Target Fabrication Efforts for Multi-Shell Direct Drive

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H. Huang, C. Shuldberg, T. Drake, … -(General Atomics)

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NNSA National Nuclear Security Administration

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Target Development and Fabrication

Revolver's Goal: Validate the controlling physics (ablator energetics, collision energetics, and feature mitigation) for direct-drive multi-shell targets at Omega and NIF over FY18-FY20 fiscal years

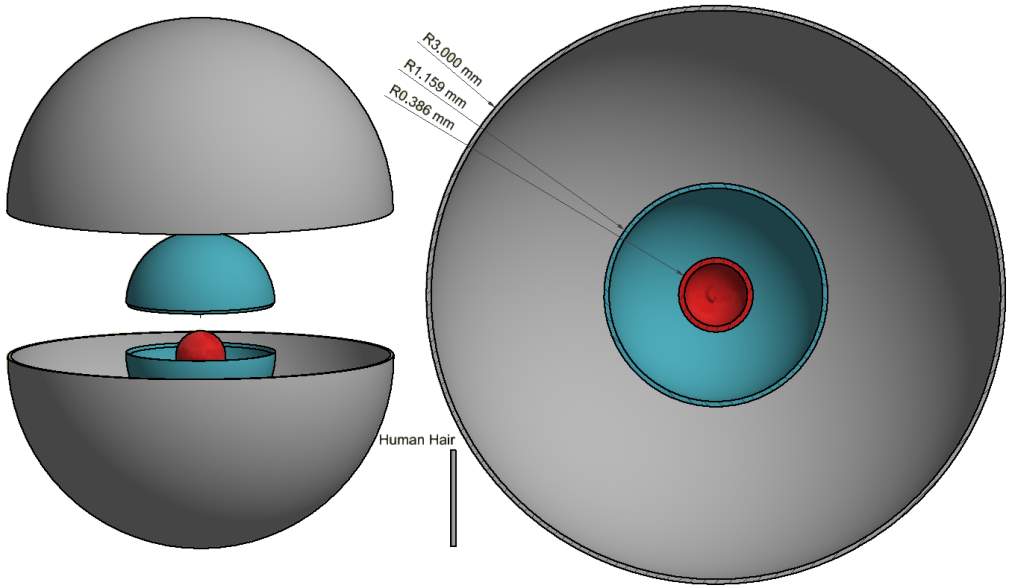
Expected Benefits

-More Energy to Target (Direct Drive)

-Larger Margins

- Physics talk: Mark Schmitt Thursday

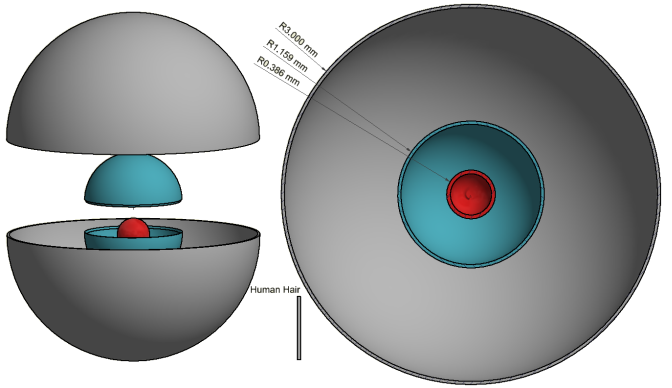
Target plan: Fabricate and field targets at Omega and NIF while concurrently developing techniques to address the fabrication needs of a full three-shell NIF Revolver ignition target.



Agenda: Revolver

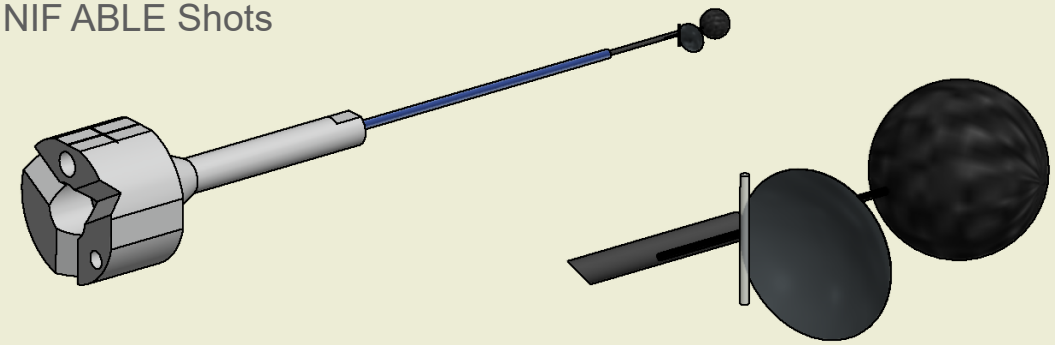
- **Overview of Triple Shell Final Concept and Development**
- **Omega Campaigns Development**
  - Fiber Optic Diagnostic
  - Finger VISAR Diagnostics
- **NIF Shots**

NIF Revolver



Omega Double Shell Keyhole

NIF ABLE Shots

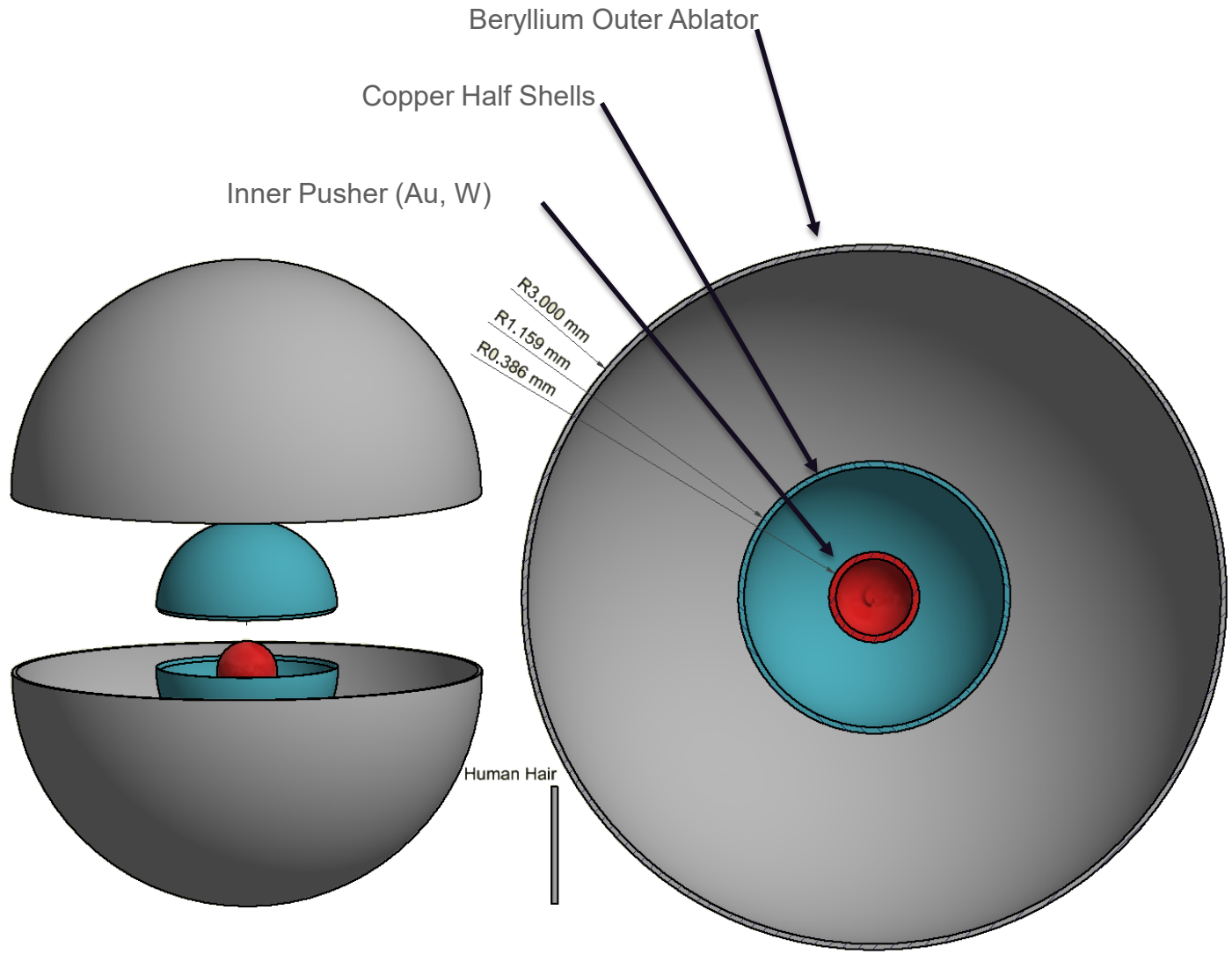


General Atomics Collaboration

- **Relying on General Atomics years of expertise in capsule fabrication**
- **FY18 deliverables**
  - Two Omega Shot days of beryllium capsules
- **FY19 deliverables**
  - 20 Cr shells for Omega Shot Day
  - 20 Mo shells with outer Be coating for Omega Shot Day
  - 20 Be shells for Omega Shot Day
  - 20 CH shells for Omega Shot Day
  - 40 Gold Cones for two Omega Shot Days
  - 4 Large 6mm diameter Beryllium shells for NIF Able Shots
- **FY20 Deliverables**
  - TBD on direction of success and development paths

