Development of an Ultra-Low Vibration Cryostat Based on a Closed-Cycle Cryocooler *

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Outline:

1. *About Euclid*
2. *Introduction to the project*
3. *Capacity map measurements*
4. *Vibration Measurements*
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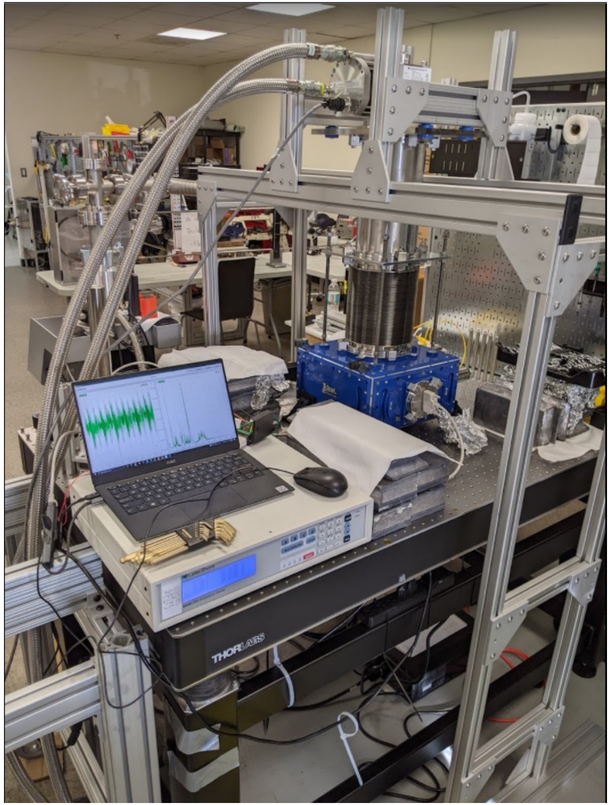

Euclid Techlabs/Euclid Beamlabs

Euclid has developed expertise and products in several innovative technologies: time-resolved ultra-fast electron microscopy; ultra-compact linear accelerators; electron guns with thermionic, field emission or photo-emission cathodes; fast tuners for SRF cavities; advanced dielectric materials; HPHT and CVD diamond growth and applications; thin-film for accelerator technologies.

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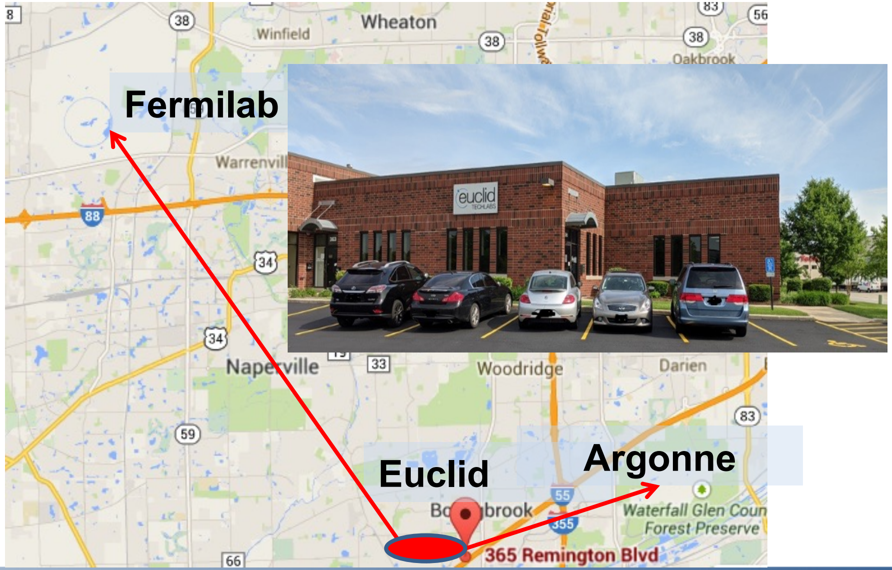
- Two labs: Beltsville, MD (material science lab). Bolingbrook, IL (accelerator R&D lab)
- Tight collaborations with national labs and universities: FNAL, ANL, Jlab, LBL, SLAC, LANL, NIST, NIU, IIT, CERN, etc.



