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June 2024

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Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

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Status of Fabrication of Optimized Ultrasound Thermometers M3CT-22IN0702035

Joshua Daw

Principal Researcher (INL)

Joshua.Daw@inl.gov

(208)-526-7114

ORCiD: 0000-0003-4377-6231

OVERVIEW

Purpose:

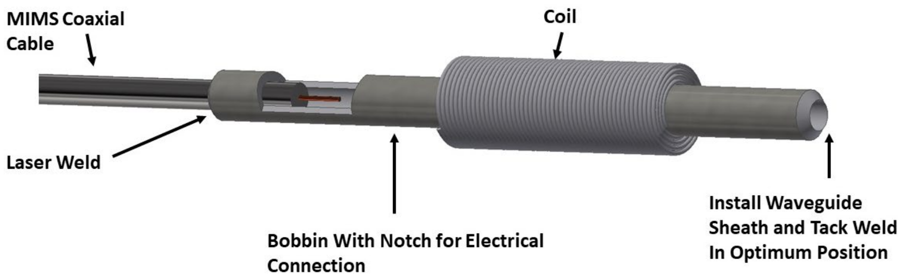
Real-time temperature measurement is arguably the most important operational parameter for characterizing irradiation experiments and the control of power plant systems. The INL developed ultrasonic thermometer is an excellent candidate for use in these applications, but still has several design aspects that can still be improved upon.

Logical Path:

The basic design of the waveguide-based ultrasonic thermometer is simple, but its fabrication is complicated. Optimizing the design and developing purpose-built electronics will make commercialization of the UT easier. Work this fiscal year has focused on:

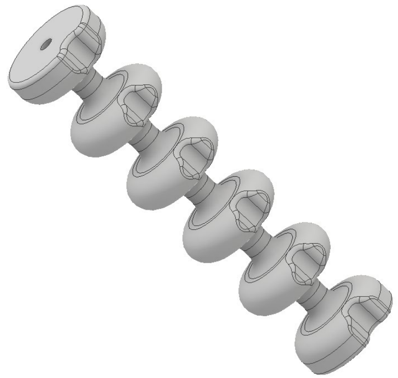
- Simplifying and advancing the coil and bobbin design
- Improving the durability of welds made to refractory waveguides
- Identifying an ideal transducer fill cement
- Developing a method of removing excess acoustic signal artifacts (damping)
- Testing UTs for a microreactor testbed experiment.

Improved Transducer Bobbin Designs



Redesigned coil bobbin to allow for easy signal optimization using a standard frequency coil

Concept design for a printed high-frequency (1 MHz), reactor-capable coil bobbin



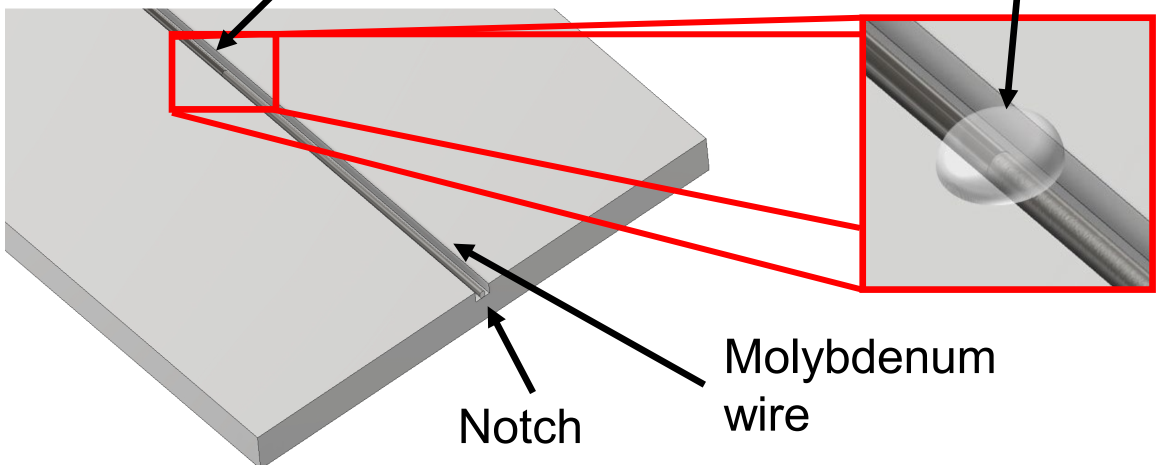
Refined high-frequency coil bobbin after the first print attempt

