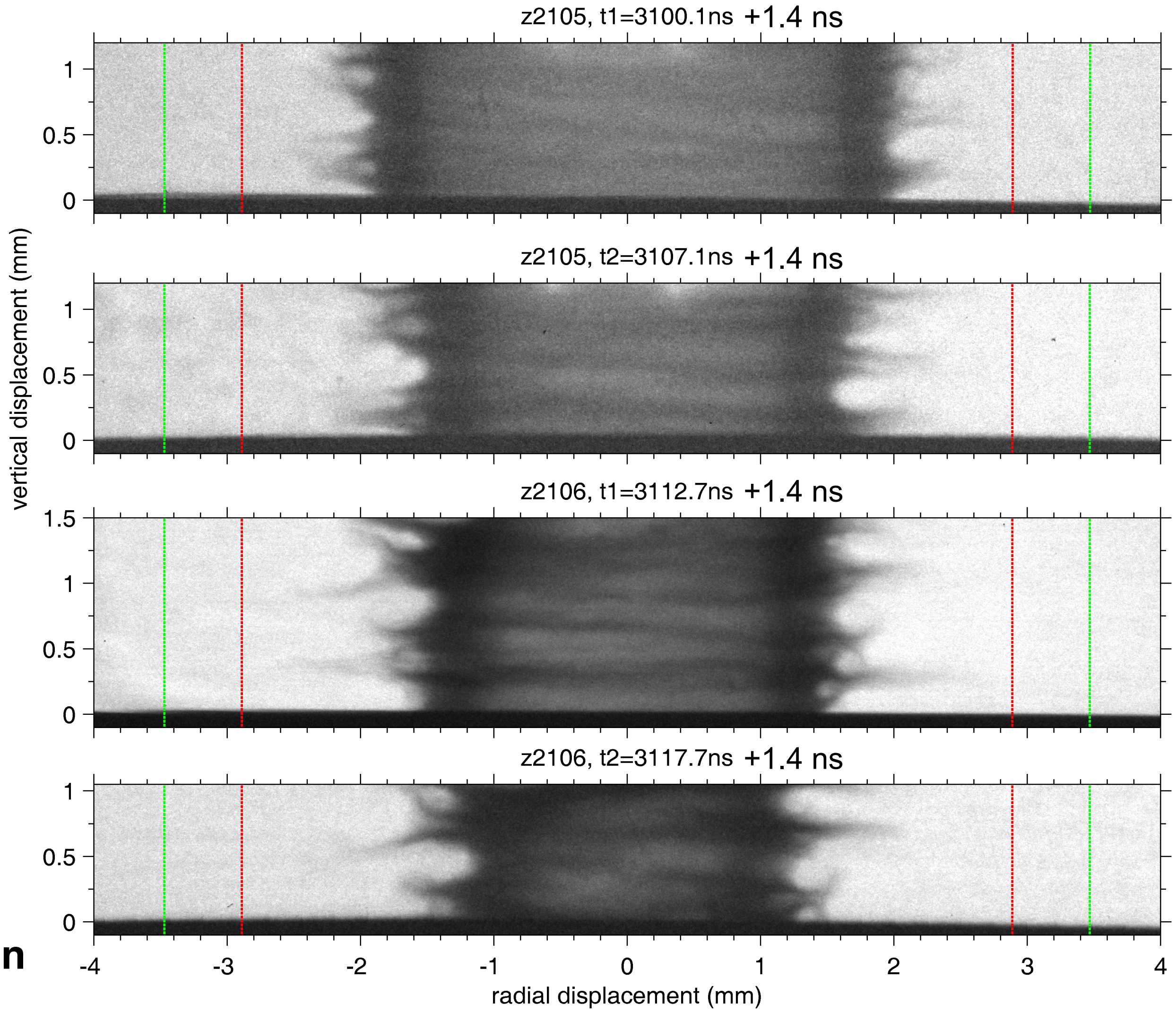


Power spectrum and real space data are better inputs to code

Beryllium is an excellent material for diagnosing the physics of a ZFE target

Beryllium Target