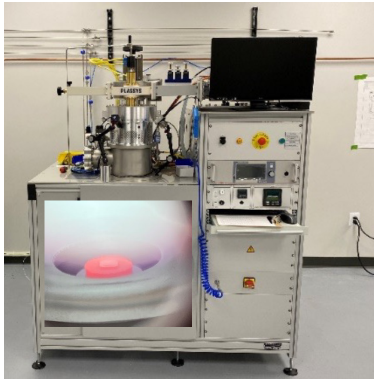
Products & Capabilities Snapshot

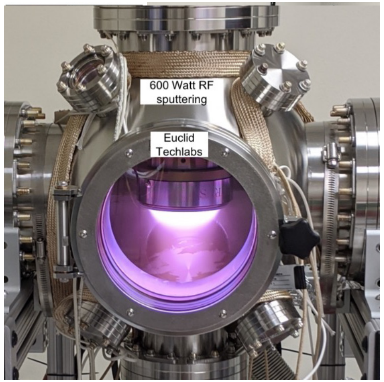
Products

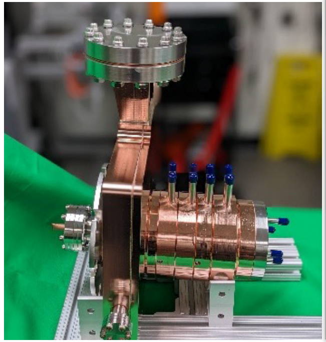
- UltraFast Pulser (UFP™) for TEM
- Dislocation free (HPHT&CVD) diamond for Xray optics
- Compact X-Ray Source
- NCRF and SRF electron sources
- Low loss ceramics (linear and non-linear)
- LINAC
- RF window
- In flange BPM

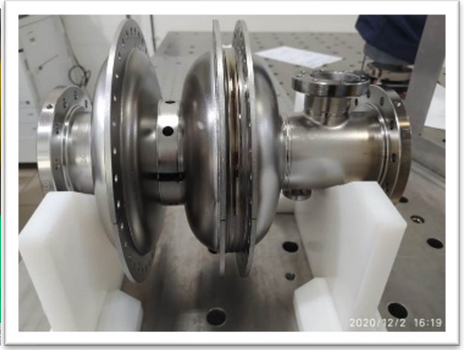
Capabilities

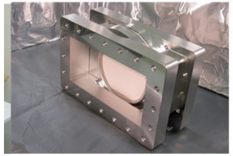
- Femtosecond Laser Ablation System
- Thin Film Deposition Lab
- EM/RF Testing Lab
- Radiation Shielding/Testing Lab
- Cryogenic 4K measurements
- Custom designs and consulting





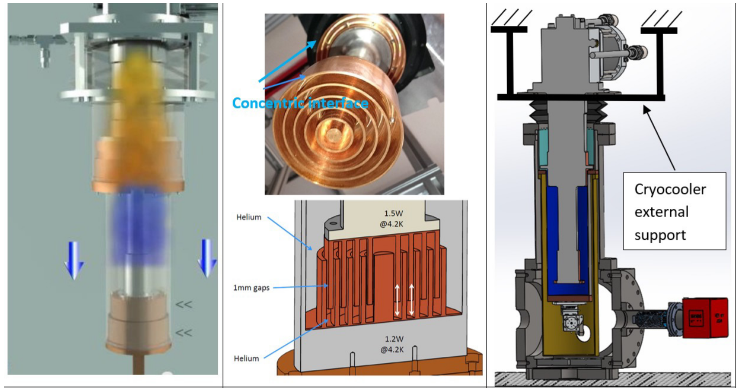




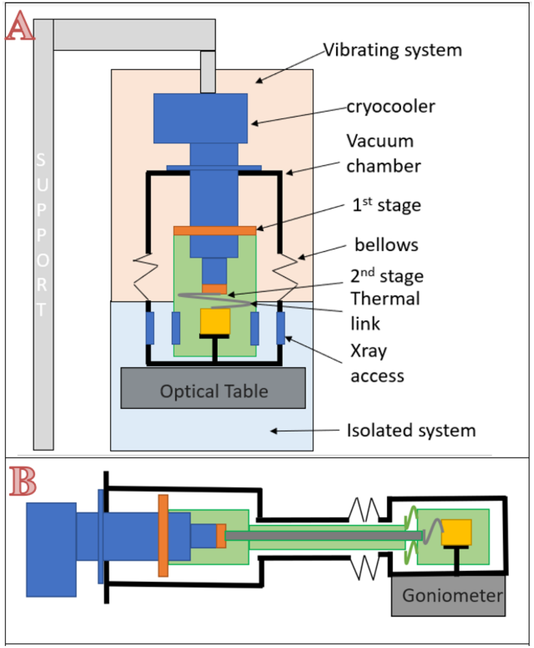


ULV cryostat schemes:

- There are two major concepts: Gas-gap barrier and Flexible strap
- Gas-gap barrier:
  - Pros: truly ULV regime, mechanically decoupled cryocooler, thermally coupled through the He gas.
  - Cons: CC need to be floating, alignment is hard, stationary operation only.
- Flexible strap:
  - Pros: ULV regime is possible, simple, cost effective and flexible
  - Cons: lower vibrations – higher thermal resistance, strap design need to address thermal short circuit problem if motion of the cryostat is req-d.