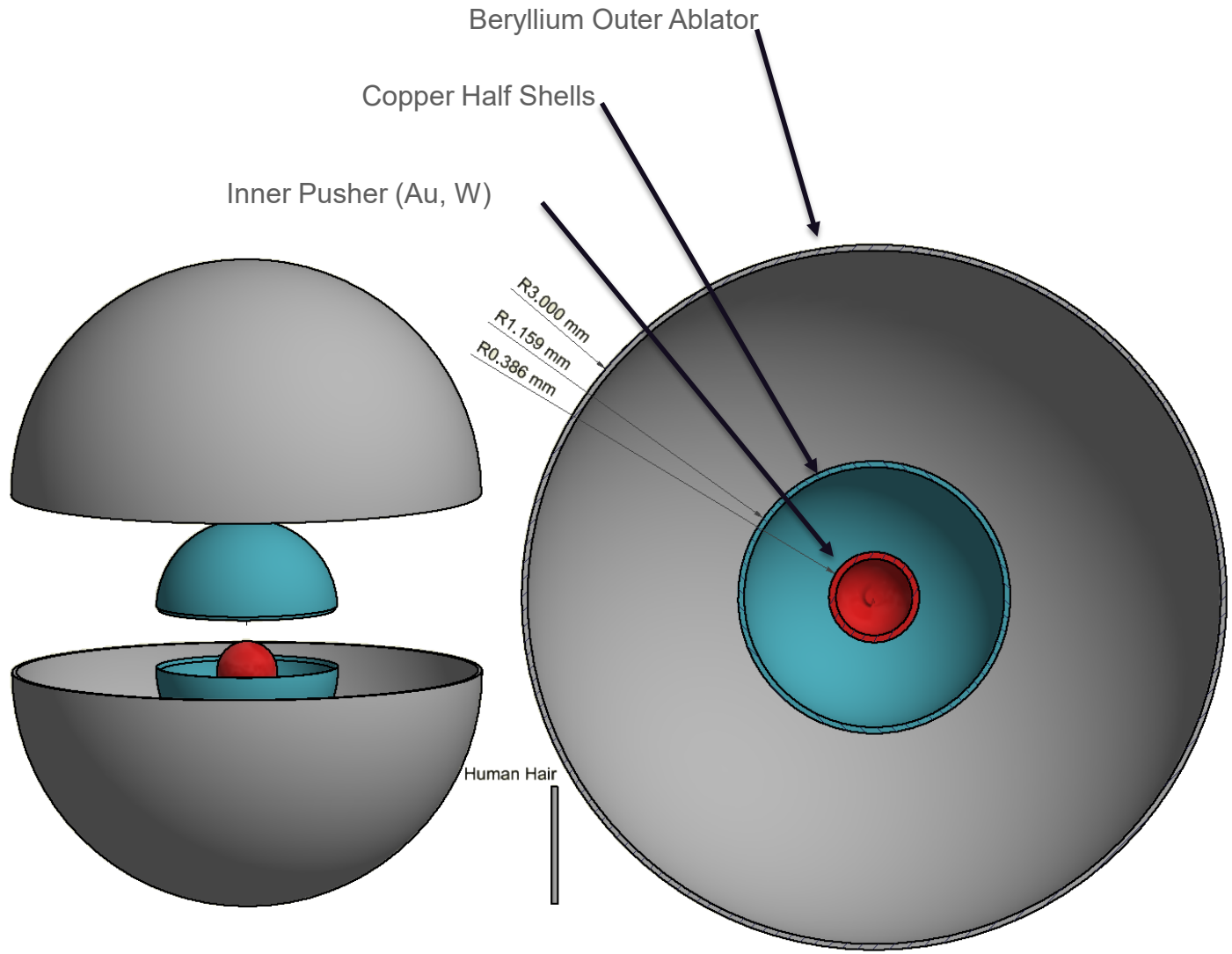
NIF Revolver Target Challenges and Risk Mitigation Options

- **Inner Au Pusher**
  - Initial Design was Au Inner Capsule: 60um Thick
    - General Atomics (GA) does not have a good way to bounce coat Au.
    - Could piggy back onto Au electroplating development of GA
  - Electroplating development has already begun at GA due to the national Double Shell and Single Shell Metal Pusher campaigns. Initial Au plating development looks promising.
  - W has strength properties consistent with non-cryo fielding of high pressure DT liquid fills.
  - Backup plan(1): Switch to W instead of Au or some other ~20g/cc material GA has confidence bounce coating
- **Inner Shell to Copper Shell Suspension → Foam**
  - 70 mg/cc foam machined to size (No Concerns)



NIF Revolver: 2nd Shell Fabrication and Interstitial Development

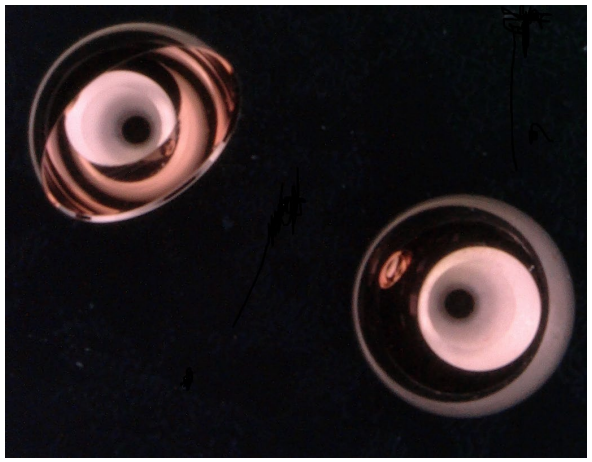
- **Copper Driver Half Shells**
  - 50um thin copper shells are challenging
- **Copper to Beryllium Shell Holding**
  - 2pp lattice



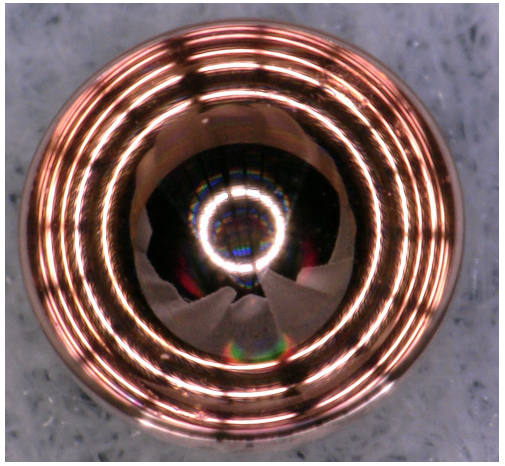
2nd Shell: Copper Half-Shell Machining

- **Machining of 50um Copper Shells**
  - Machined 3 sets of male and female shells with step joints
    - Joint design taken from latest lessons learned from the C10 Double Shell Campaign
  - Machined on same Diamond Turning Lathe setup currently for Double Shell Aluminum machining
  - OD Surface Finish: 14 nanometers
  - ID Surface Finish at pole: 17 nanometers
  - Copper did show historical issues of ‘grain pullout’ shown here with 0.45 um deep hole.
  - Risk Mitigation: Approved to explore possible improved machining materials of mid-Z