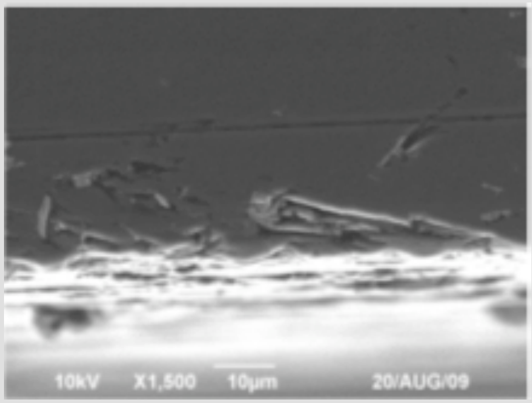
Machined perturbation

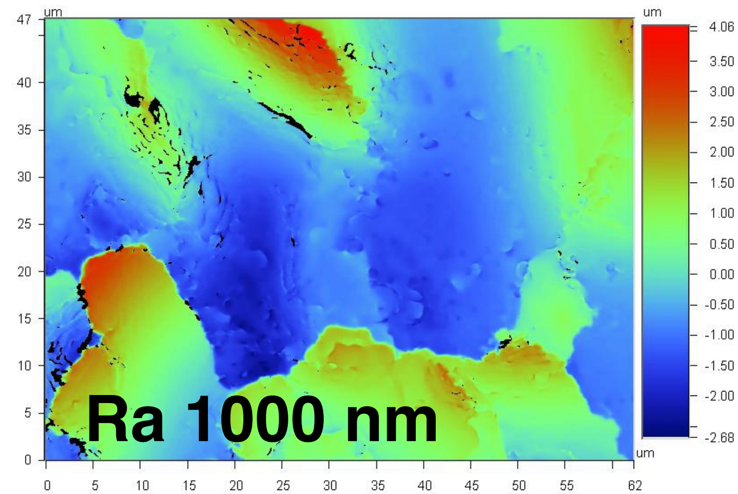


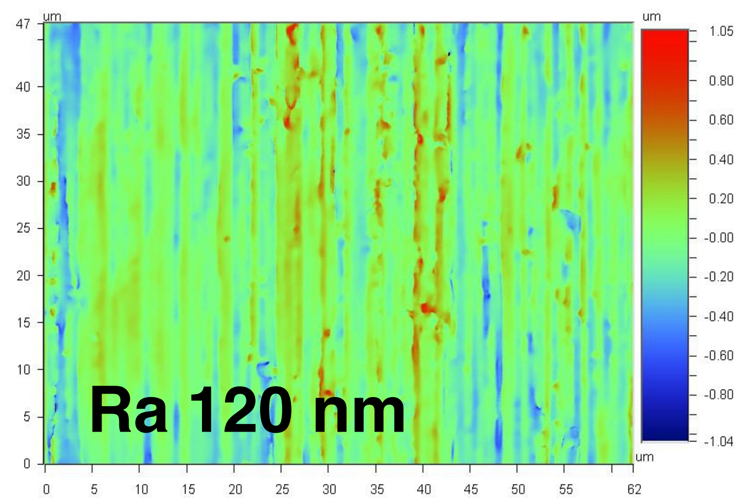
Simultaneous measurements of ID, OD, and density