Waiting for the completion of printed bobbins: testing to be performed in the first quarter of FY-23

Improved Method of Laser Welding Magnetostrictive and Refractory Wires and Heat-Treating Refractory Waveguides

Magnetostrictive wire

An isopropanol droplet eliminates oxidation of refractory wire and promotes rapid cooling

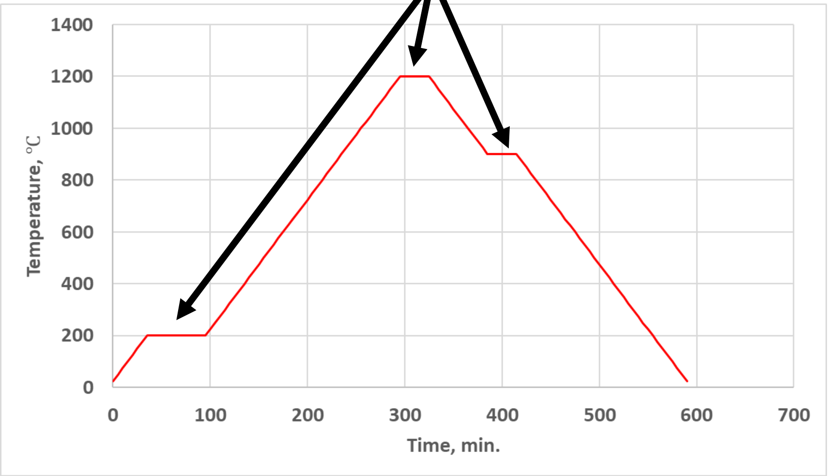


Notch

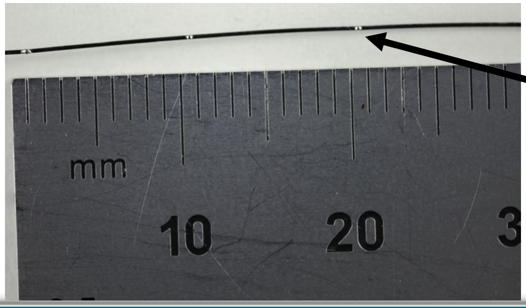
Molybdenum wire

Stainless-steel (SS) weld platform

Temperature holds at 200, 1200, and 900℃. Heating and cooling rates of 5℃/min.

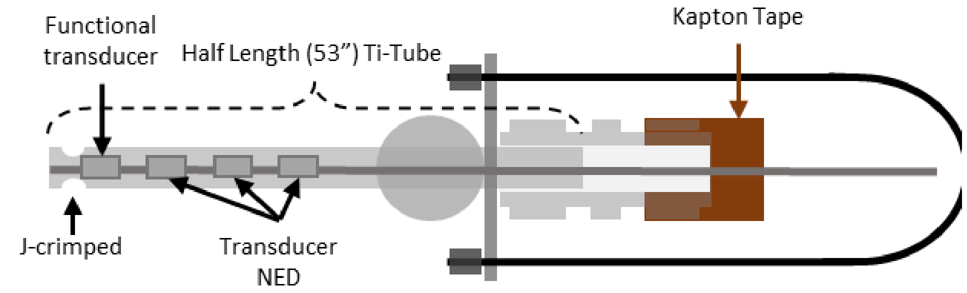


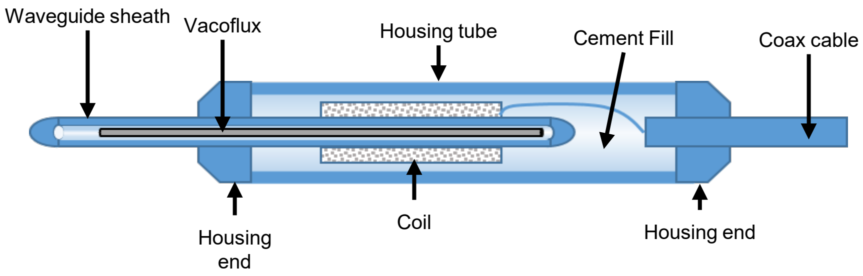
Molybdenum heat treat profile



Laser-welded bump reflectors on the molybdenum waveguide become very brittle. A new heat treat restores ductility.