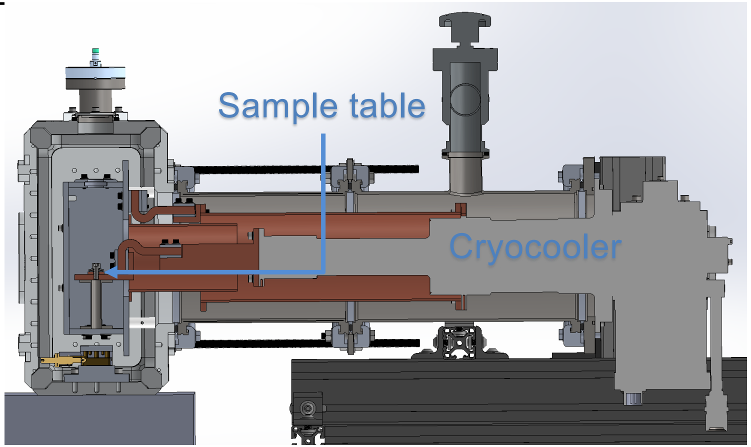
Gas-gap barrier

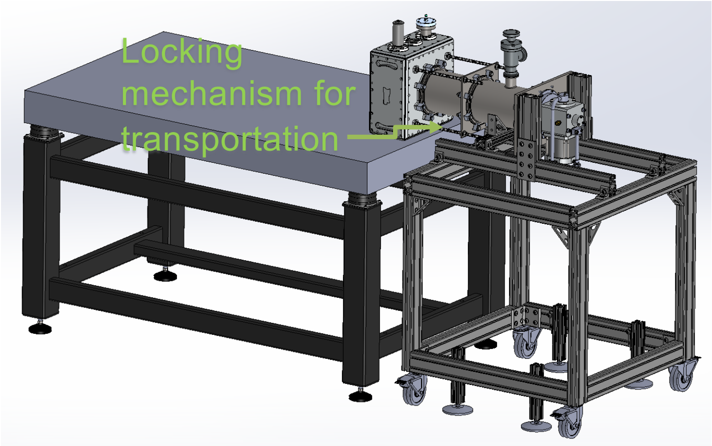


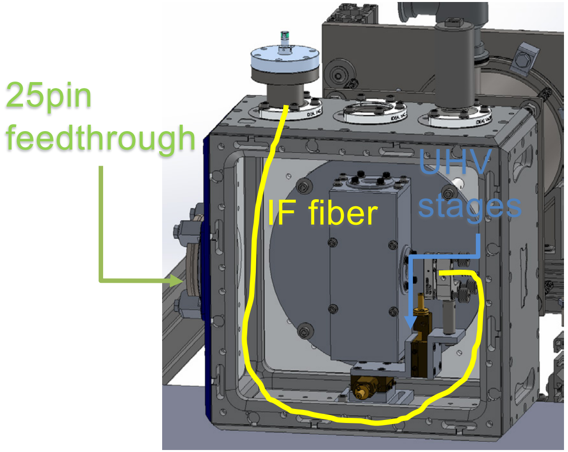
Flexible braiding scheme

ULV Cryostat Model

- Cryostat design was finished
- Optical interferometer is integrated inside for vibrations measurements; vacuum positioners are required for initial adjustment
- Mechanical decoupling is provided by flexible lines (copper braid for 4K and 30K and vacuum bellows for vacuum)
- Thorough thermal management was performed



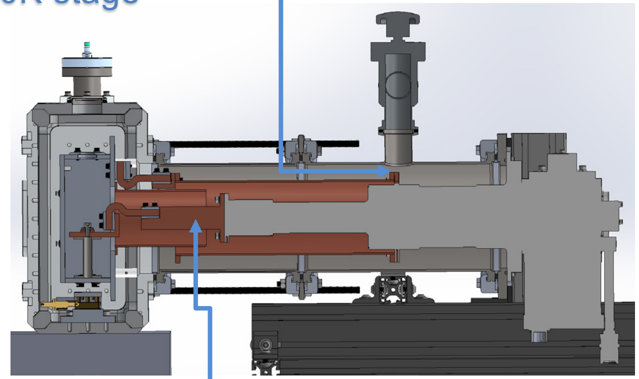




Thermal management

1. 1st stage:
   - Radiation: 13W with 0.05 emissivity (AL taping if needed).
   - Conduction: 1W through 4 peek posts.
2. 2nd stage
   - Radiation: 25mW from 30K thermal shield total expected; 2x330mW through optical view port if IR is not blocked (300K to 4K)
   - Conduction: 1mW through the table post from thin-walled SS.

