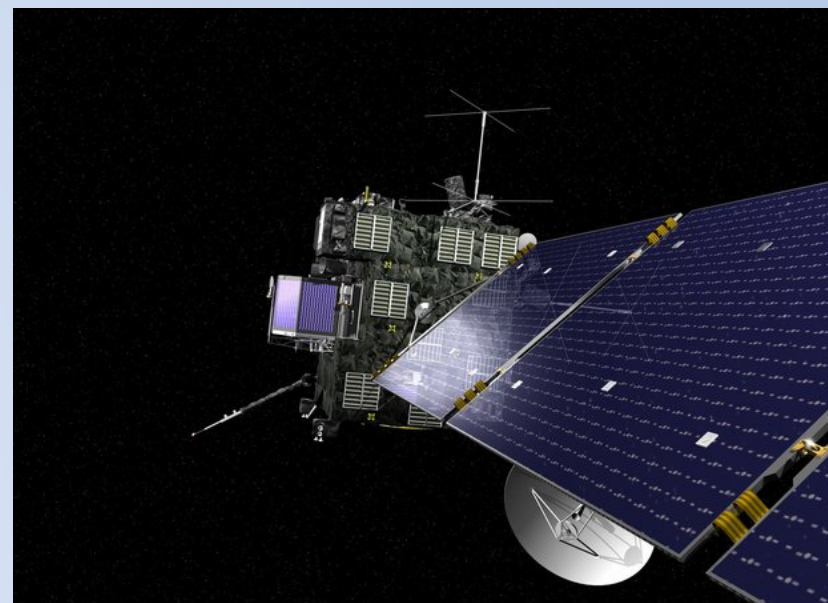
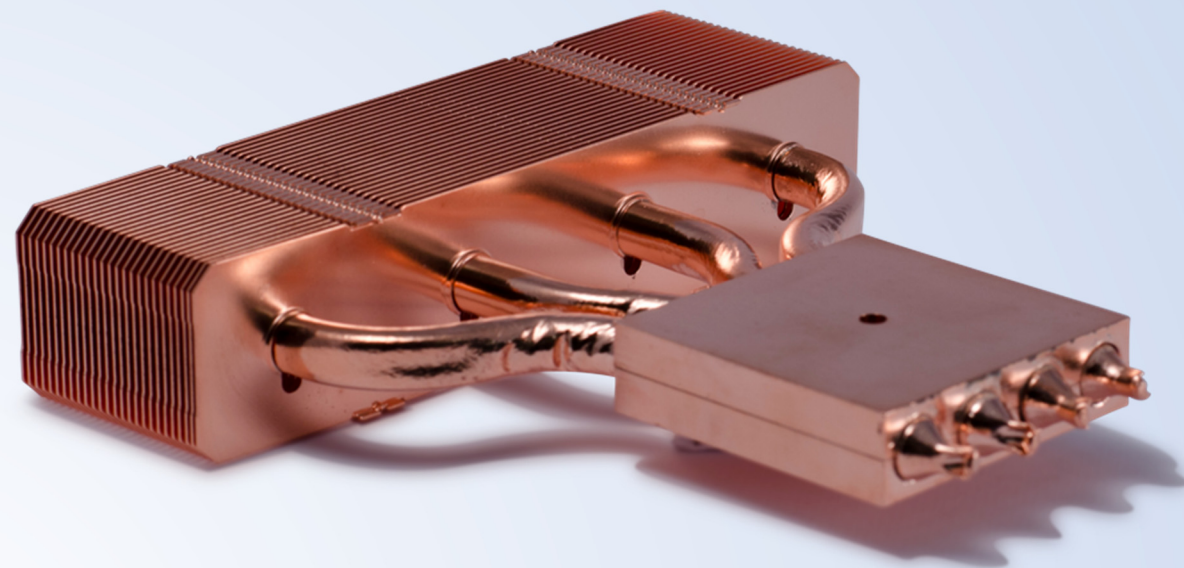


