The Strength of Solid DT

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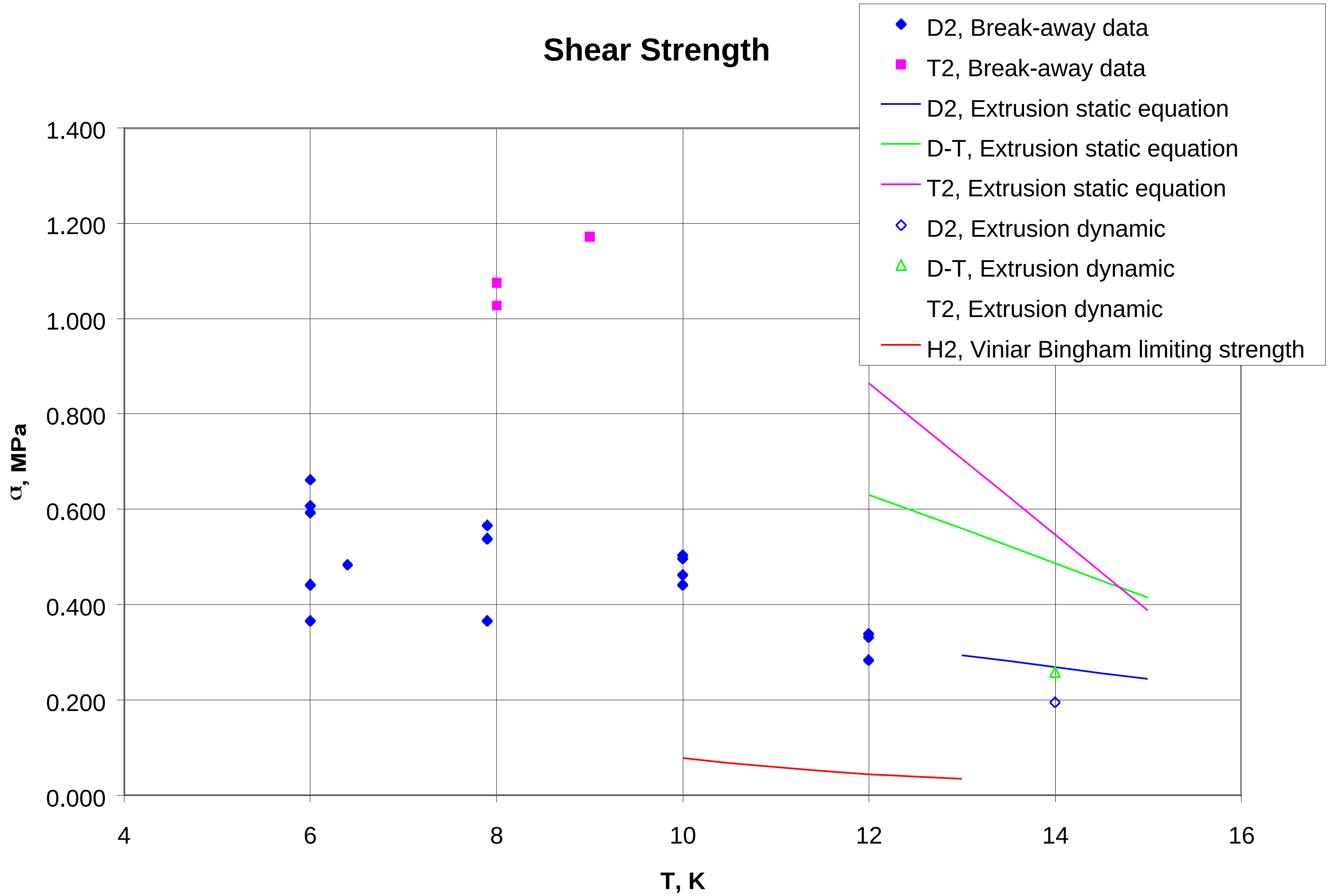
Summary of literature data on solid hydrogens

- For solid H_2: high pressure data @ 4.2 K (Towle '63)
- For solid D_2: Stress vs. strain & Young's modulus on poly-crystalline samples (~ 10 mm dia.) from 1.4 K to 15.6 K (Bol'shutkin et al. '70)
  - Souers' evaluation of this data suggests that at 16.4 K (n.b.: 2.4 K below the triple point) - the yield stress ≈ 50 kPa.
- For T_2 and DT, ONRL data on pellet extrusions gives shear strength estimates of ~800 to 400 kPa from 12 K to 15K, resp. The data extrapolates to ~ zero at the triple points. (Gouge '99)
- For 50-50 DT near the triple point: NADA!!
  - Extrapolating the Russian data to 0.8 K below the triple point, (19 K for DT), I 'guesstimate' the yield stress ≈ 10 kPa.