TREAT Concurrent Test Results: Fill Cement Comparison





Some in-core UT failures are thought to be attributable to degradation of the fill cement causing coil wire mobility and shorting or open-circuit failure of the coil. In addition to the currently used Sauereisen, three other cements with desirable properties have been identified:

- Saueresen Electrotemp Cement No. 8
- Aremco 538 N
- Aremco 575 N
- Aremco 675 N.

Sauereisen No. 8, Aremco 538 N, and Aremco 575 N have been included as concurrent tests in several TREAT transients. This testing is ongoing and has yet not produced an obvious "best" candidate.

UT Fabrication Improvement

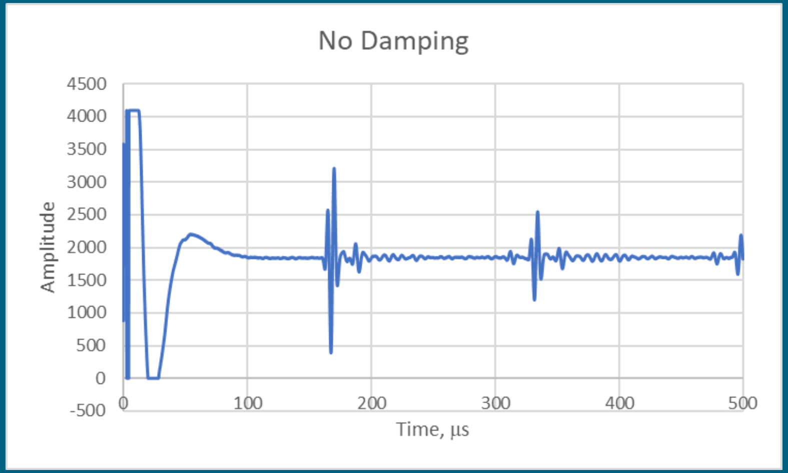
- Damping strategy testing started
  - ~200 kHz targeted as the typical UT operating frequency
  - Three design elements tested
    - Sinusoidal plate (in both opposed and offset configurations)
    - Tapered and profiled wedges (to simulate a swaged tube profile)
    - Porous media closely matching the acoustic impedance of the waveguide (ultra-fine SS wool)
    - Tested in various combinations of the three elements
  - The results of these tests will be used to fabricate an in-core-capable damper, to be tested in the first quarter of FY-23

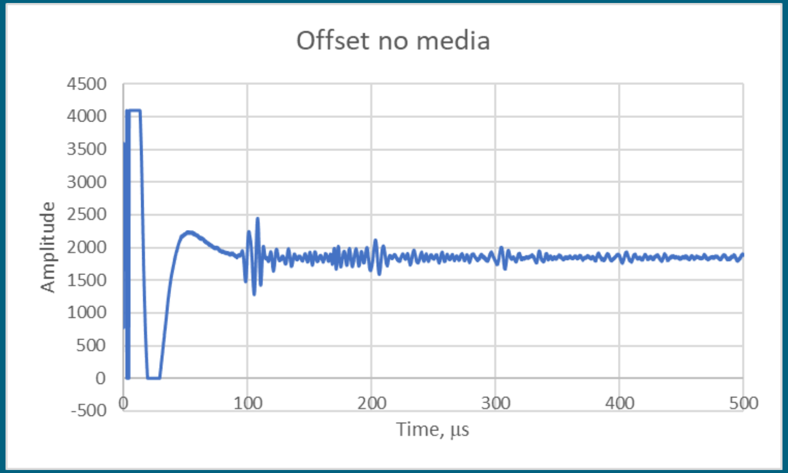
Sinusoidal Plate in Opposed Configuration

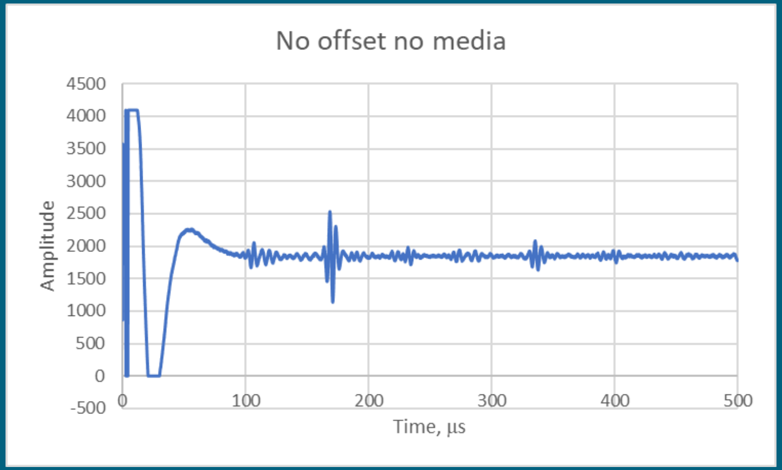
Sinusoidal Plate in Offset Configuration