Beryllium is a hazardous material that is difficult to machine

Surface Defects in cross section



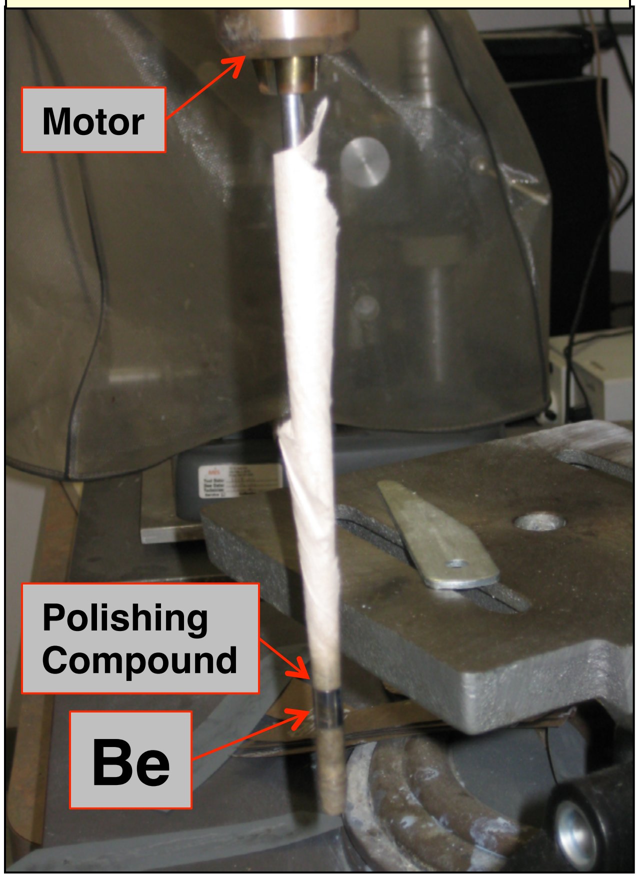




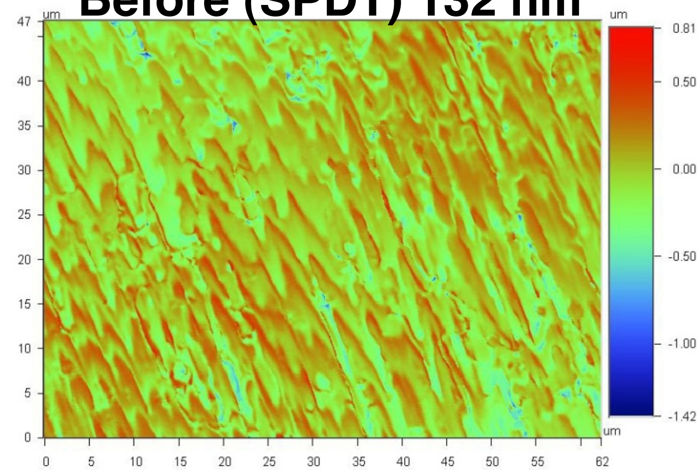
- **Carbide former- wears diamond tool**
- **Subsurface damage mitigation critical to improving surface roughness**
- **Still rougher than Aluminum as machined**
- **Polishing is needed for further improvement**

The surface roughness has been further improved by polishing the ID and OD of Beryllium tubes

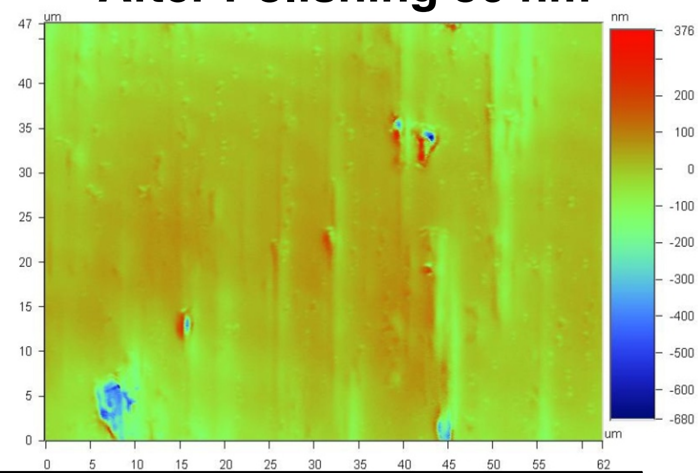
Polishing Setup



Before (SPDT) 132 nm



After Polishing 36 nm



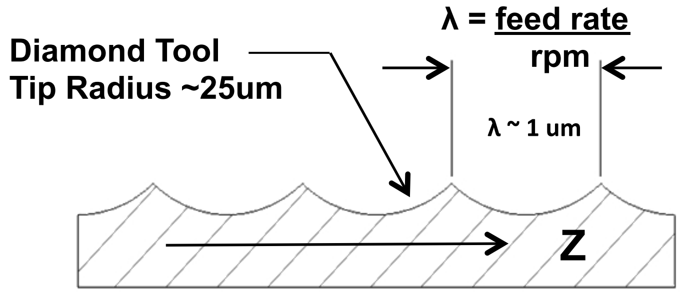
Significantly improves the surface roughness after diamond turning while maintaining dimensional tolerances

3D Gorgon calculations suggest even a small degree of initial azimuthal correlation can affect the late-time dynamics