Hydrogenic solid shear strength data from ORNL H, D, T pellet experiments

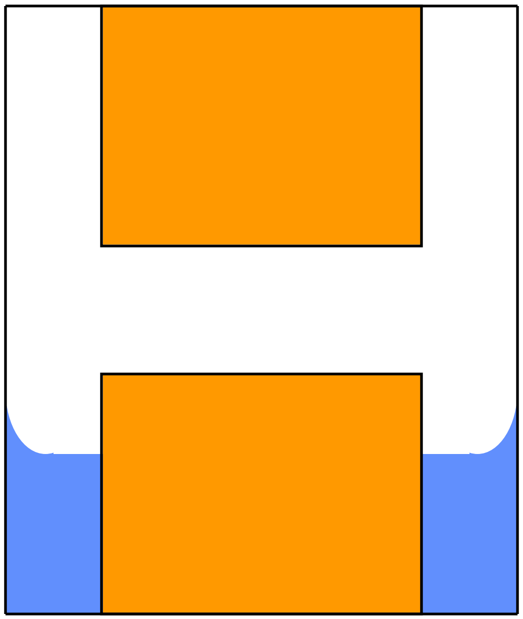


Experimental determination of the yield strength of a solid requires:

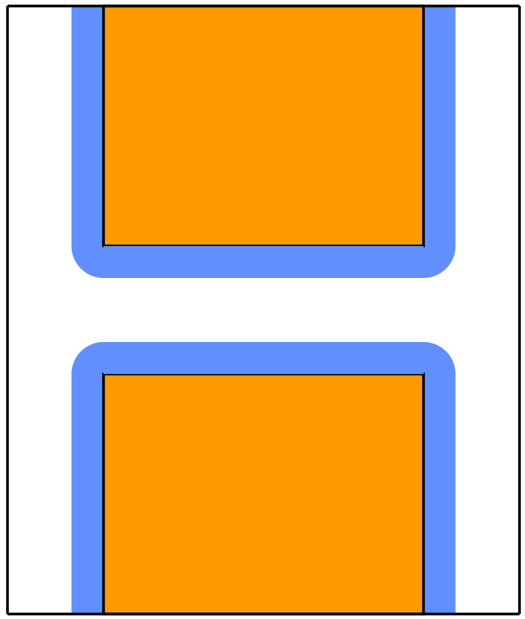
- A properly configured solid specimen (a compression specimen or a tensile stress specimen), and
- One or both of the two following methods:
  - Method A:
    - A means of applying stress
      - tensile or compressive force
    - A measurement of strain
      - a change in sample length, e.g., measured optically
  - Method B:
    - A means of applying strain
      - tension or compression from a linear actuator
    - A means of measuring the stress in the sample
      - a linear force sensor, i.e., a piezoelectric sensor

For solid DT, beta-layering permits us to fabricate a specimen for either compression or tension:

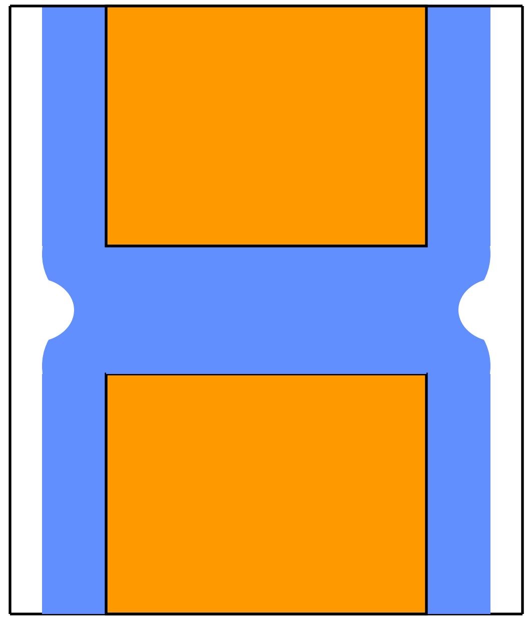
We begin with two blocks of copper, confined inside a cell at ~ 20.0 K. We then condense in an amount of liquid DT:



If we now freeze the DT and wait for beta-layering to develop a uniform solid layer at 19 K, the boundary of the layer will follow an isotherm:

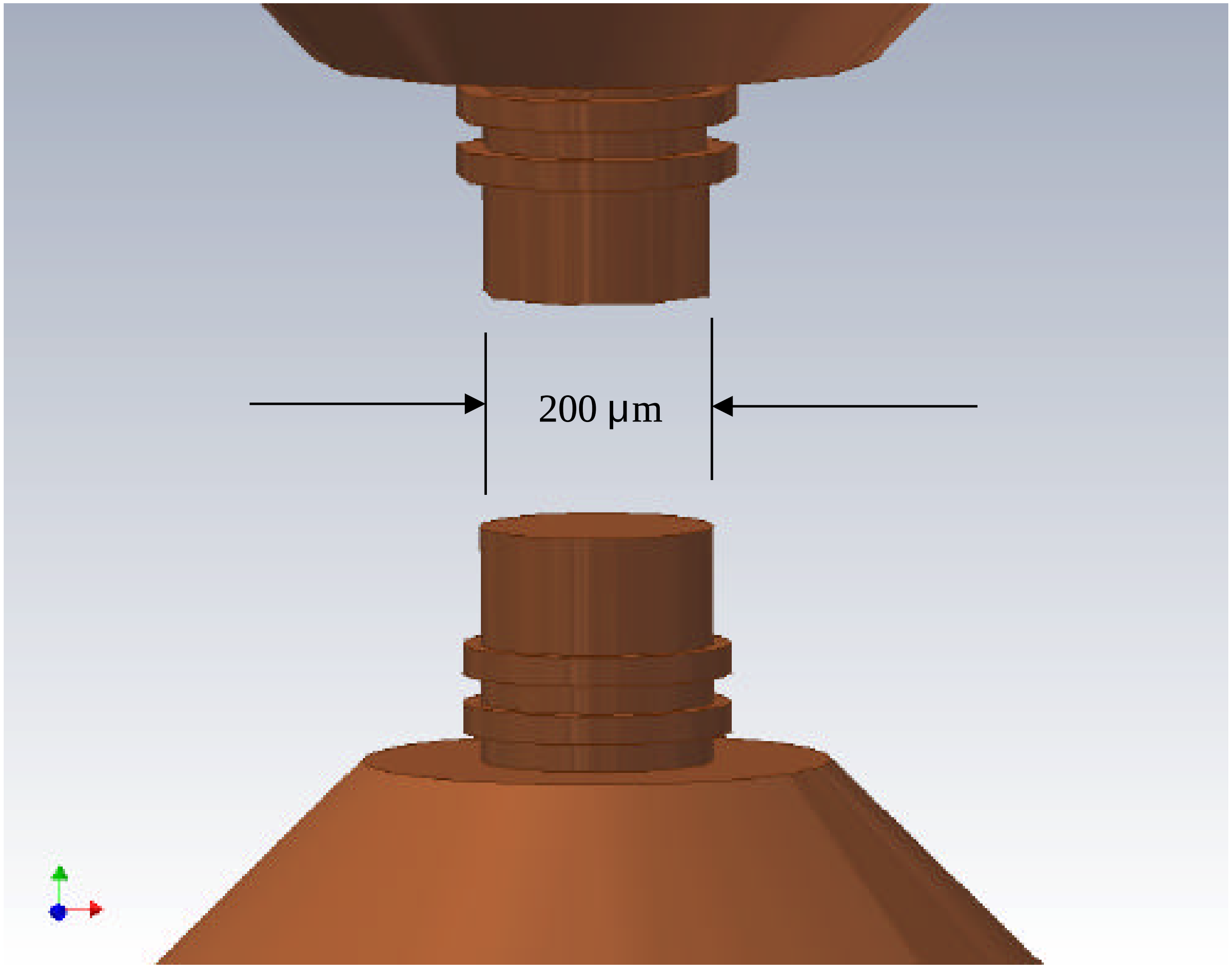


If we had added more DT, the solid would bridge the gap, creating the desired free standing specimen, complete with a notch:

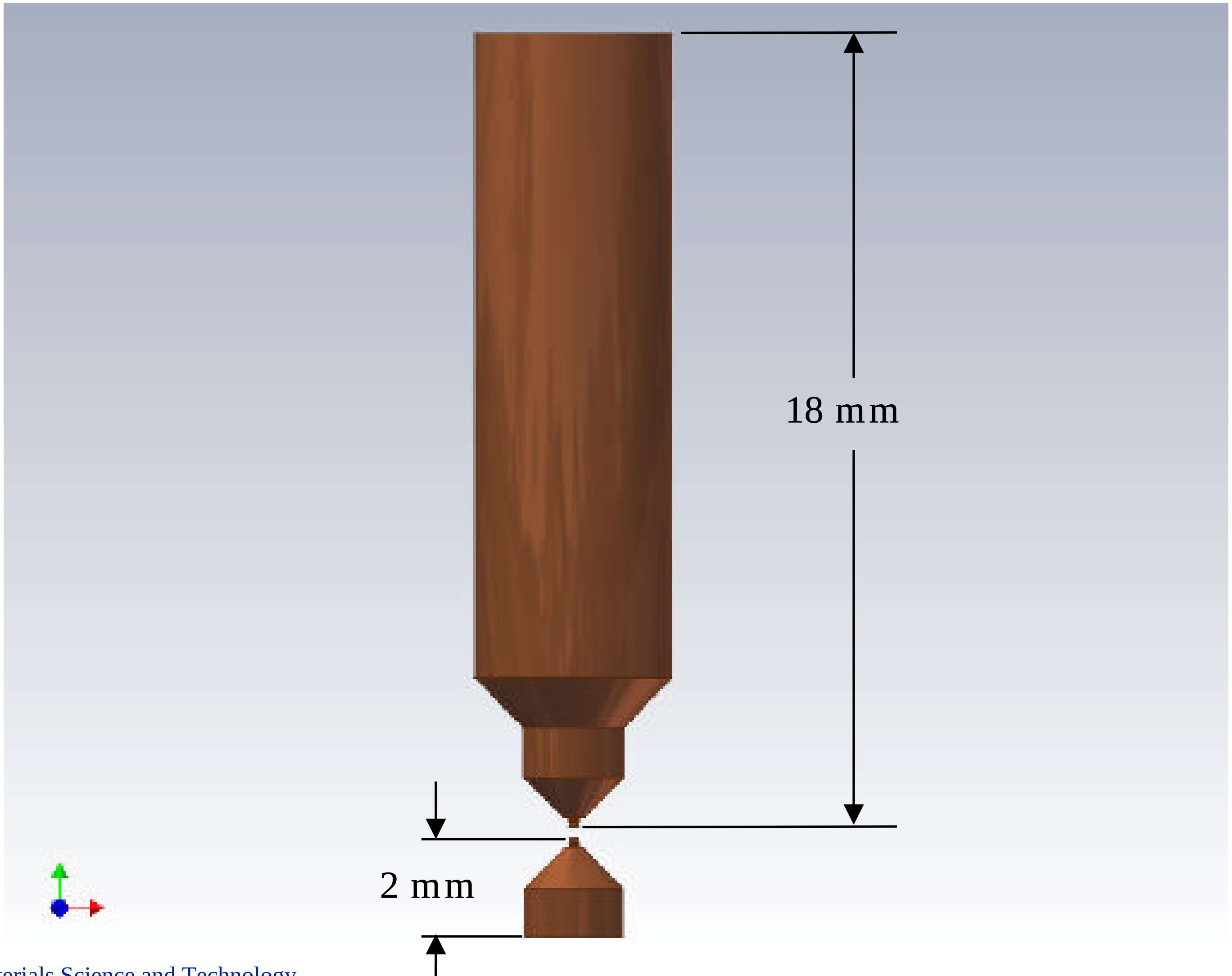


Now, if we could just *move* one of these copper blocks, ….

We add some grooves to these 'sample mounting posts' to help hold on to the solid DT specimen:



The 'posts' are only 200 μm ∅ x 200 μm long, machined on to more manageable copper pieces:



The upper post screws onto a linear actuator, designed especially for motion at cryogenic temperatures
(if we can find one!!)

At this point, I needed to seek expertise to assist in the design of a proper actuation/detection system:

As luck would have it, we have a new (Director's funded) postdoc in our division with experience in small scale materials strength measurements:

J. Gregory Swadener

Education

1998	Ph.D. Engineering Mechanics, The University of Texas at Austin Dissertation: Primary fracture toughness of a glass/epoxy interface Dissertation advisor: Kenneth M. Liechti
1992	M.S.M.E. Mechanical Engineering, University of Notre Dame
1984	B.M.E. Mechanical Engineering, Georgia Institute of Technology

Professional Appointments

April, 2001	Postdoctoral Fellow, MST-8, Los Alamos National Laboratory
1998-2001	Research Assistant Professor, University of Tennessee and Oak Ridge National Laboratory (under the direction of Dr. George M. Pharr)
1992-1998	Graduate Assistant/Postdoctoral Fellow, The University of Texas
1991-1992	Graduate Research Assistant, Notre Dame University
1988-1991	Sr. Product Engineer, Uniroyal Plastics Company
1984-1988	Analytical Engineer, Textron Marine Systems

Research Interests

Nanoindentation, interfacial fracture, adhesion, mechanics of interfaces, **small-scale mechanical behavior of materials.**

LINEAR ACTUATORS

Cryogenic motion control made easy!