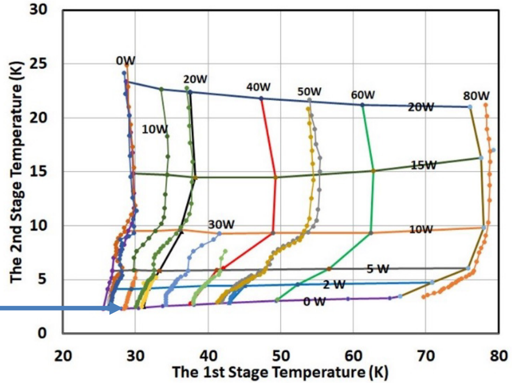
30K stage



4K stage

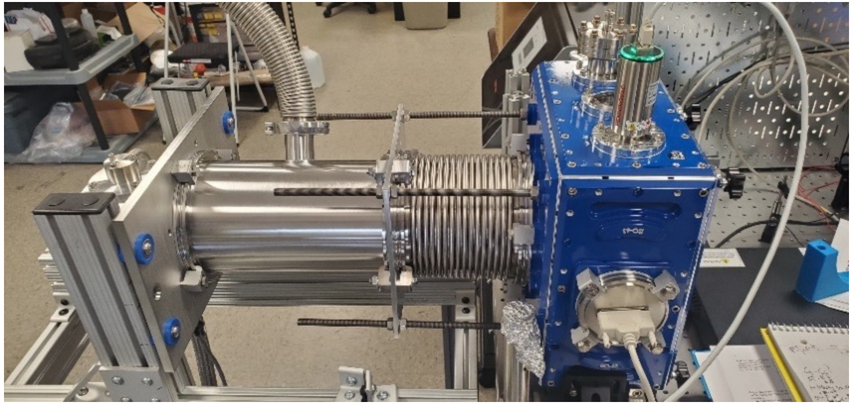
Table 1. Static heat load to 1st and 2nd stages			
	Radiation	Conduction	Total
1st	13W	1W	14 W
2nd	25mW	1mW	26mW

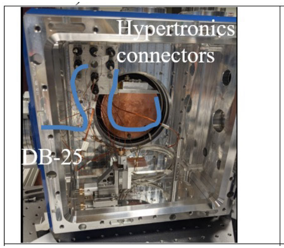
Expected 1st stage T=30K

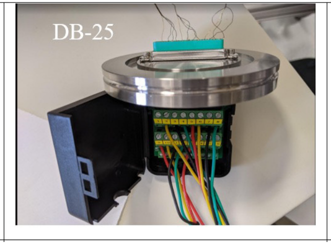


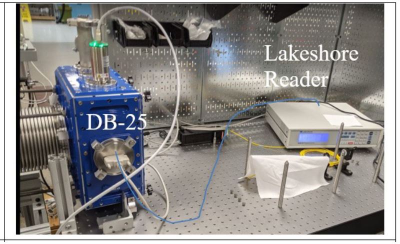
Capacity map measurements.

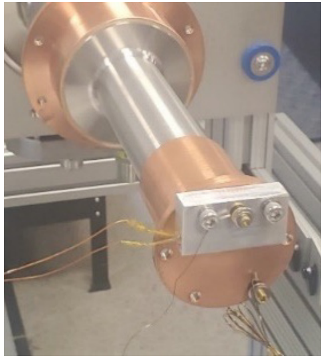
- Simplified set-up: vacuum cube does not have rad enclosure and sample table
- 2 heaters: 2nd stage is 50W heater, 1st stage is 100W heater.
- 5 Cernox sensors to the reader