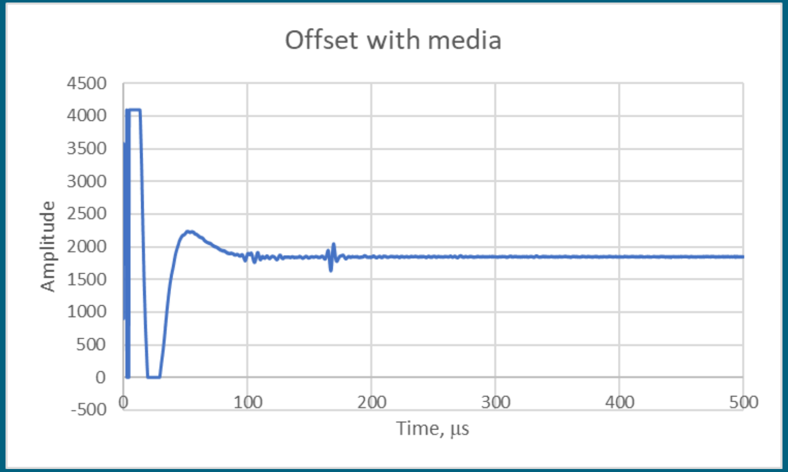
Flat Tapered and Profiled 3-D-printed Wedges

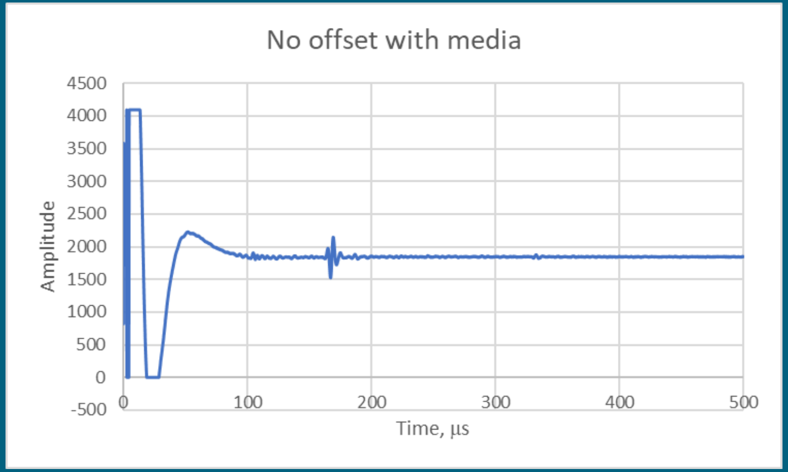
Initial Damping Test Results: Sinusoidal Plate and Media Only