Specifications:

<u>Electronics</u>

- ***Input Power:105-125 VAC,***
- ***Controller Geometry:***
235 x 133 x 305 mm
9.25 x 5.25 x 12 inches
- ***Control:0-5 V analog***

<u>Actuator</u>

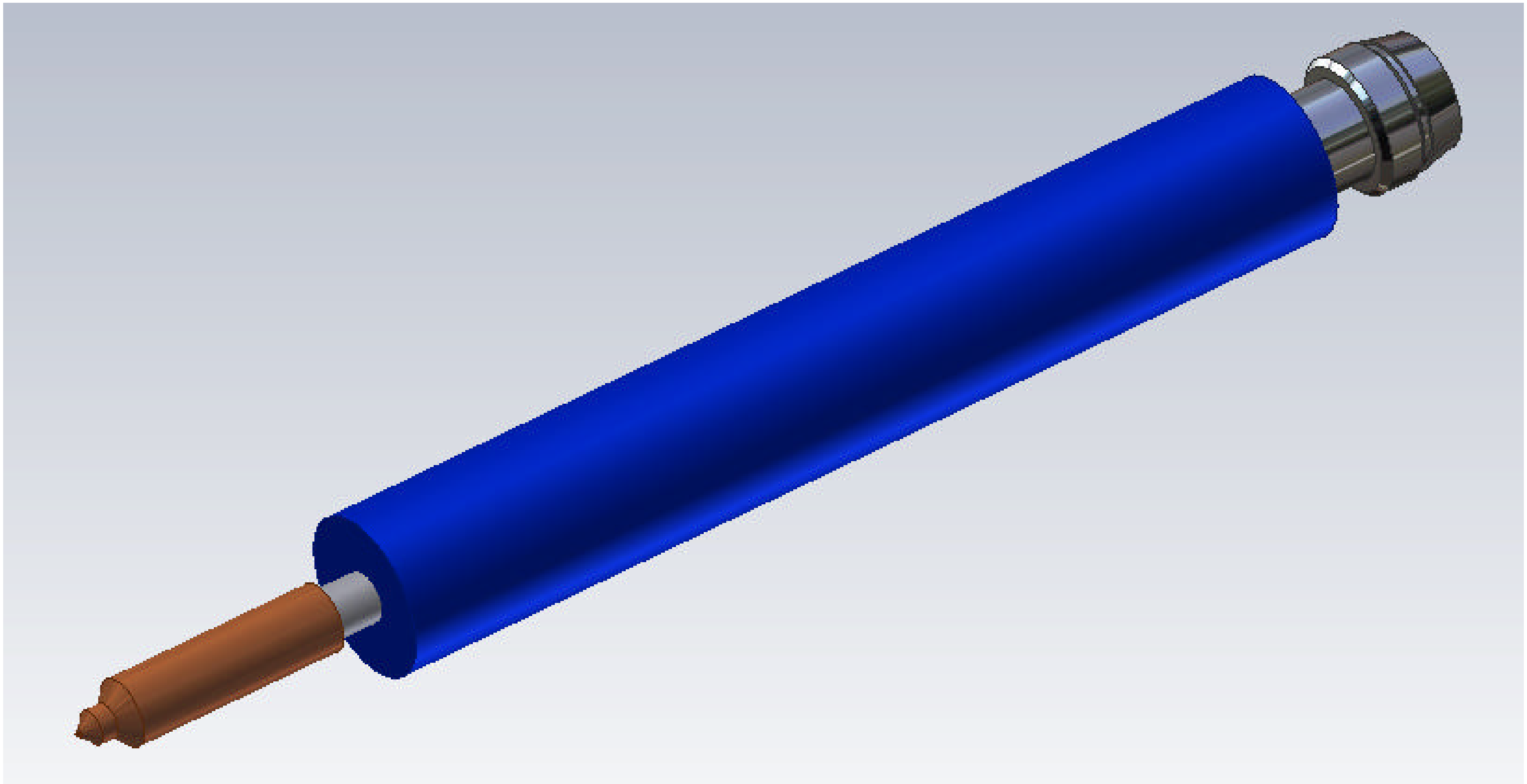
- ***Stroke: 100 microns***
- ***Force: 50 N ~ 11 lbf.***
- ***Resolution: <0.1 microns***
- ***Geometry: 10 mm dia. X 50 mm***
0.394 x 2.0 inches
- ***Weight: 25 g***