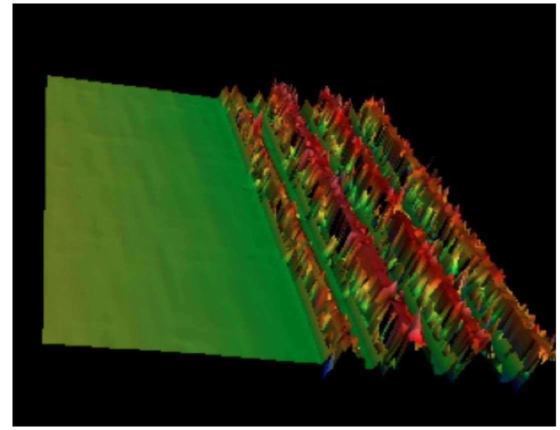
Gorgon Simulations

Correlation

No correlation



Diamond turning imposes a helical groove on the target's cylindrical body



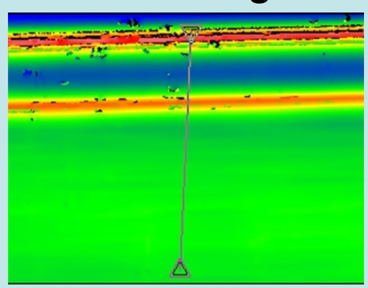
Wavelengths of 1-15 μm
~ nm to μm P-V

Several methods have been investigated to modify the surface roughness

Longitudinal grooves

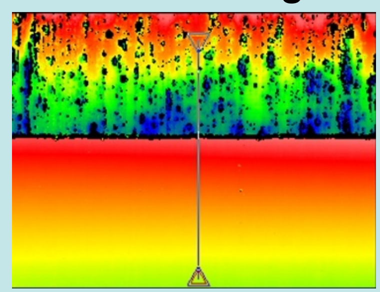
Groove perpendicular to B-Field

Correlated Roughness



Top half of target rough, bottom smooth

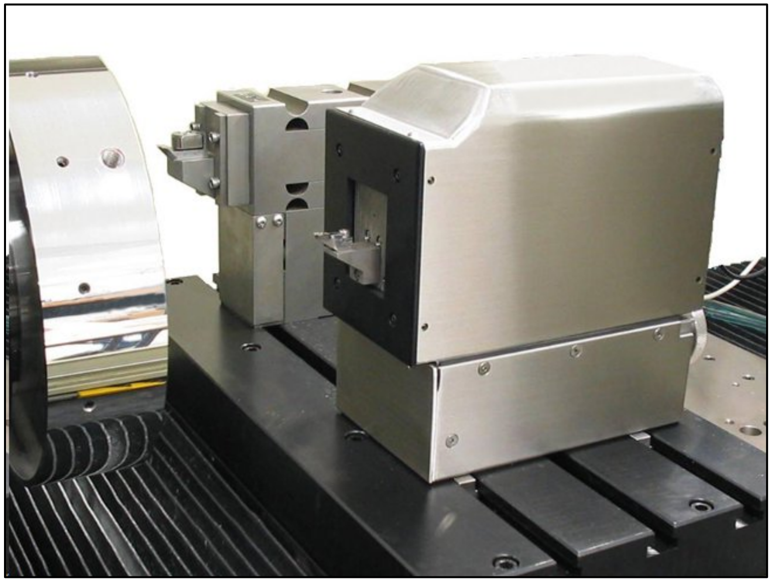
Uncorrelated Roughness



Top half of target rough, bottom smooth

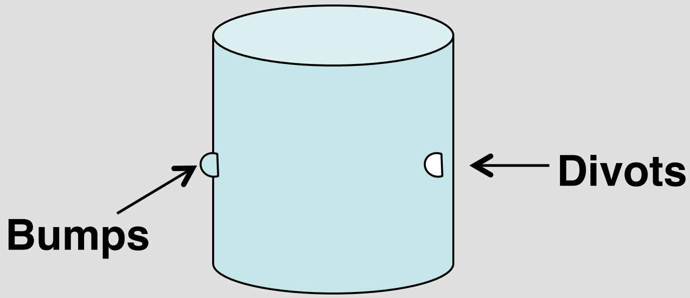
In the coming year, we will be investigating the manufacturing of 3D target features

A standard lathe cuts f(r,z)
With the new tool we have acquired, we can cut f(r,z,θ)