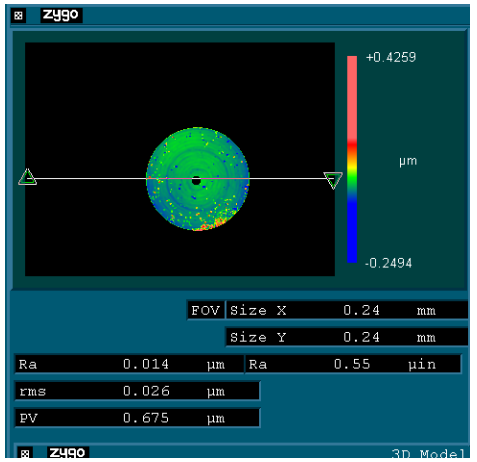
OD of shells



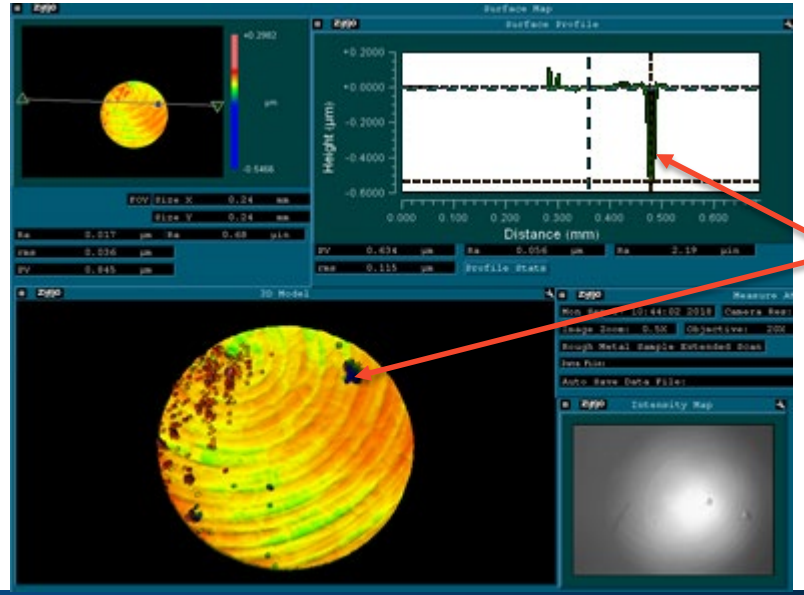
ID of shells



OD Surface Finish Ra= 14 nm

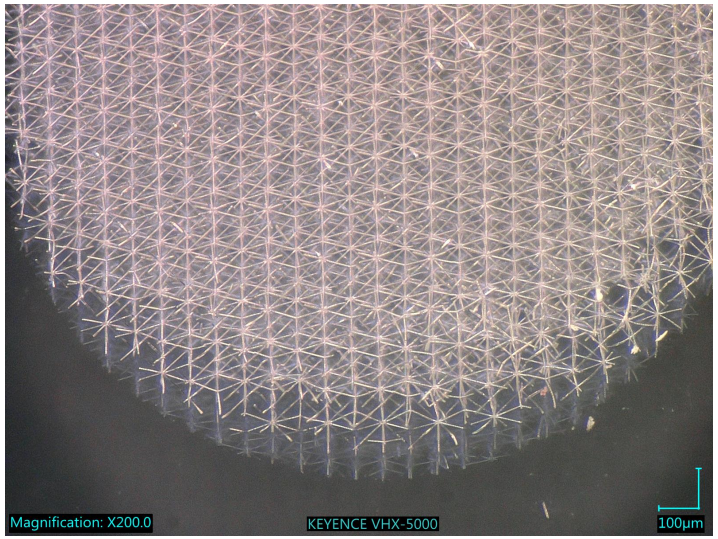


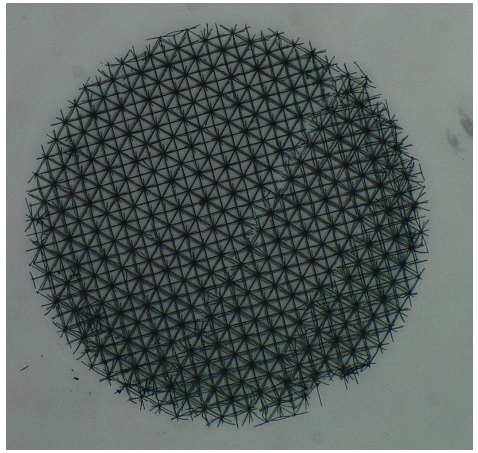
ID Surface Finish Ra= 17 nm

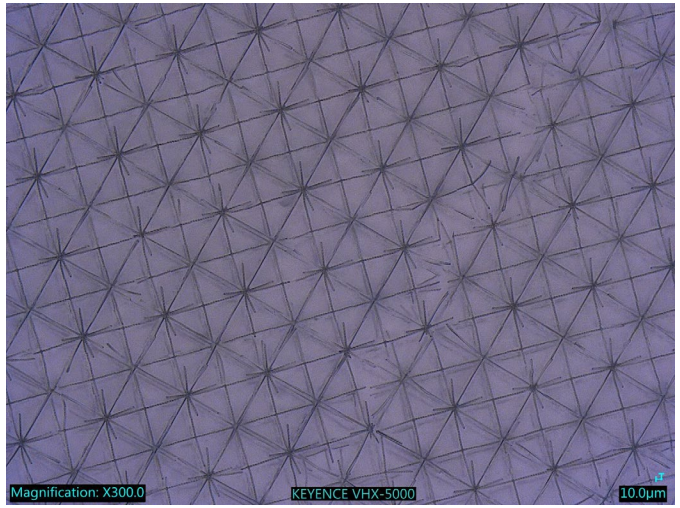


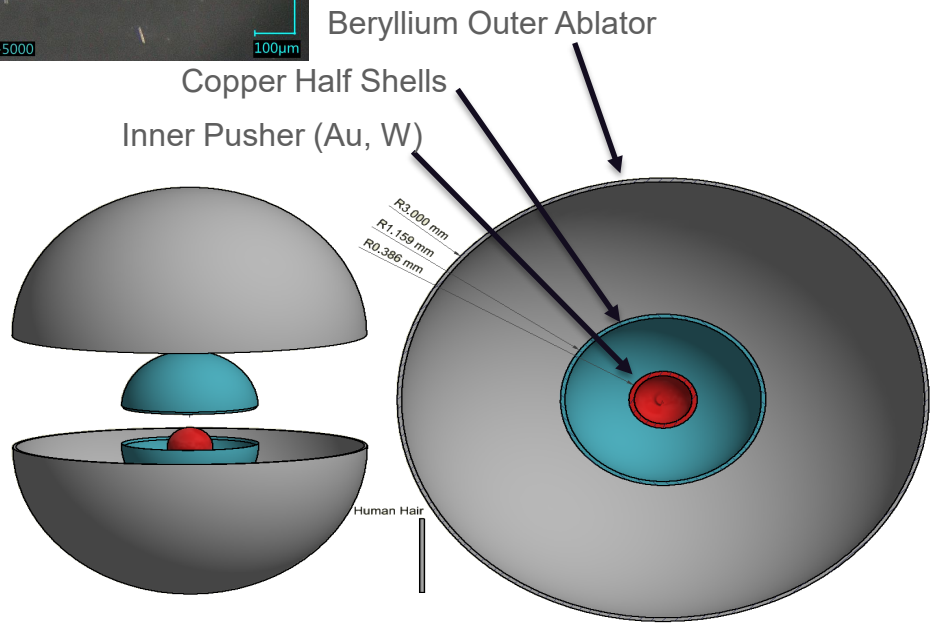
NIF Revolver: Be-Cu Interstitial Foam

- **Copper to Beryllium Suspension (Super Low Density Foam, 2pp, or Tents)**
  - 2-Photon-Polymerization (2PP)
    - 3D Additive Manufacturing with 1 micron resolution
    - Already successfully printed 1-2 mg/cc foam lattice but is it strong enough and scalable to large size
      - 2mm OD
    - Backup: increase lattice to 3-5 mg/cc to increase cross-stitching success
  - GA 5mg/cc CH foam, questionable to machine inner diameter profiles



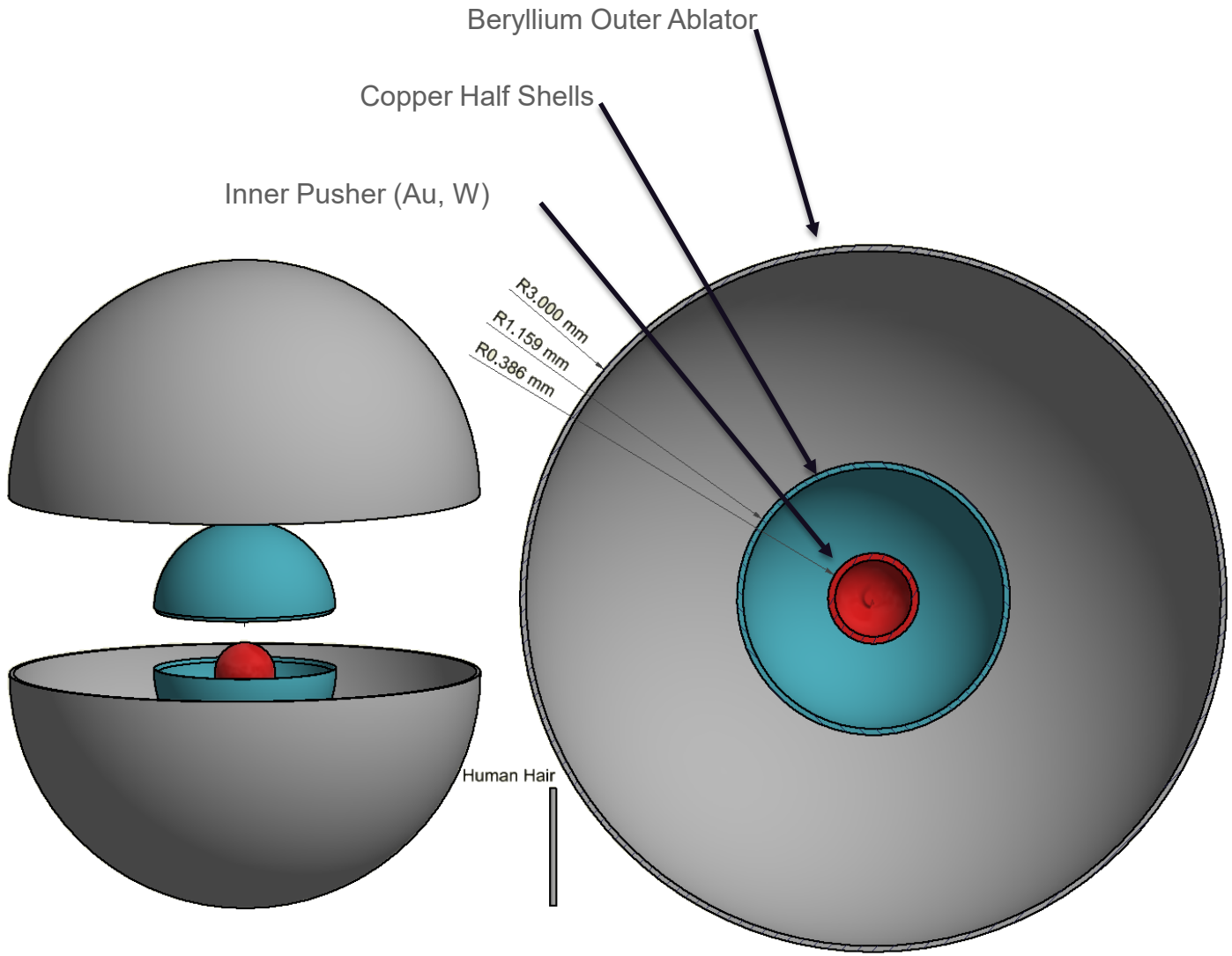






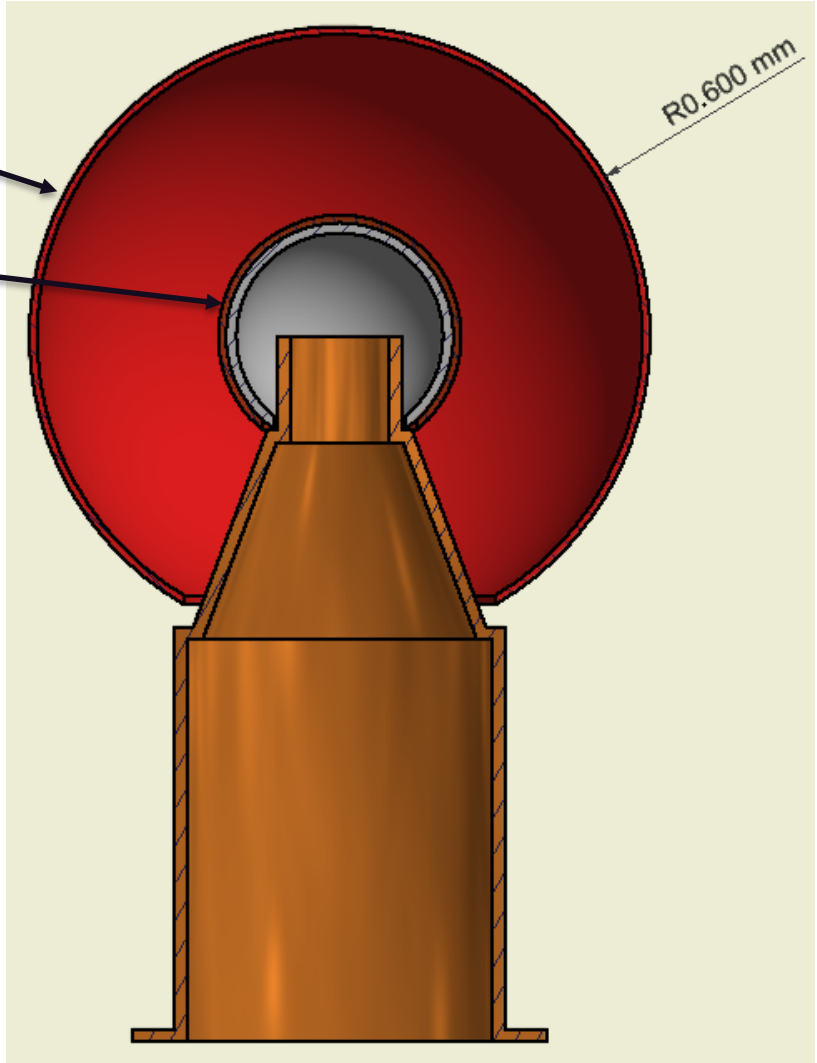
NIF Revolver Target Challenges and Risk Mitigation Options

- **Beryllium Ablator Half Shells**
  - 50um thick beryllium shells and at such a large diameter is very developmental
    - 6mm Diameter
  - Concern: Normal Be refined grain sizes are still on the 30-50um size…which is the wall thickness
  - Backup(1): use powder pressed materials to reduce grain size
  - Backup(2): have GA bounce coat large beryllium shells and EDM in half to make two shells
    - Any spring back on the lip?
  - Backup(3): switch to CH as the outer ablator.