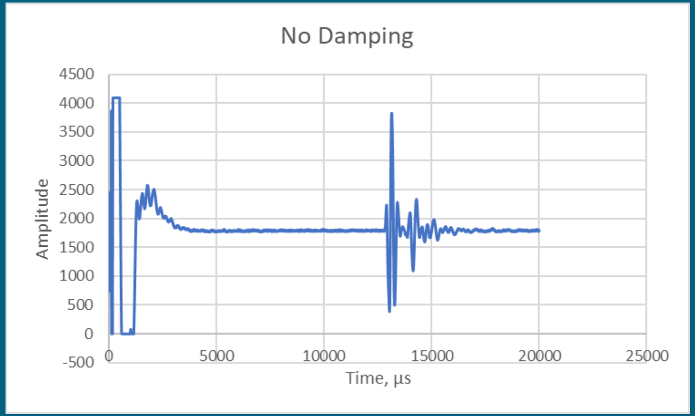


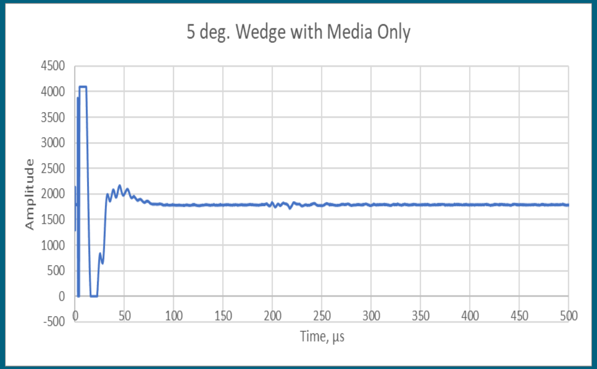


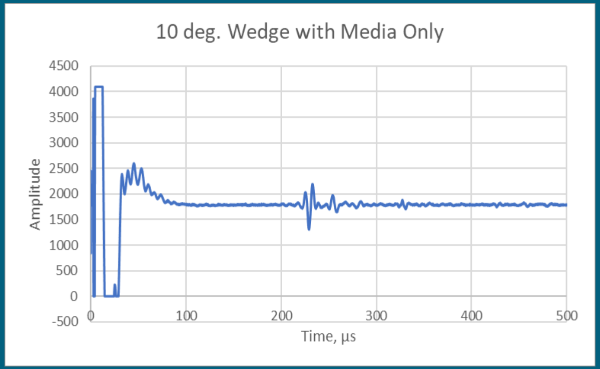


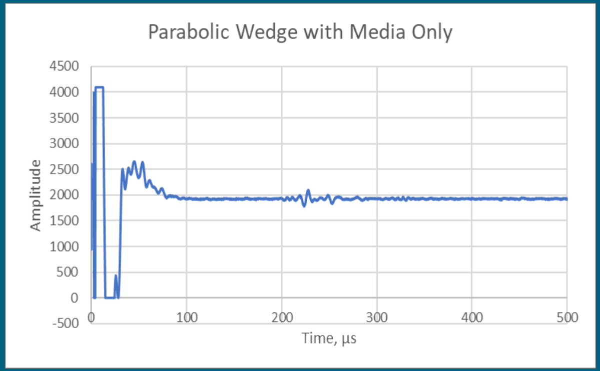
	Offset, no media	No offset, no media	Offset, with media	No offset, with media
% Reduction in 1st echo	86.52046	51.67123	85.11257	77.94026
Note:	Adds artifact and obscures signal	Adds small artifact	Adds small artifact	Adds small artifact

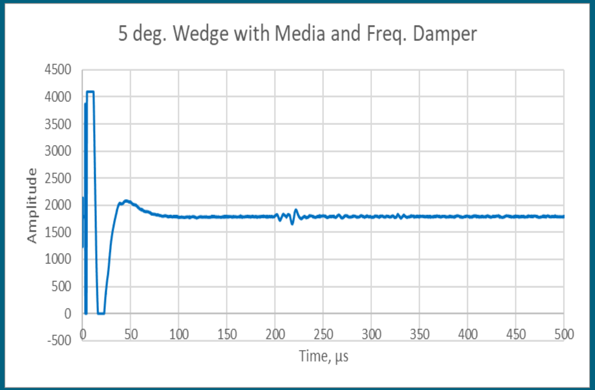
Updated Damping Test Results: Wedges, Sinusoidal Plate, and Media