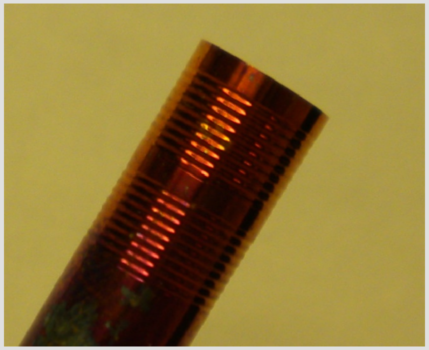


Opens up the capability to study 3D instabilites

Beryllium isolated defect targets

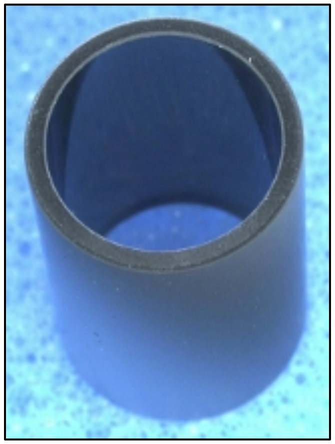


Helical patterns



GA has been investigating new materials and fabrication techniques for liner research

Beryllium on Sapphire



Conductor on insulator

Beryllium w/ 2 μm inner Aluminum shell

Inner shell as a radiographic tracer

Germanium

Test of casting a cylinder from powder

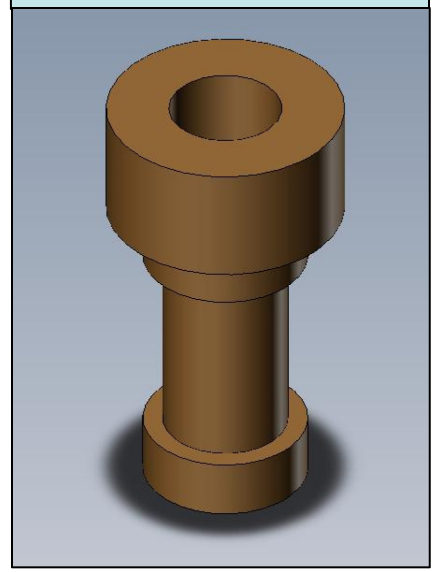
MgB_2 Superconductor

Superconducts @ 39K

We routinely explore their feasibility of various concepts with target designers

New robotic technologies which will be used to support Liner Initiation targets

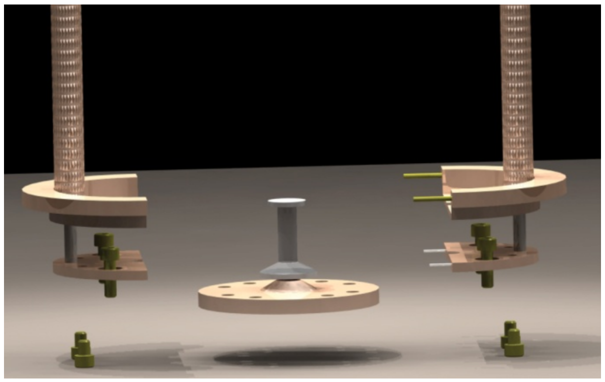
Target Model

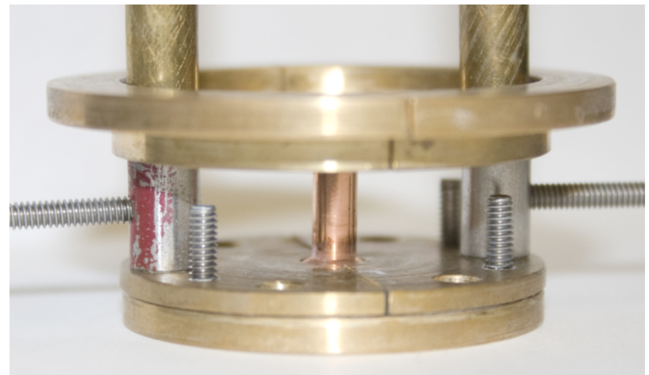


These technologies are enabling low-cost delivery of high-quality targets

GA and SNL supported experiments at Cornell to study the azimuthal uniformity of liner initiation

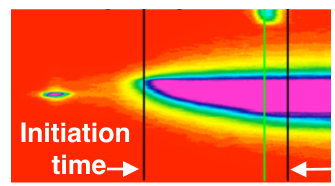
Load hardware was designed to enable free standing copper foil cylinders