FY19A Revolver Shots in January 2019 – Revolver Keyhole

- **Keyhole Target Campaign**
  - Outer Shell: Be Shell
    - 1200um ID
    - 15um Thick
  - Inner Shell: Cr Shell
    - 400um OD
    - 20um Thick
    - Over coated with 15um of CH
      - Only have CH coating on outside of inner shell

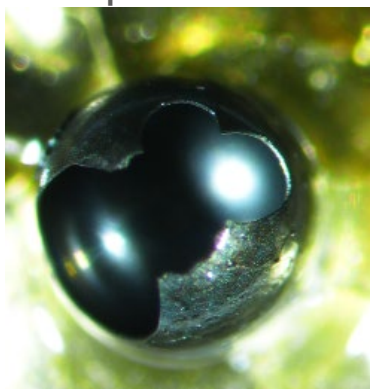


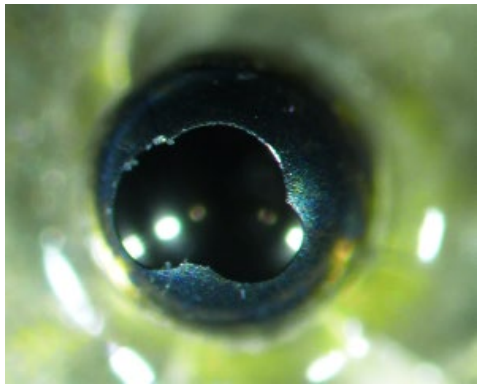
FY19A Revolver Shots in January 2019 – Challenges of Micro-EDM Shells

- **Micro EDM of Be Shells**
  - Historically we've always done in the 90-120um thick Be shells
  - These were 15 and 20um thick….challenging
  - First 3 attempts failed
    - 1st) Typical rotating circular electrode
    - 2nd) Put a flat on the side to alleviate internal pressure
    - 3rd) Used a smaller electrode and burned 36 holes around circumference

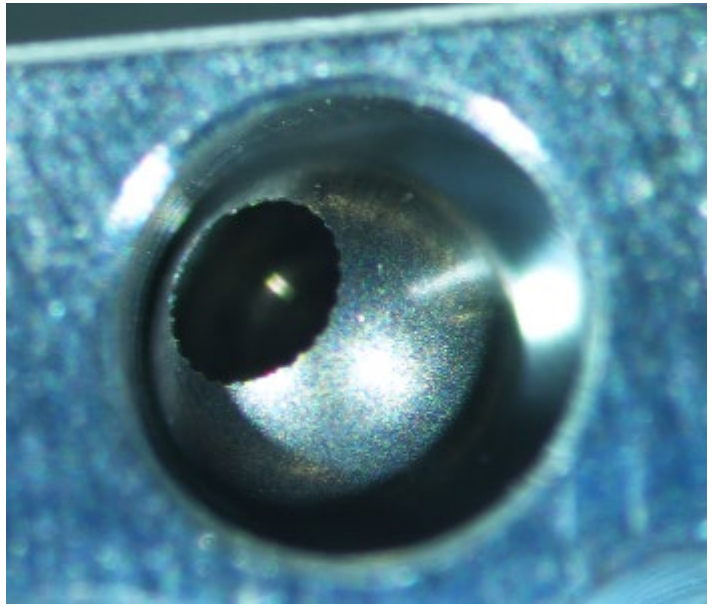
      (on Manual Micro-EDM Machine)

First Couple Failures



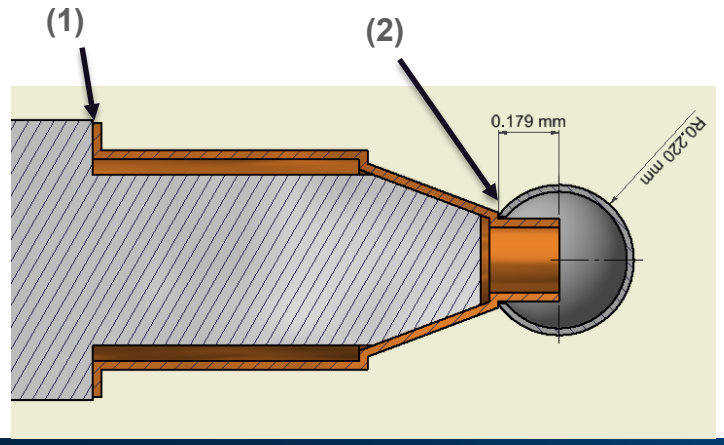


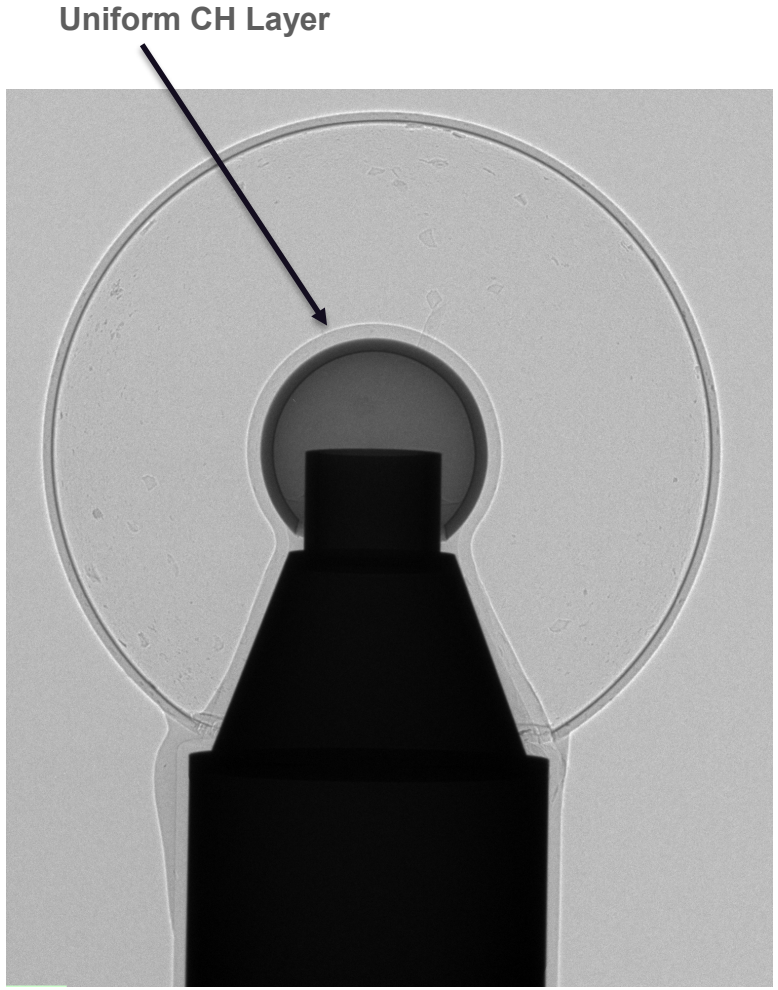
Painstaking Long Process – Old Manual EDM

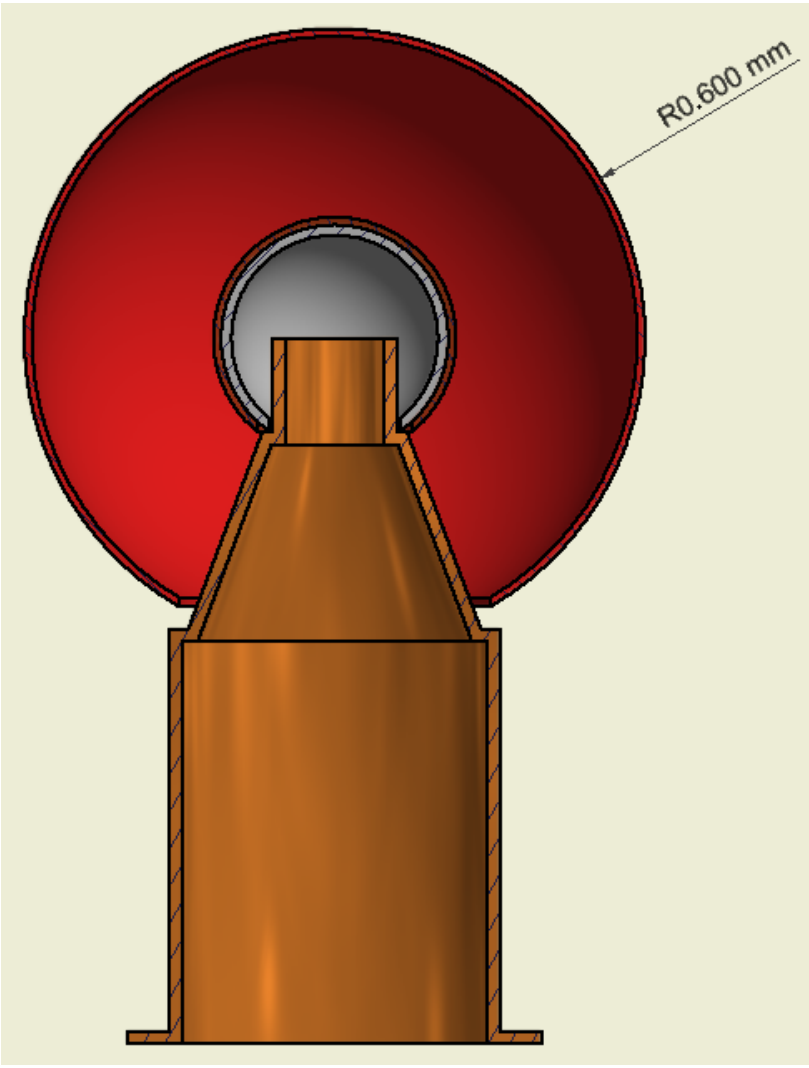


FY19A Revolver Shots in January 2019 – CH Cushion Coating

- **CH Coating Procedure**
  - Overcoat with 15um of CH (Parylene)
  1) Attach Gold Cones to Coating Mandrels with Water Soluble Glue
  2) Attach Cr shell with typical UV glue (making sure it is fully sealed)
  3) Coat 15um of Parylene on cone and Cr Shell
  4) Machine/Part off Water Soluble Glue to break through CH
  5) Water leach to remove