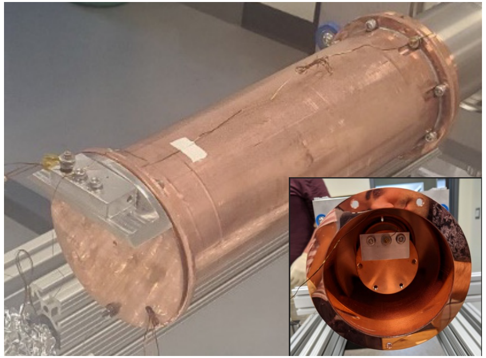






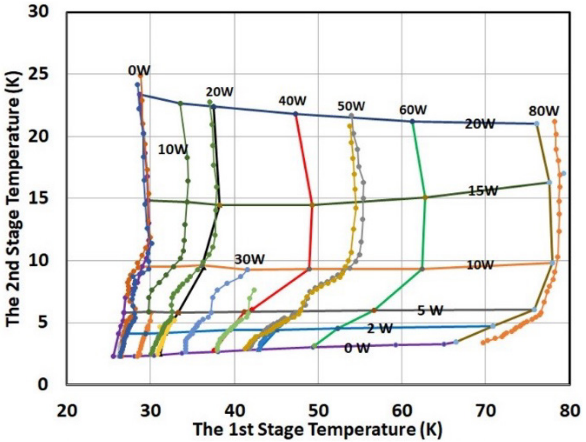




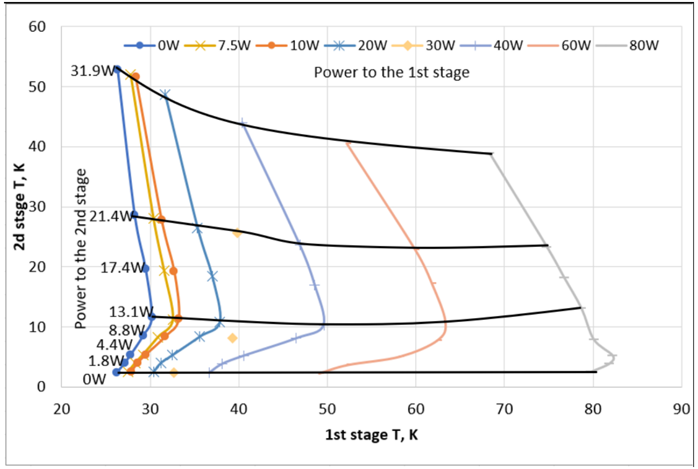


Capacity map measurements.

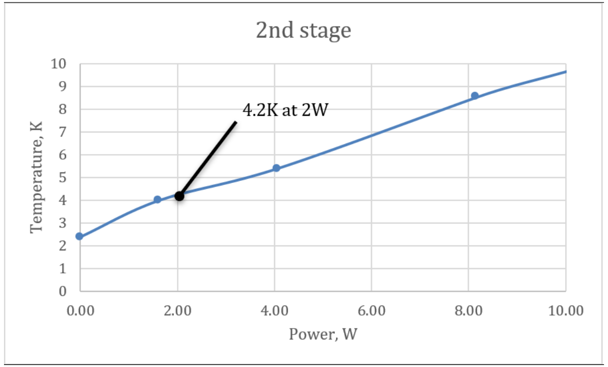
The results are generally in agreement with the manufacturer's documentation.
The capacity of the 2nd stage at 4.2 K is 2 W for a wide range of temperatures of the 1st stage.
All the additional sources were investigated: radiation, conduction through wires, dissipation in wires etc… and all are negligible except for the radiation to the 1st stage – 5W.



SRDE-418 capacity map provided Sumitomo



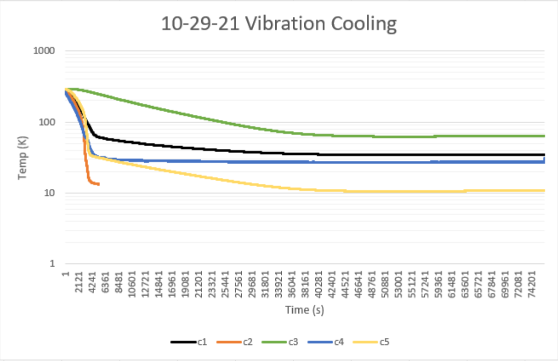
SRDE-418 capacity map measured by Euclid



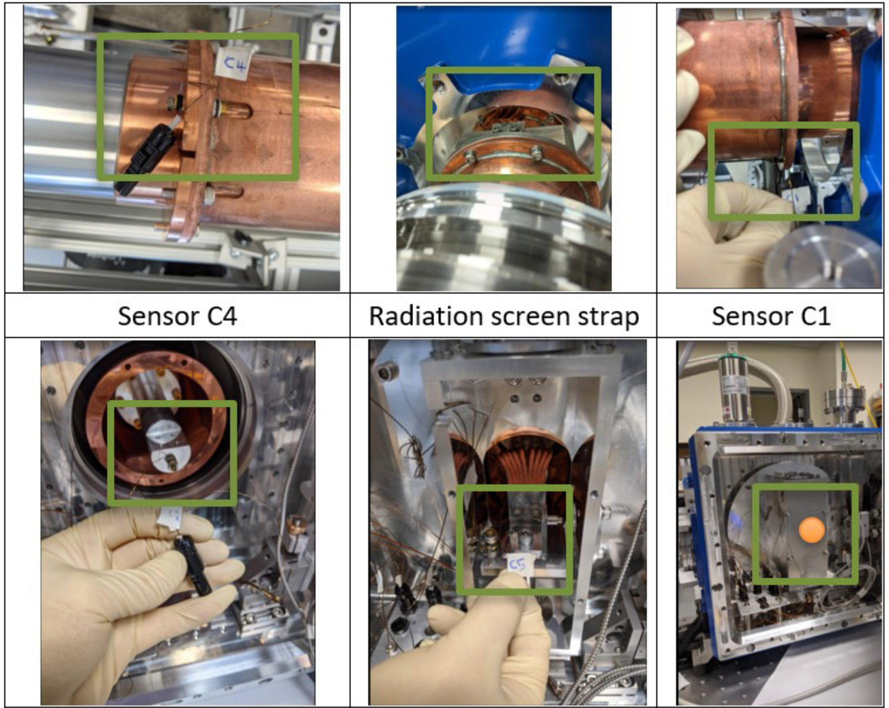
SRDE-418 capacity map measured by Euclid