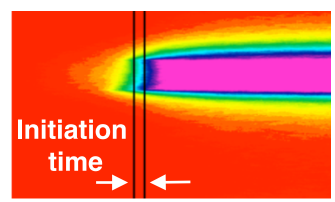


30 targets
Cu foil thickness 1-25 um

23.5 um thick liner

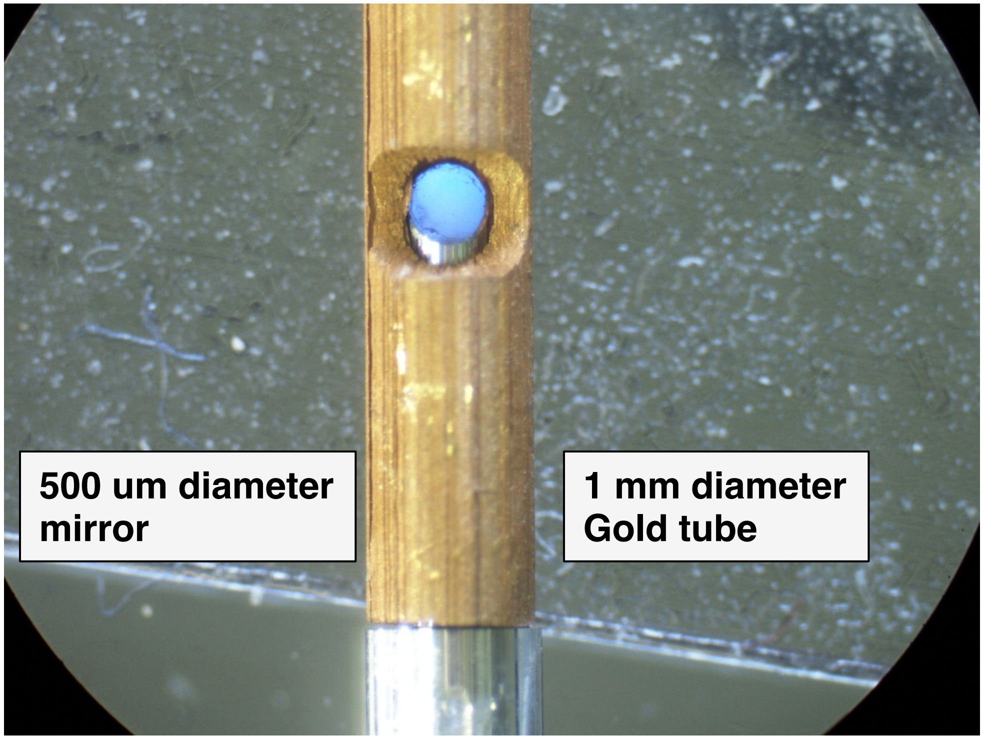


2.5 um thick liner

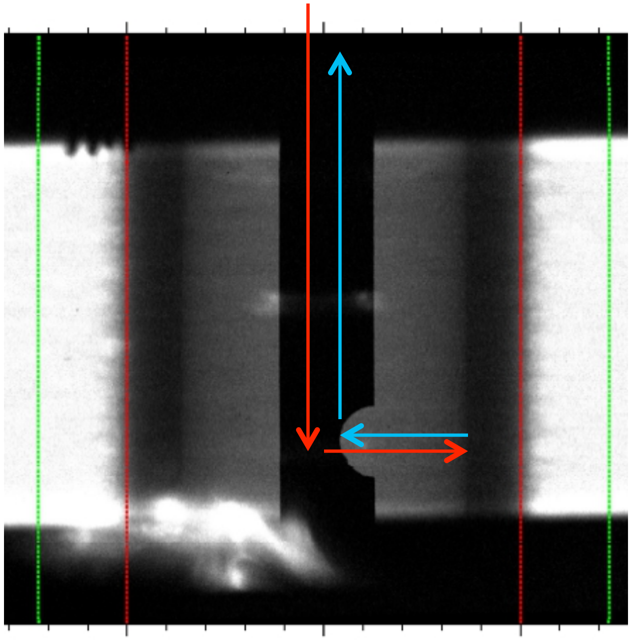


A novel diagnostic was supported by our microfabrication capabilities

VISAR turning mirror see through a cut out in the gold rod



VISAR light path



Internal VISAR mirrors were designed, fabricated, and fielded to measure the liners imploding velocity

High-quality targets enable high-quality experiments

Questions?