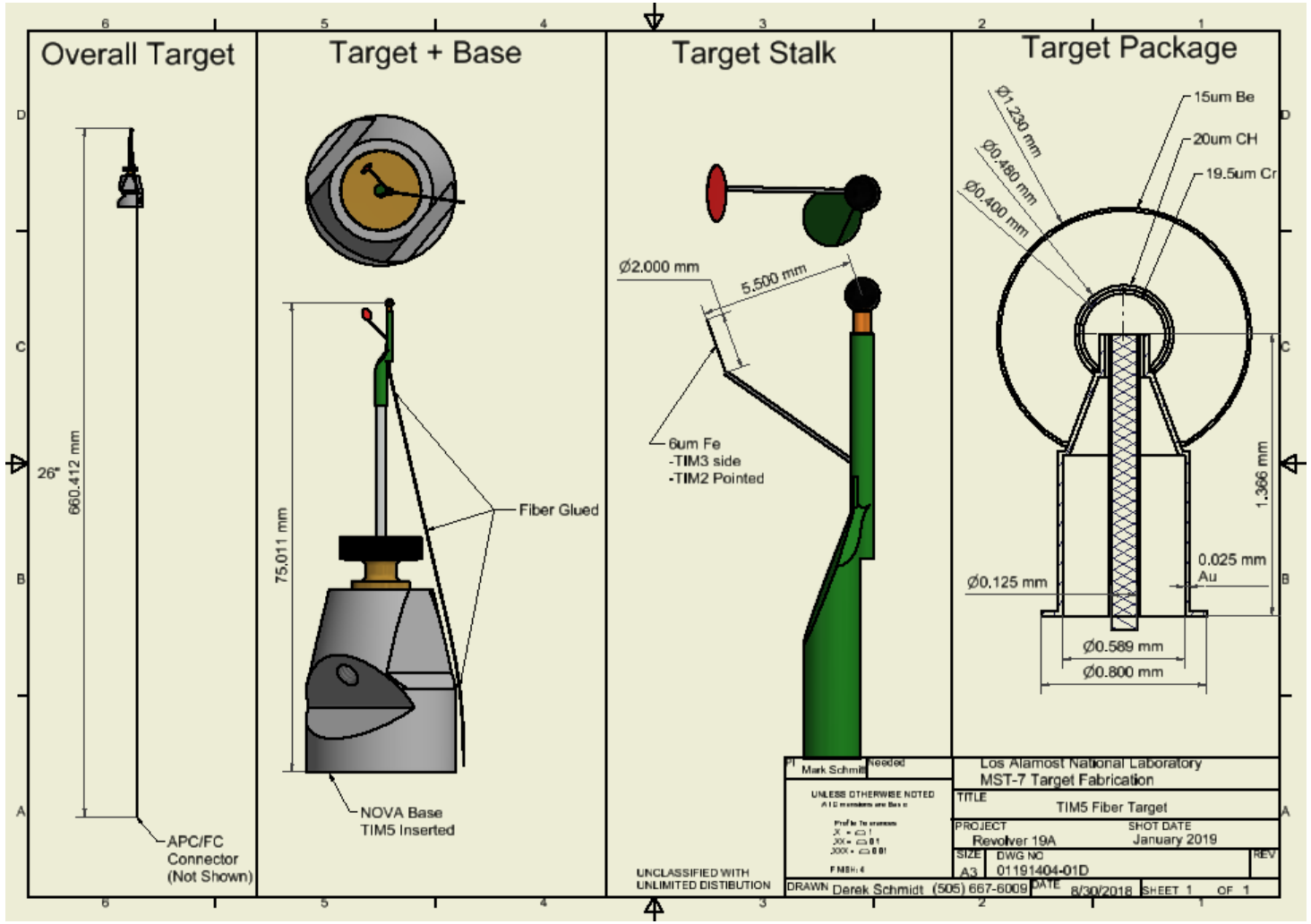






FY19A Revolver Shots in January 2019 – Fiber Optic Target Novel New Diagnostic Capability

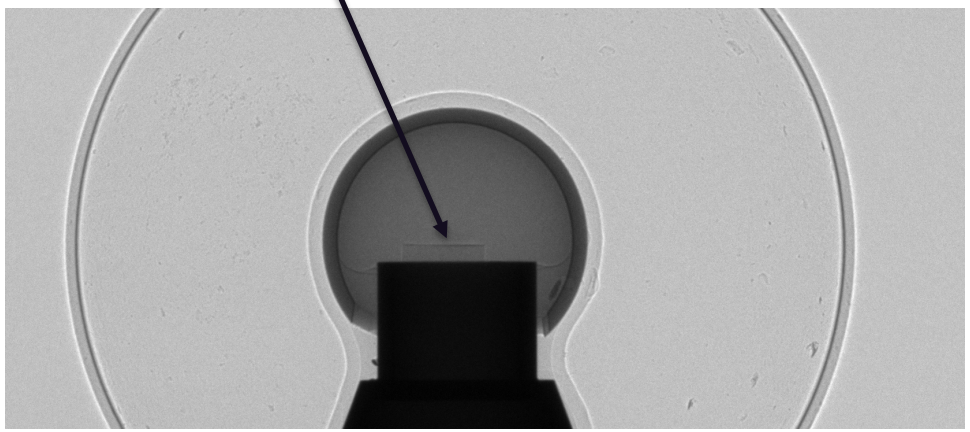
- **Fiber Diagnostic Targets**
  - Multi-Group and Laboratory Effort
    - LANL, LLE, MSTS
  - Novel new fiber diagnostic being developed for January Omega Shots, if successful will result in new diagnostic capability available across all laboratories nationally using Omega facility
  - LLE doing development work to pass through fiber optic on TIM5 to develop new capability, Chuck Sorce leading effort
  - New capability development with MSTS's Jason Mance on fielding fiber optic diagnostic chassis
  - MSTS supplying fiber optics and connectors, plus support equipment and expertise on shot day

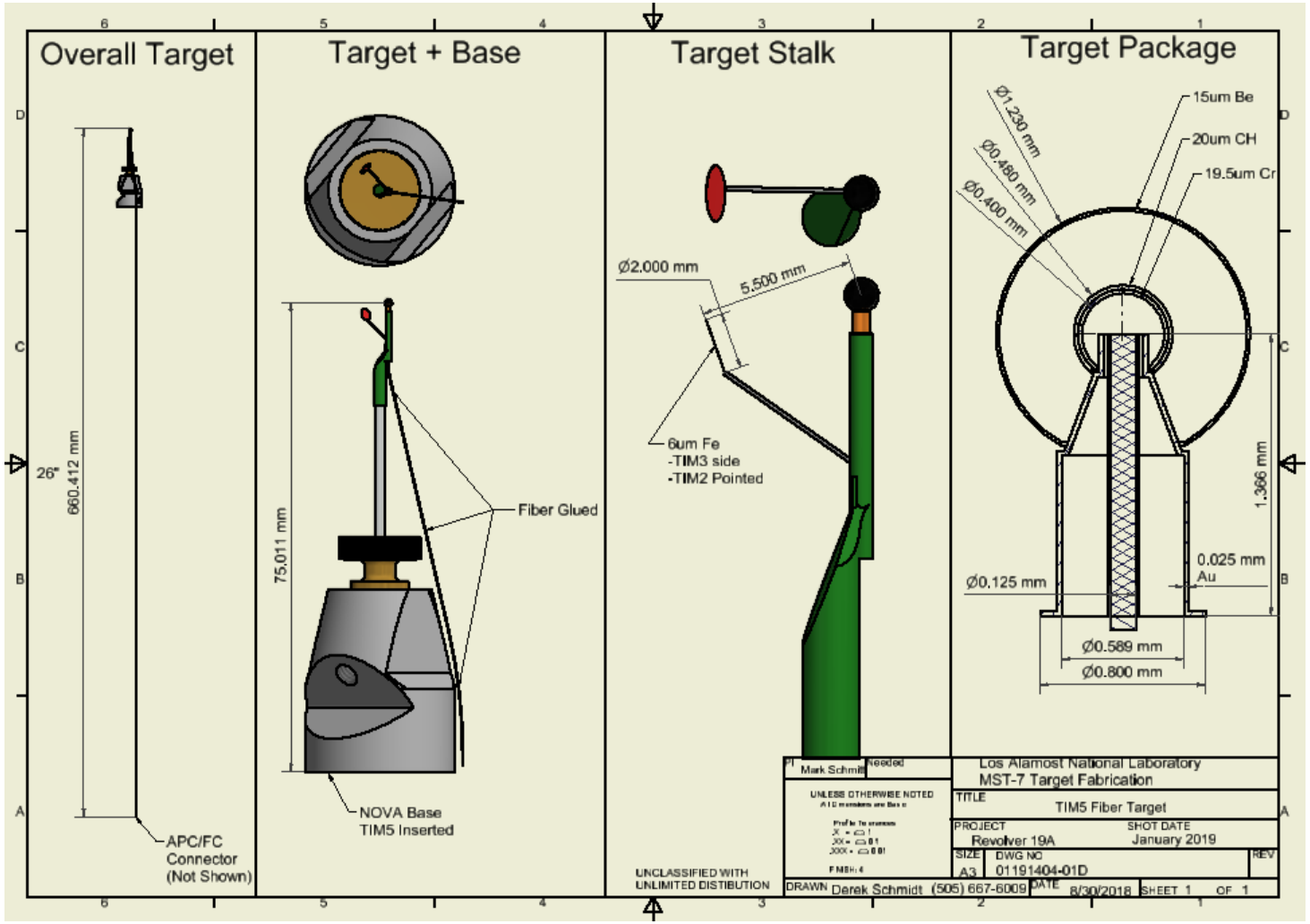


FY19A Revolver Shots in January 2019 – Fiber Optic Target Novel New Diagnostic Capability

- **Fiber Diagnostic Targets**
  - Fiber optic runs up through Additive Micro-Fine Green Stalk
  - Robust Nova Mounts used for stability of the target and fiber optic wrapping around
  - Results: Still need some more development work but an internal velocity was measured

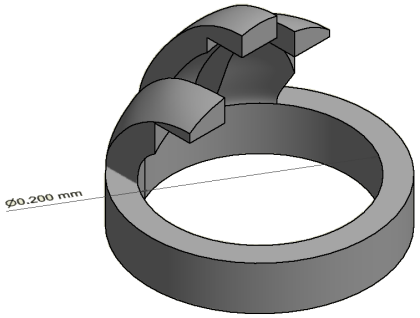
One bad target where fiber optic was too tall