Cryostat cool-down

1. The following temperatures were reached:
   - 1st stage C4 – 27K
   - the end of copper radiation screen C1 – 35K
   - the top of the AL radiation screen assembly C3 – 63.5K
   - the AL cold finger connected to the 2nd stage C2 – 13K before connection was lost ,
   - sample table C5 - 10.7K.
2. The sample table temperature of 10.7K can be reduced to 5K with the copper cold finger, but for proof of principle it was enough. Estimated heat is 0.2W.



Cool-down recorded



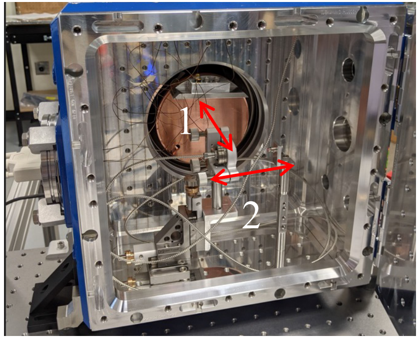
Sensor C4	Radiation screen strap	Sensor C1
Sensor C2	Sensor C5	Sensor C3

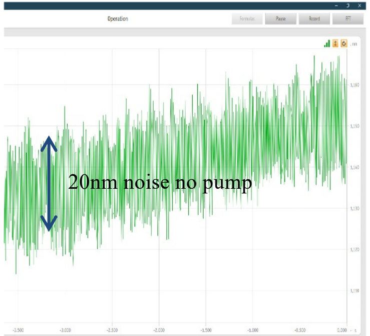
T-sensors in the Cryostat

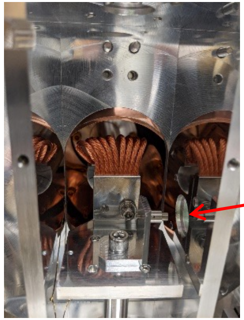
Vibration studies using Interferometer

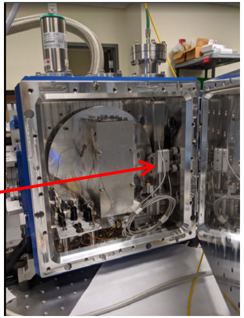
1. Cryocooler vibrations:
   - 7-µm until fully cooled
   - half of that once cooled down

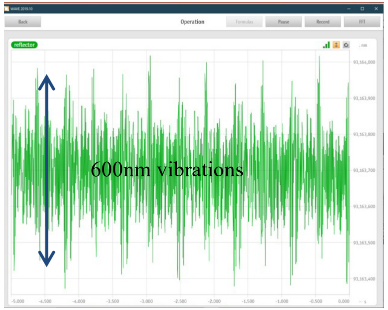
2. No pump 20nm
3. With pump 40nm
4. Cryocooler on 600nm: 2 braids and bellows 200nm each.