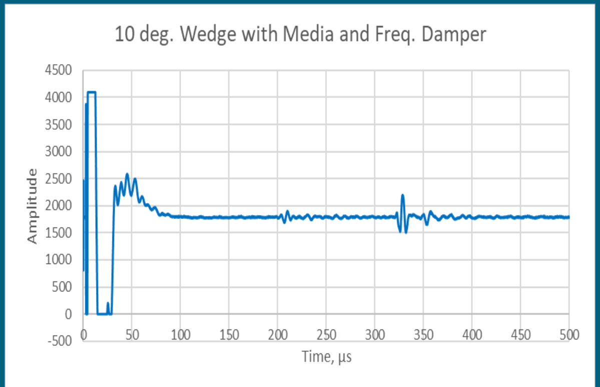


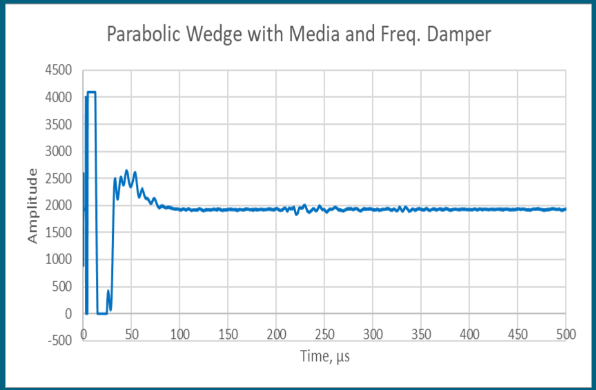












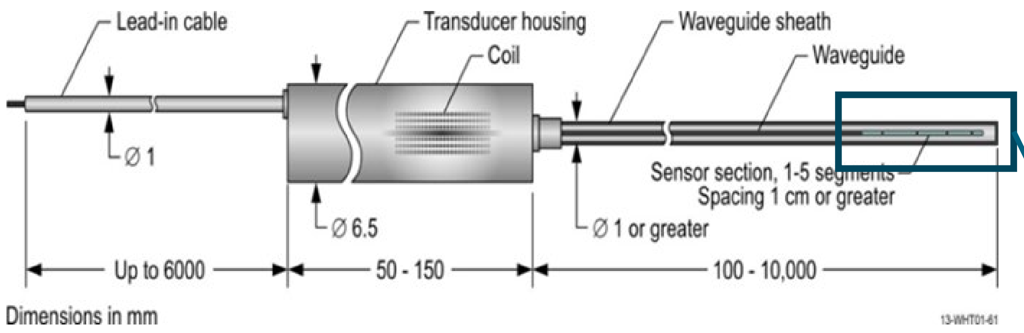
	5 deg. wedge, with media	5 deg. wedge, with media and sinusoidal plate	10 deg. wedge, with media	10 deg. wedge, with media and sinusoidal plate	Parabolic wedge, with media	Parabolic wedge, with media and sinusoidal plate
% Reduction in 1st echo	**99.12**	98.30	97.47	89.27	98.95	98.70
Note:	**Adds very small artifact**	Adds small artifact	Adds large artifact	Adds small artifact	Adds very small artifact	Adds small artifact

SPHERE UT Testing

SPHERE is an electrically heated non-nuclear testbed used to test heat pipes

- 2 UTs were fabricated for SPHERE/MAGNET testing
    - Vacoflux-50 magnetostrictive material welded to waveguides
        - A new technique (previously described) was used to maintain ductility
    - 316-stainless-steel waveguides in a 316 SS sheath
    - Molybdenum waveguides in a 316 SS sheath
- Each sensor uses three waveguides, with welded bump reflectors for segmentation
    - The molybdenum waveguides were heat treated using a new annealing process
- Due to space constraints within the SPHERE assembly, only the SS UT was tested