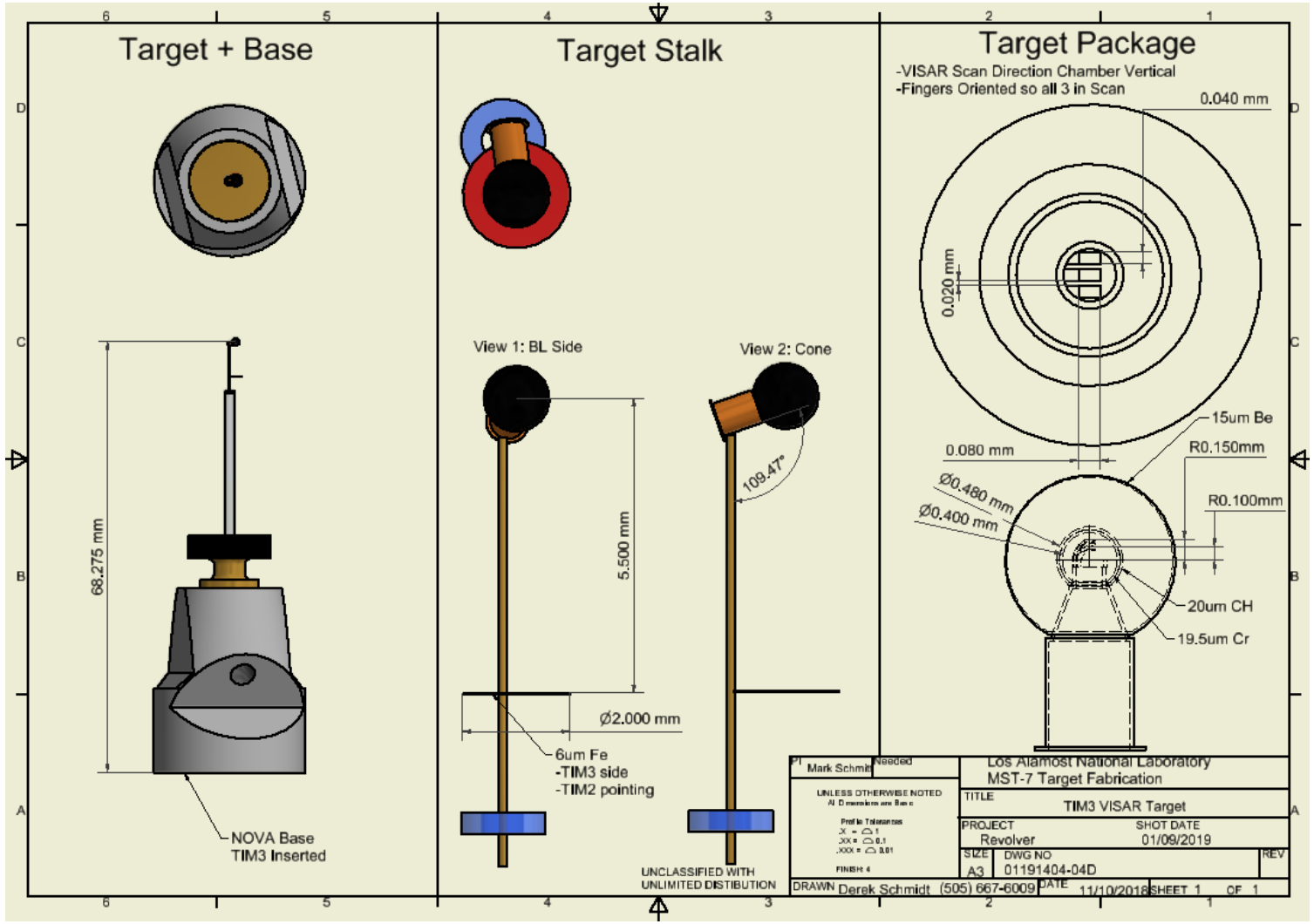


FY19A Revolver Shots in January 2019 – VISAR Finger Targets Novel New Diagnostic Principle

- **VISAR Finger Targets**
  - First time ever concept that could lead to new diagnostic concept on Omega
  - VISAR will lineout across 3 40um wide fingers
  - Spherical radius fingers are designed to radii of 100um, 125um, and 150um
  - Time: 2pp printer can print 20 in 4 hours
  - Fingers must be remounted and inverted to be flashed with 10nm of aluminum for reflectivity



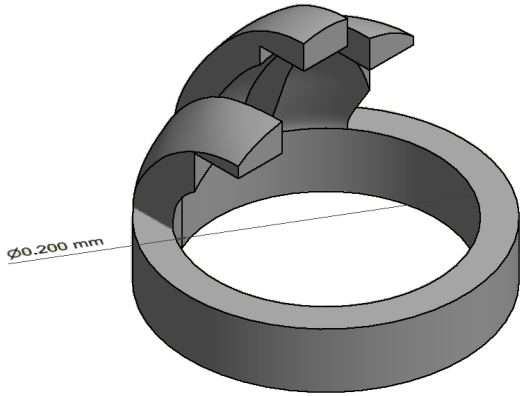
2pp Spherical Fingers

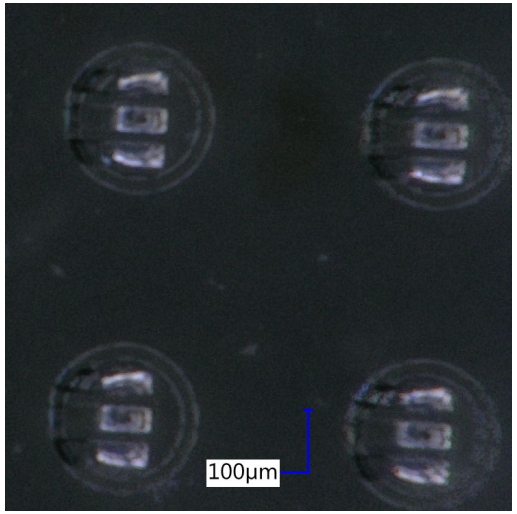


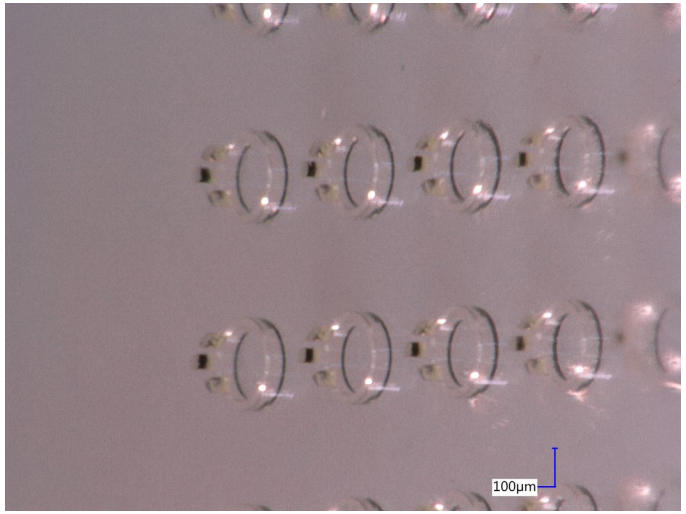
VISAR Finger 2PP Print

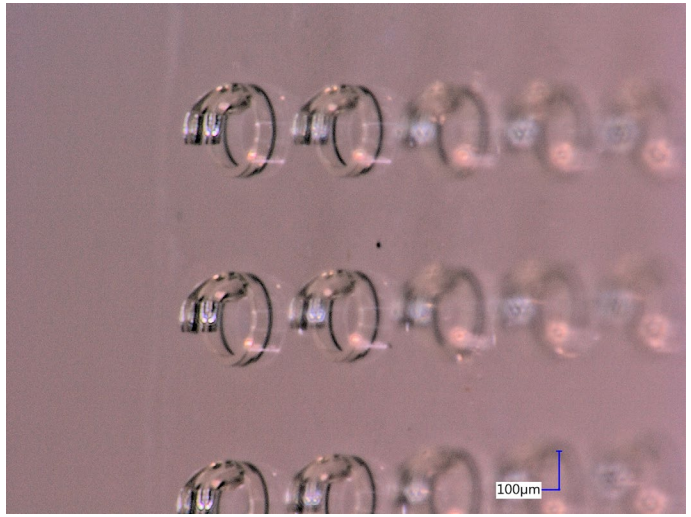
- **Very small features and details able to be printed with high accuracy**
  - 40um wide fingers
  - 200um ID for the whole part
  - 20 parts can be printed in 4 hours

Omega Spherical VISAR Finger Diagnostic





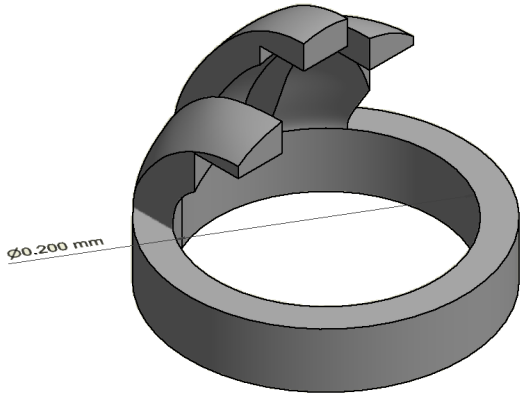


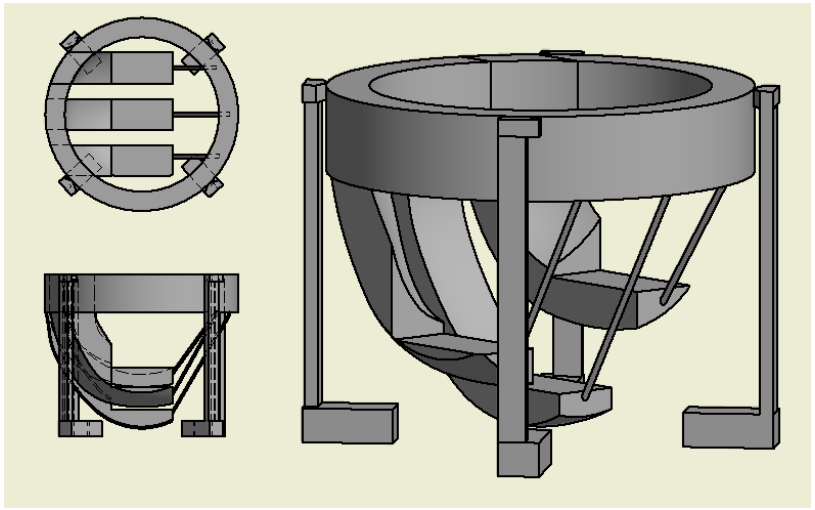


VISAR Finger 2PP Print

- Added Small 5um Trusses to hold fingers flat during curing
- Added Legs for coating run to held align the bottom of the fingers vertical for PVD flash coating of 10nm aluminum for the VISAR
- Legs broken off after coating run