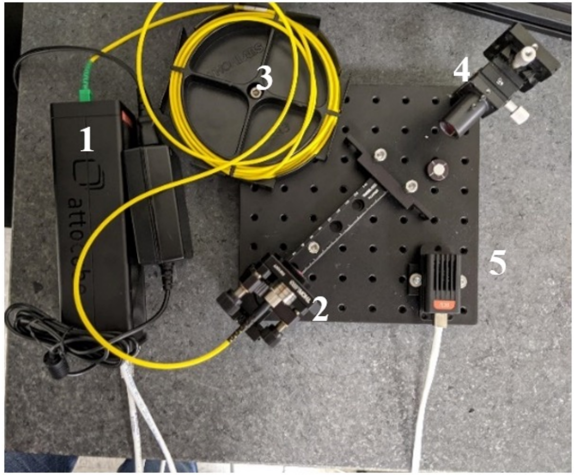






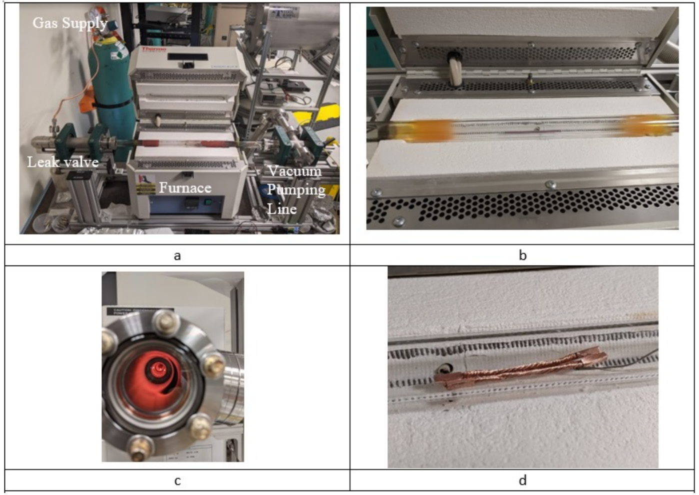




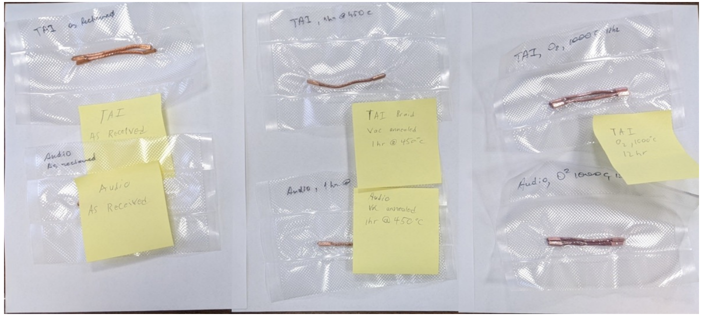


1 – Attocube interferometer
2 – interferometer head
3 – fiber
4 – retroreflector/mirror
5 – ECU (environment correction unit)

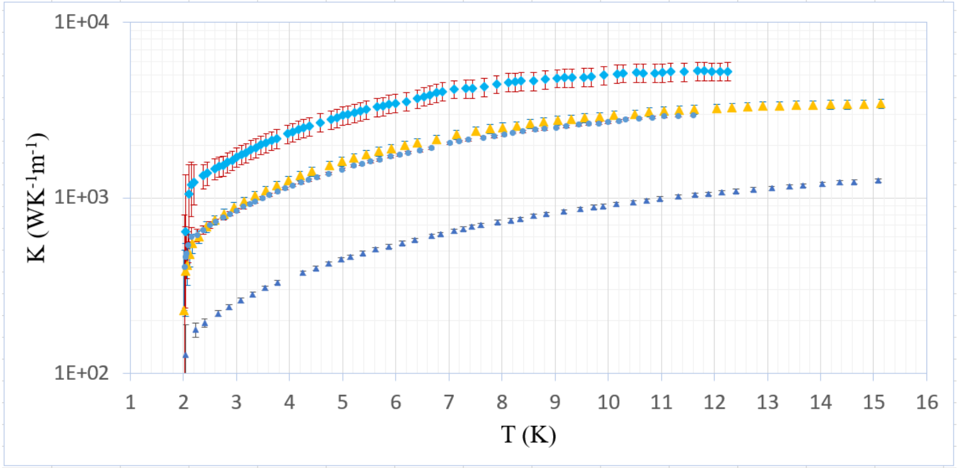
Copper braids annealing studies



Annealing and samples preparation at Euclid



RRR was improved from 50 to 300!
K(4K) from 300 to 2000 W/m/K

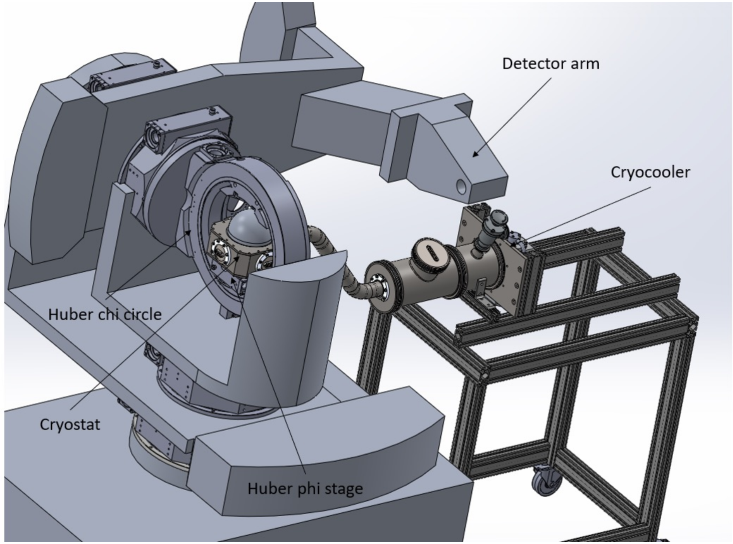


Special thanks to G. Ciovatti (JLAB) for these measurements!