<u>Options</u>

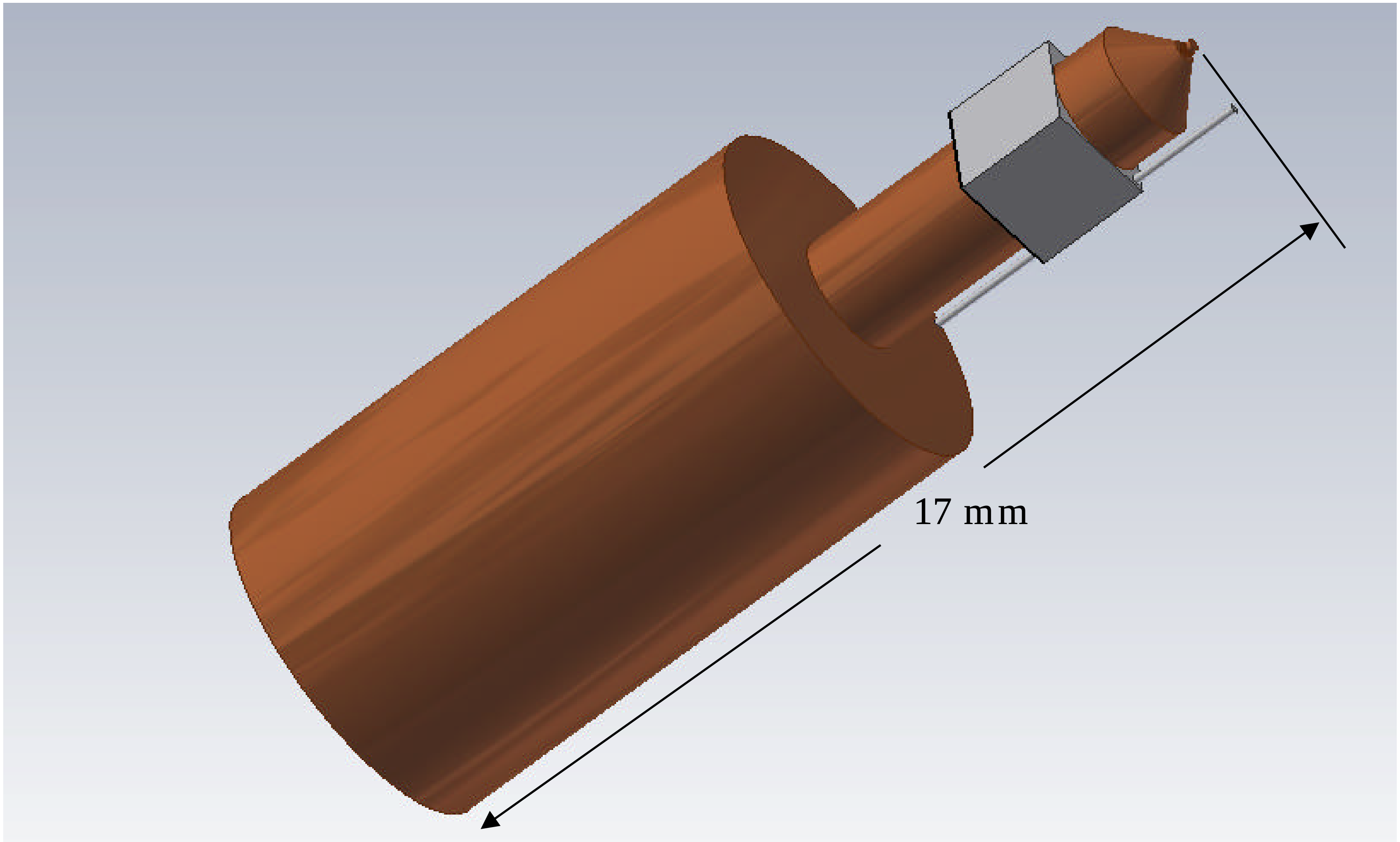
- ***IEEE-488.2 Interface***
- ***RS232 Interface***
- ***Custom cable lengths***
- ***Special mounts***
- ***Cryogenic operation***
- < 5 K
- < 180 K
- ***Cryogenic electronics***

Custom configurations available

With an actuator, the upper assembly might look something like this:



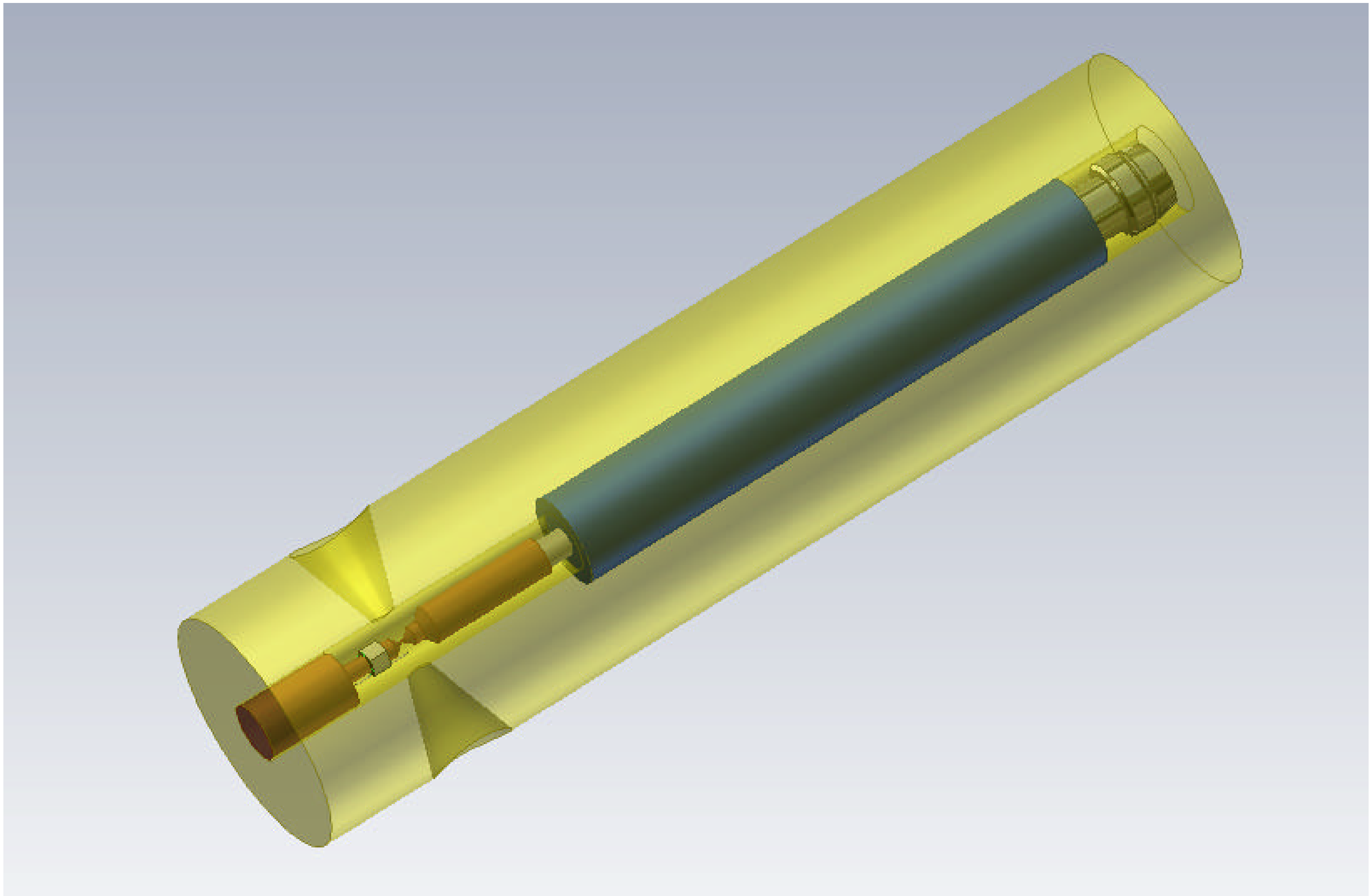
We add a piezo to the lower post to measure stress:



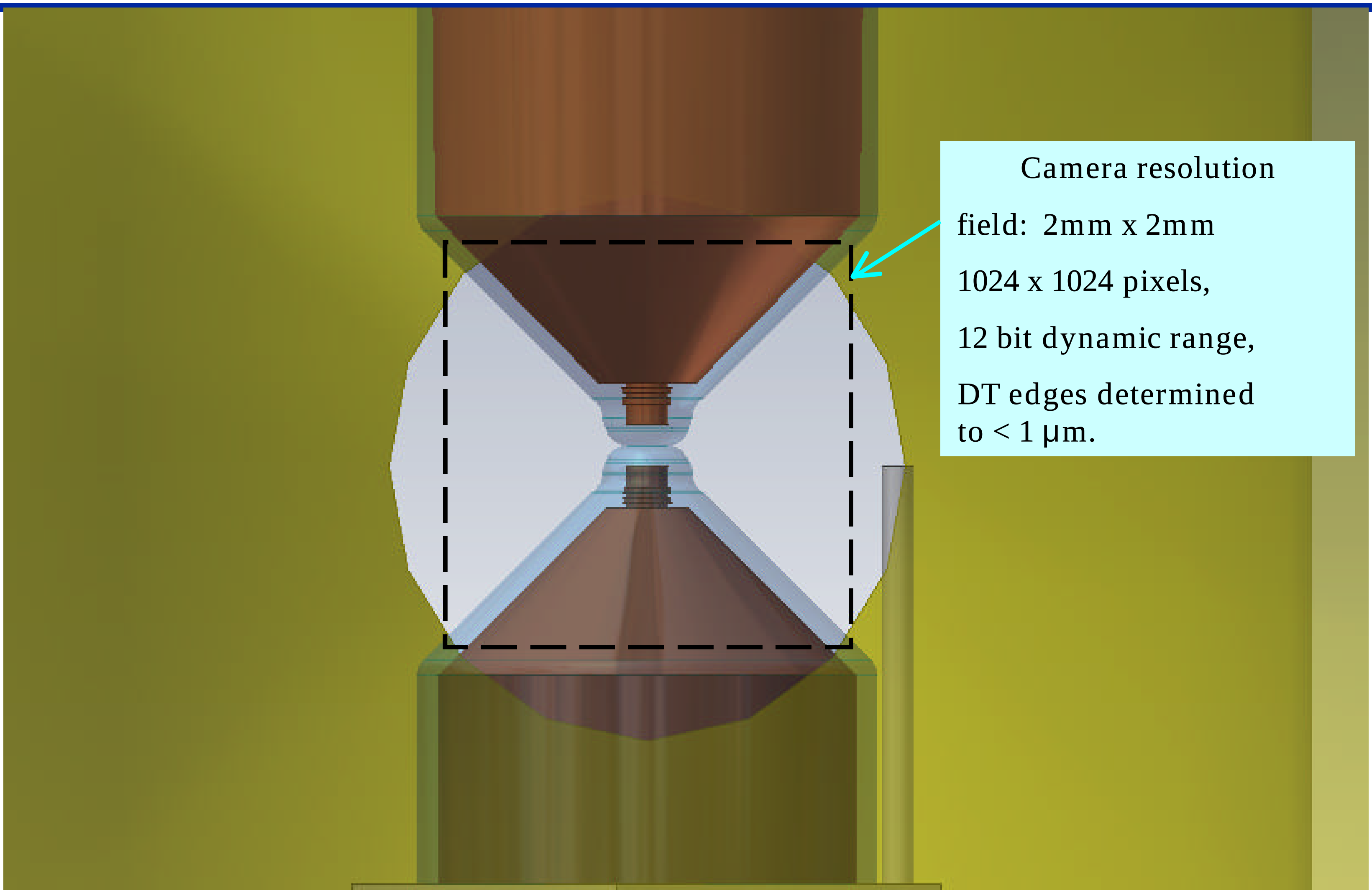
Alternatives to the piezo detector element:

Material	PCB Piezotronics	Adaptronics	Adaptronics	TRS Ceramics
	218C Charge Sensor	FPM 101	FPM 231	PZN-PT
d33 (pC/N)	n/a	200	680	2000
d31 (pC/N)	n/a	-70	-300	-950
e33/e0	n/a	600	4000	5000
Sensitivity (pC/N)	3.6			
Capacitance (pF)	14			
For 2x2x2 mm:				
Charge/Load (nC/N)	0.0036	0.200	0.680	2.000
(electron/microN)	22	1200	4100	12500
Voltage/Load (V/N)	0.26	18.4	9.6	22.6
d33 - piezoelectric constant		cf: force on piezo at yield: ~ 300 microN		
d31 - 31-piezoelectric constant				
e33/e0 - relative dielectric constant				
Note: reported values are for 295 K				
Charge and voltage sensitivity at 18 K is approximately 30%				

Finally, we enclose all of this assembly inside a tritium cell with optical ports:



What the camera might see:



Camera resolution

field: 2mm x 2mm

1024 x 1024 pixels,

12 bit dynamic range,

DT edges determined to < 1 μm.

Proposed experimental procedures:

- Calibrate piezo at 19 K with 1 gram weight, then:

  Assuming 1 μN resolution,

- Run load test at 10 μN/s
  - should resolve ~ 30 points in the elastic range
  - permits determination (with an accuracy of ~ 2-3%) of:
    - elastic modulus
    - 0.2% offset yield strength
- Run both compression and tension experiments
  - yield strength may be higher in compression
- Look for effects of radiation hardening
  - run tests on 'aged' samples
  - ^{3}He bubble voids may be problematic

What's next?

- Details on actuator
  - look for & fix showstoppers
    - check actuation in presence of frozen DT
    - we need a modified electrical connector
- Details on piezo detector
  - check for effects of beta deposition
    - fixes: epoxy coating, grounding of posts, etc.
- Complete design of cell
  - thermal modeling of layer formation
  - Specify/design electrical feed-thrus
- Redesign cryostat if necessary
  - this assembly may be too long for existing apparatus
- Keep at it!!