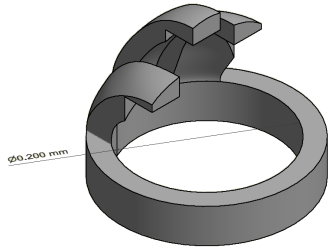
Omega Spherical VISAR Finger Diagnostic

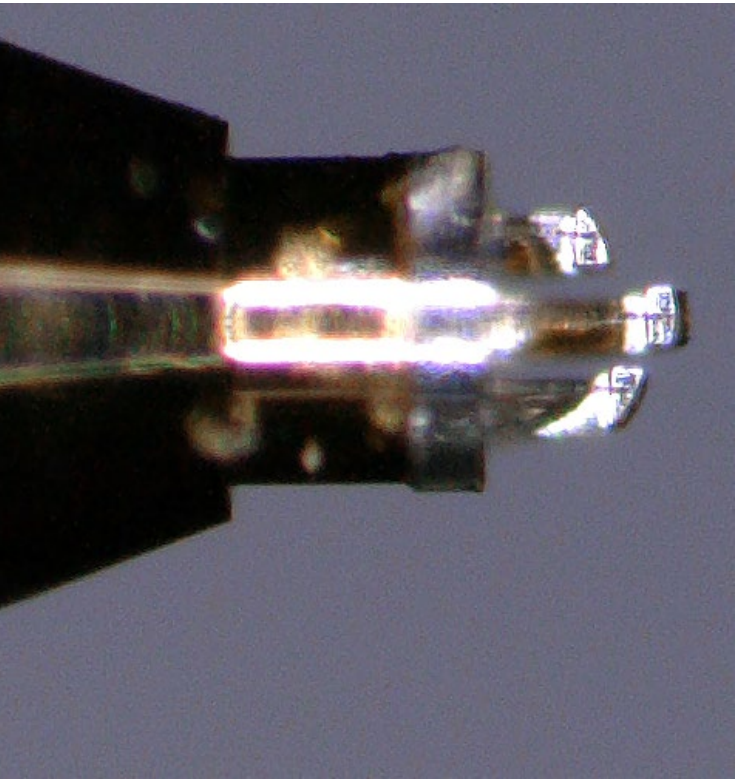


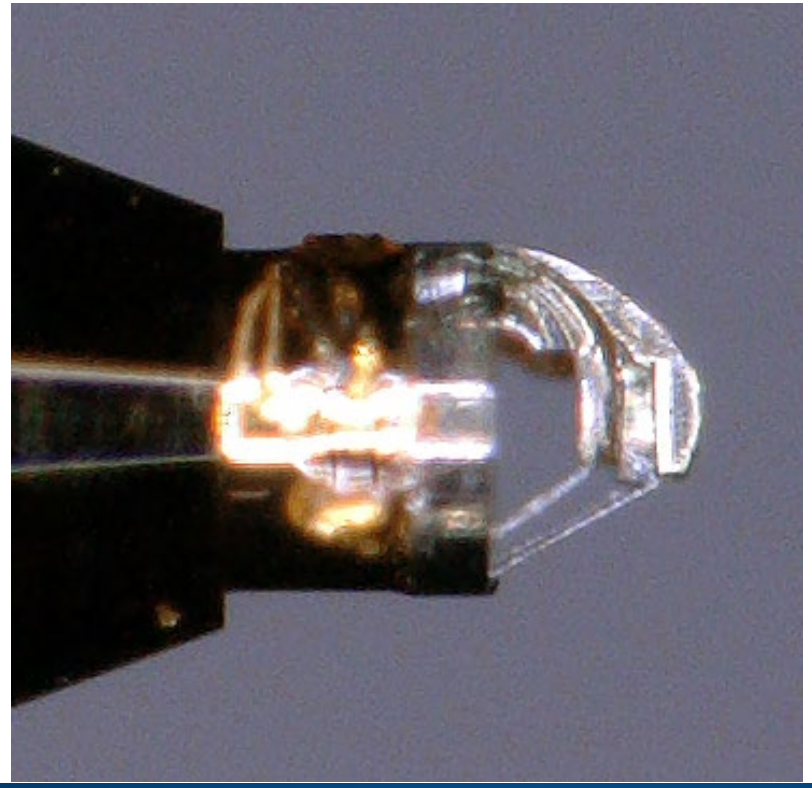


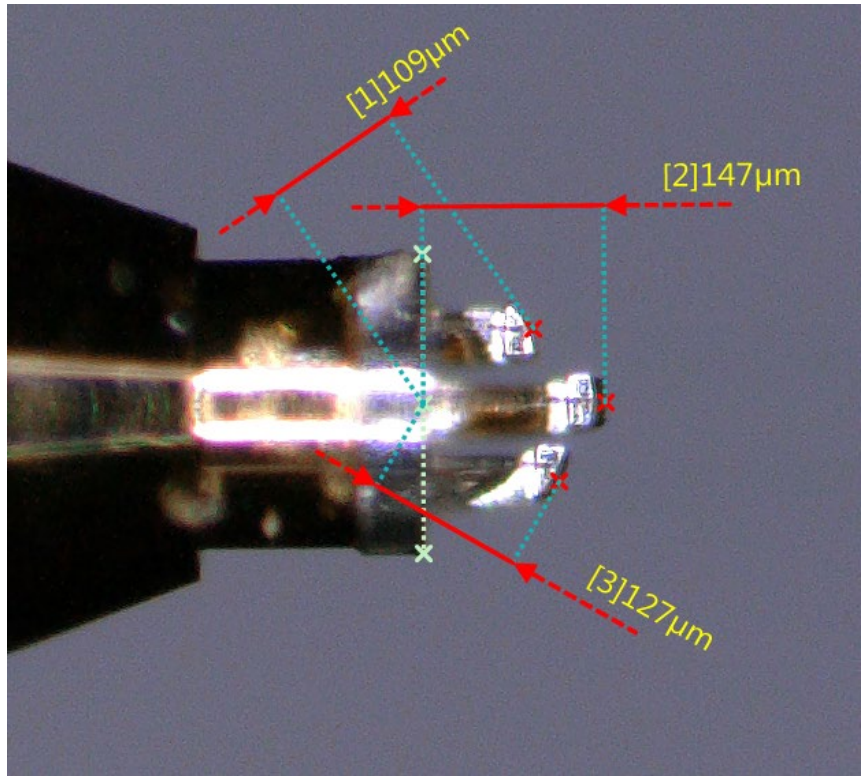
VISAR Finger 2PP Assembly and Inspection

- Parallelism of the landings on each finger was imaged
- Each target had to have each radial height measured to the outer radius of each finger

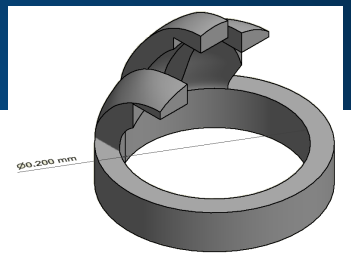




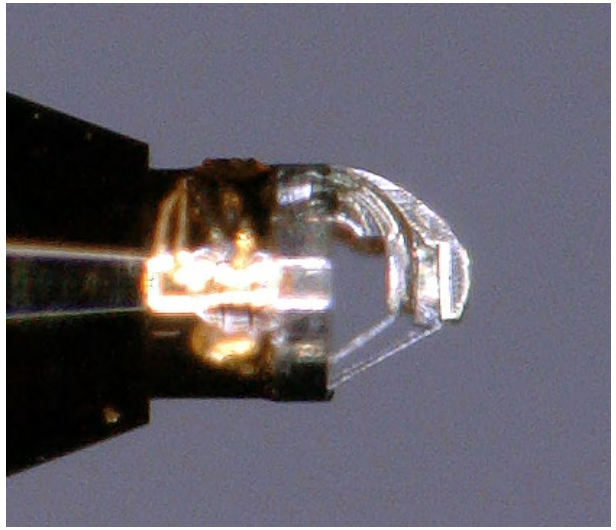


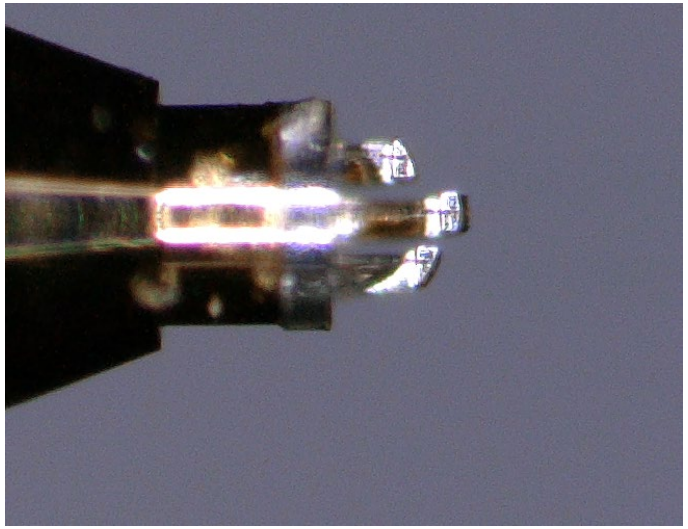


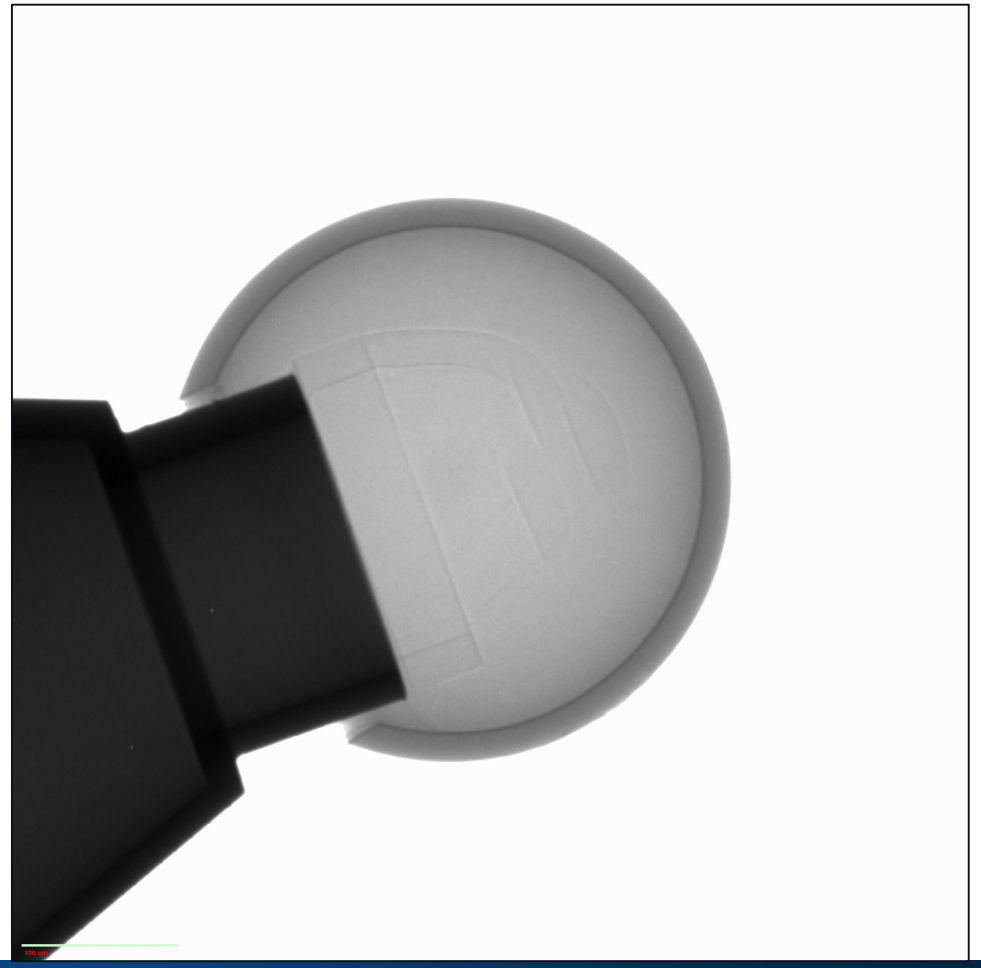
VISAR Finger 2PP Assembly and Inspection