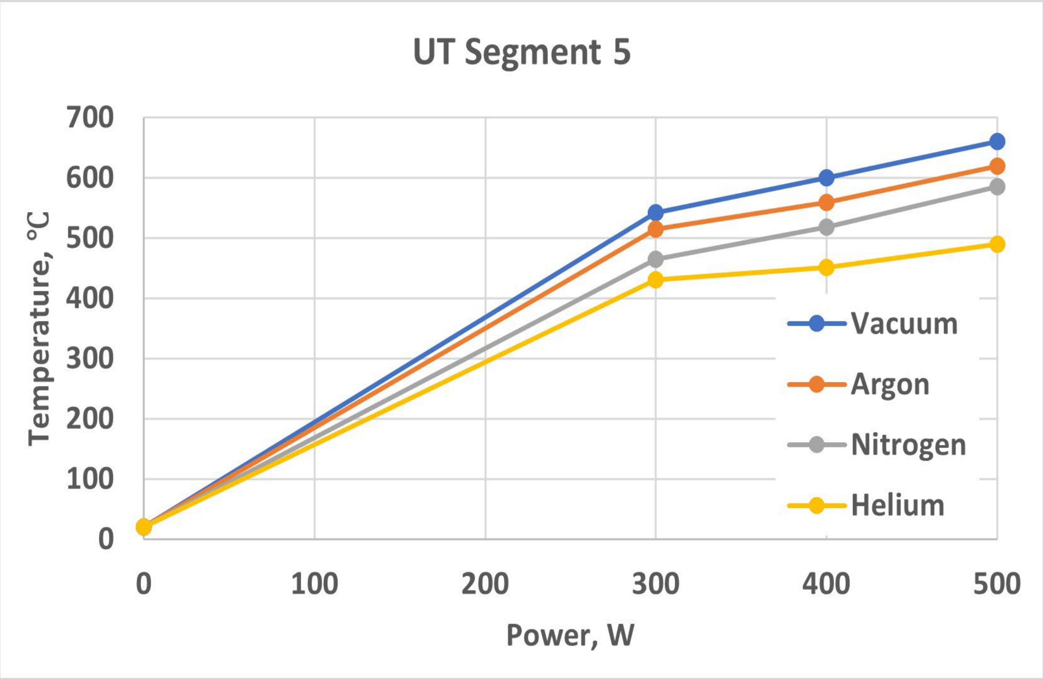
Total length: 36 inch



5 Sensor Segments: 3 inches each
3 Segments within heat pipe

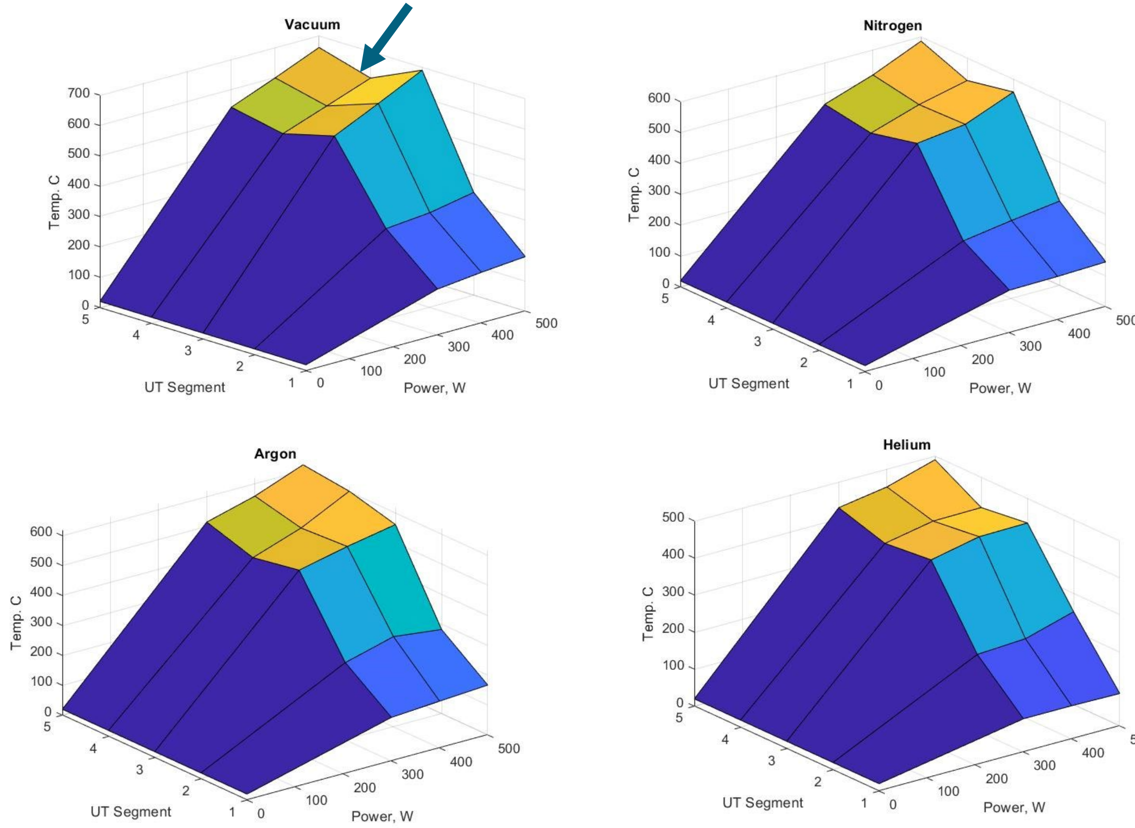
SPHERE Testing Results

- Data collected for 4 environments, at 0–500 W
- At over 500 W, the signal became unusable



Temperature vs. power for the UT segment nearest the center of the SPHERE experiment

Looking into the cause of the apparent dip (real or a processing artifact?)



Temperature vs. power vs. segment for 4 different atmospheres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