Conclusions

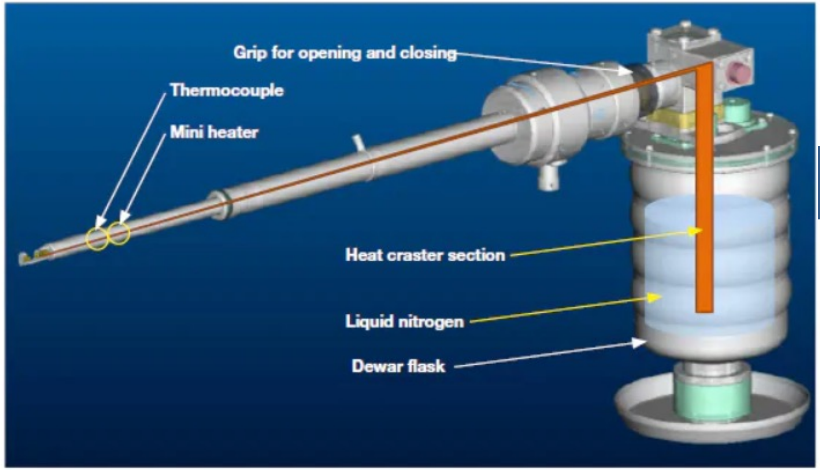
Under period of 9 months:

- Cryostat design was developed, manufactured and tested.
- Capacity map of the cryocooler has been measured.
- The cryostat was cooled down to 10K which was satisfactory for the 1st version.
- Vibration studies has been conducted: each braid and the bellows provides 200nm vibrations.
- Copper braid annealing studies has been conducted: RRR improved to 300.
- Second version of the cryostat has been designed compatible for XRD experiments with goniometer.

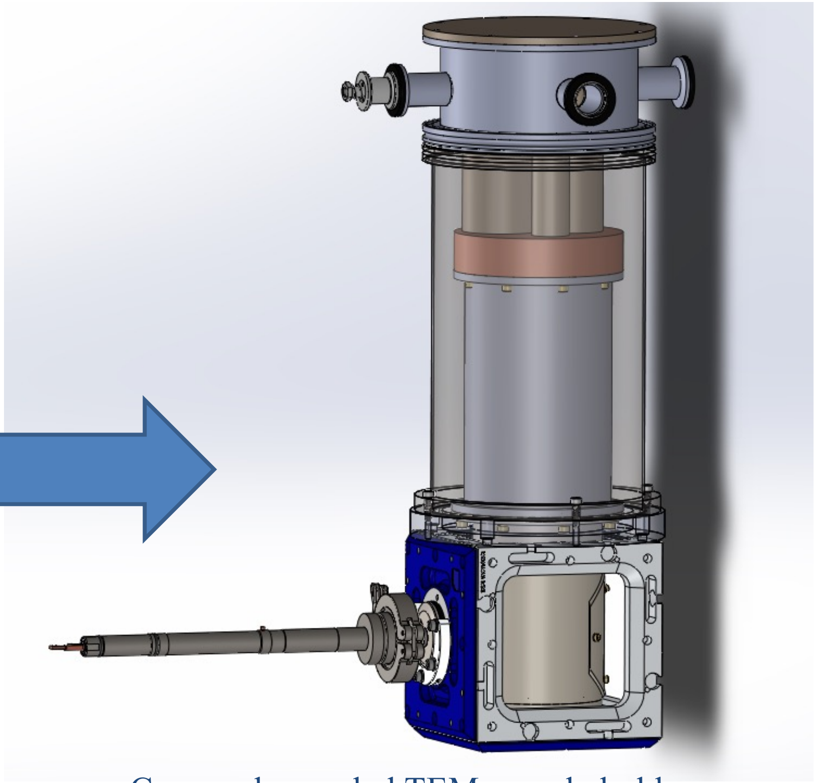


Future/Current work: Technology Spin-off for BNL

- TEM cryo-holder: substitute He_L sample holder to conduction cooled by a cryocooler.
- Design has been developed and is being manufactured at the moment



He_L TEM sample holder



Cryocooler cooled TEM sample holder

THANK YOU!

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