- **X-ray images on the Versa confirmed the heights of the flats**
  - Validation that the fingers made it past the Cr shell assembly



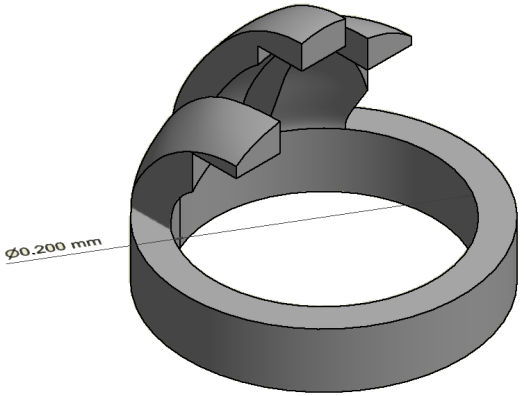


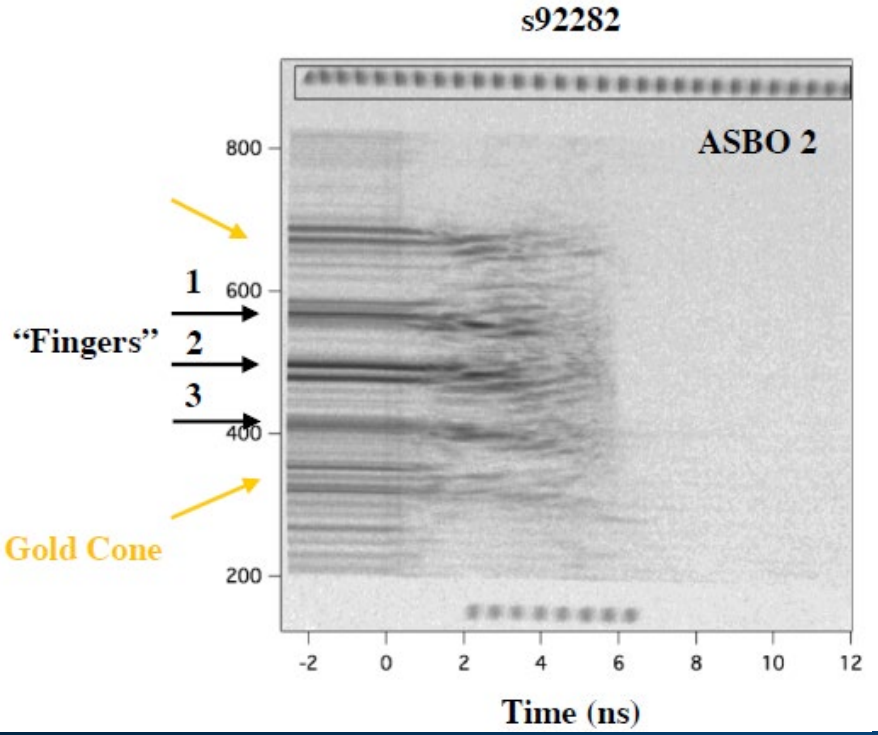


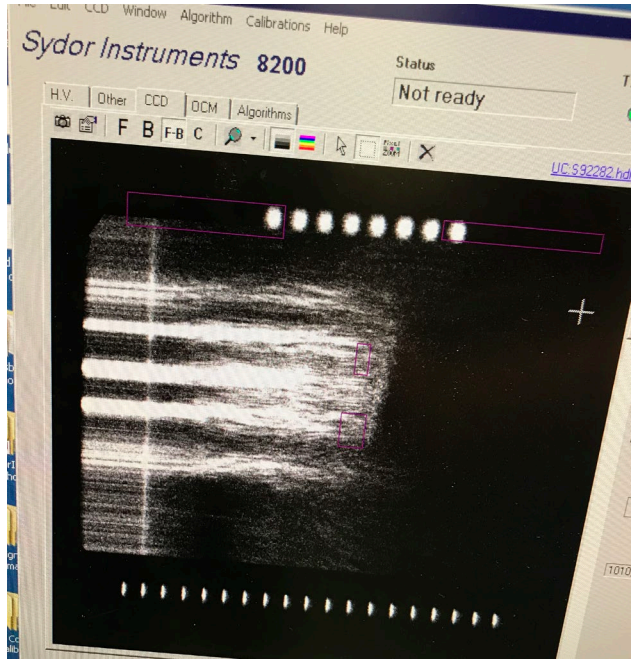
VISAR Finger Diagnostic Failure

- Optimistic originally on how strong the signal was from 50um wide VISAR fingers
- But pre-heat blew up the flash aluminum coating on the tips of the fingers
- August 2019 shots will look into new optional coatings

Omega Spherical VISAR Finger Diagnostic

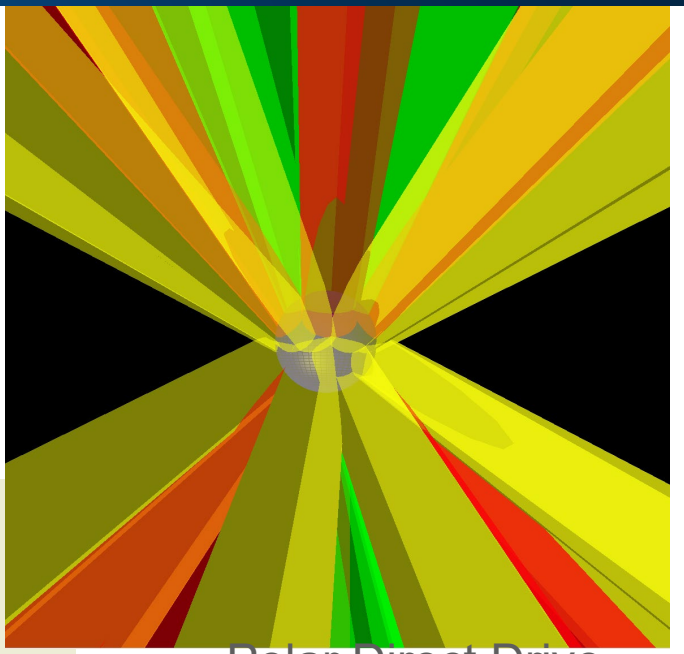




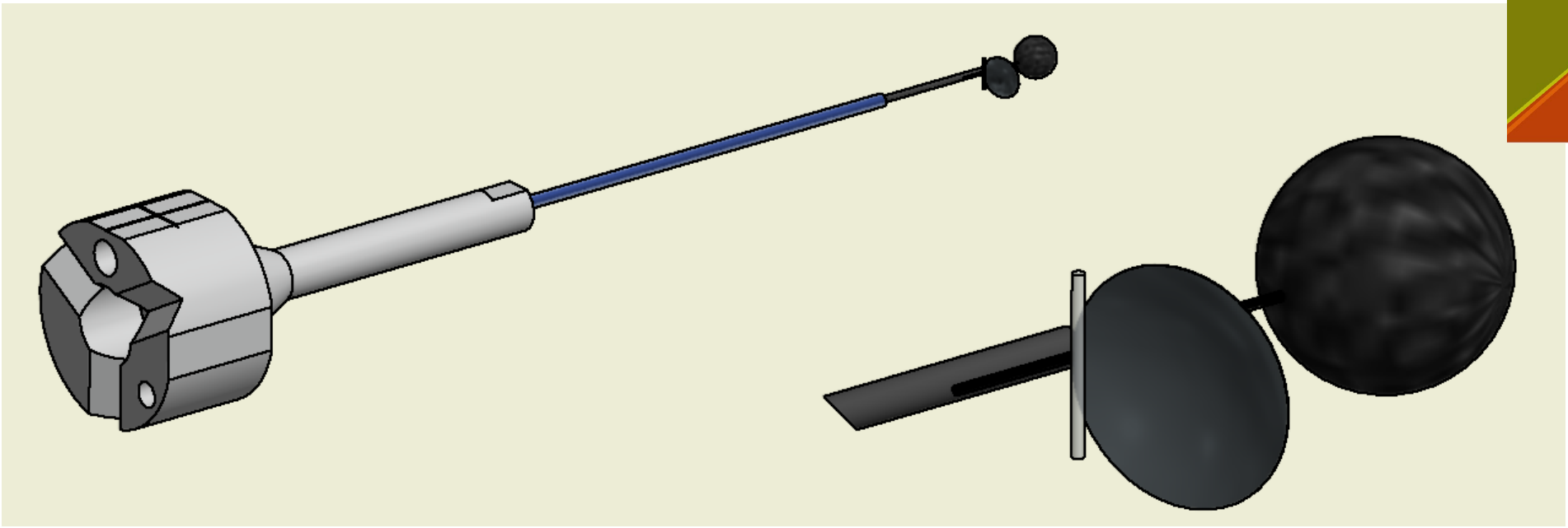


NIF Able Shots Planned for June and September 2019

- 5mm Beryllium Shell
- Spherical Iron Backlighter
- Polar Direct Drive



Polar Direct Drive of Capsule



Revolver Conclusion

- **Triple Shell Final NIF Target Development**
  - Inner Shell Fabrication has options for GA to bounce coat
  - Proven we can cut the Copper Hemi-Shells
  - 2pp Interstitial foam is promising initial prints
- **Omega Shots**
  - Developed a target with an internal fiber optic diagnostic
  - Developed a 2pp printed VISAR finger
- **NIF Able Shots first shot is planned for June 2019**