# Development of Low Vibration Cooling Systems for Beamline Optics Using Heat Pipe Technology

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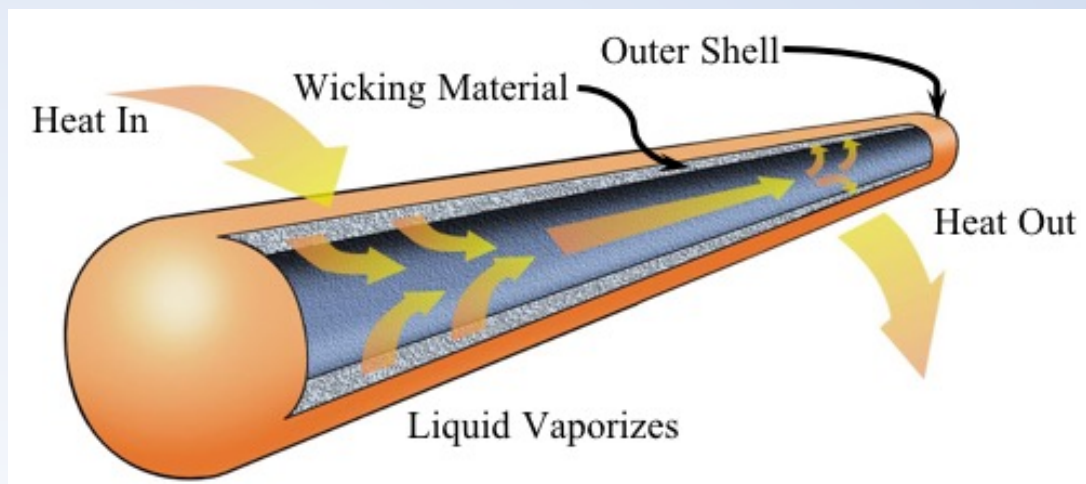


# Beamline Thermal Control

- Heat accumulates quickly and things melt easily
- Optics need to maintain shape
- Minimize Slope Errors and not distort the beam
- Water Cooling Effective But...
- Presents Many Challenges:
  - Vibrations disturb Optics
  - Vacuum contamination by leaks
  - Air Guarding Presents challenges:
    - Design
    - Assembly
    - Maintenance

# Heat Pipes

- Works through an evaporation and condensation cycle
- Has Very High Thermal Conductivity
- Working Fluid determined by operating temperature
- Size and Orientation Play a Role

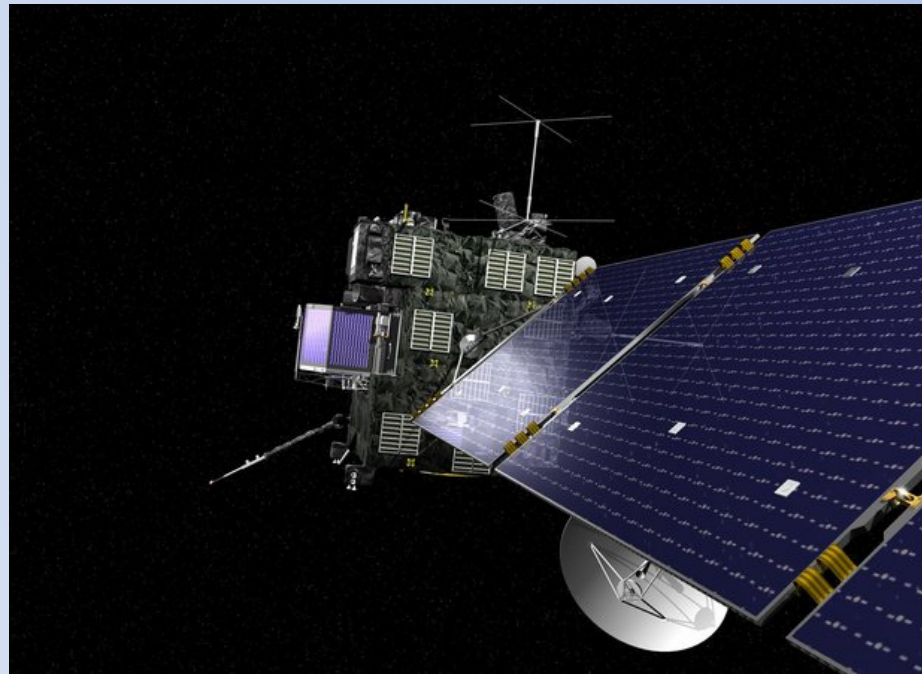


Temp (°C)	Working Fluid
-200 — -80	Liquid Nitrogen
-45 — 120	Methanol/Acetone
5 — 230	Water
500 — 900	Sodium/Potassium

Material	Conductivity (W/m ·K)
Heat Pipe	10,000+
OFHC Copper	390
6061 Aluminum	167
304 Stainless Steel	16.2

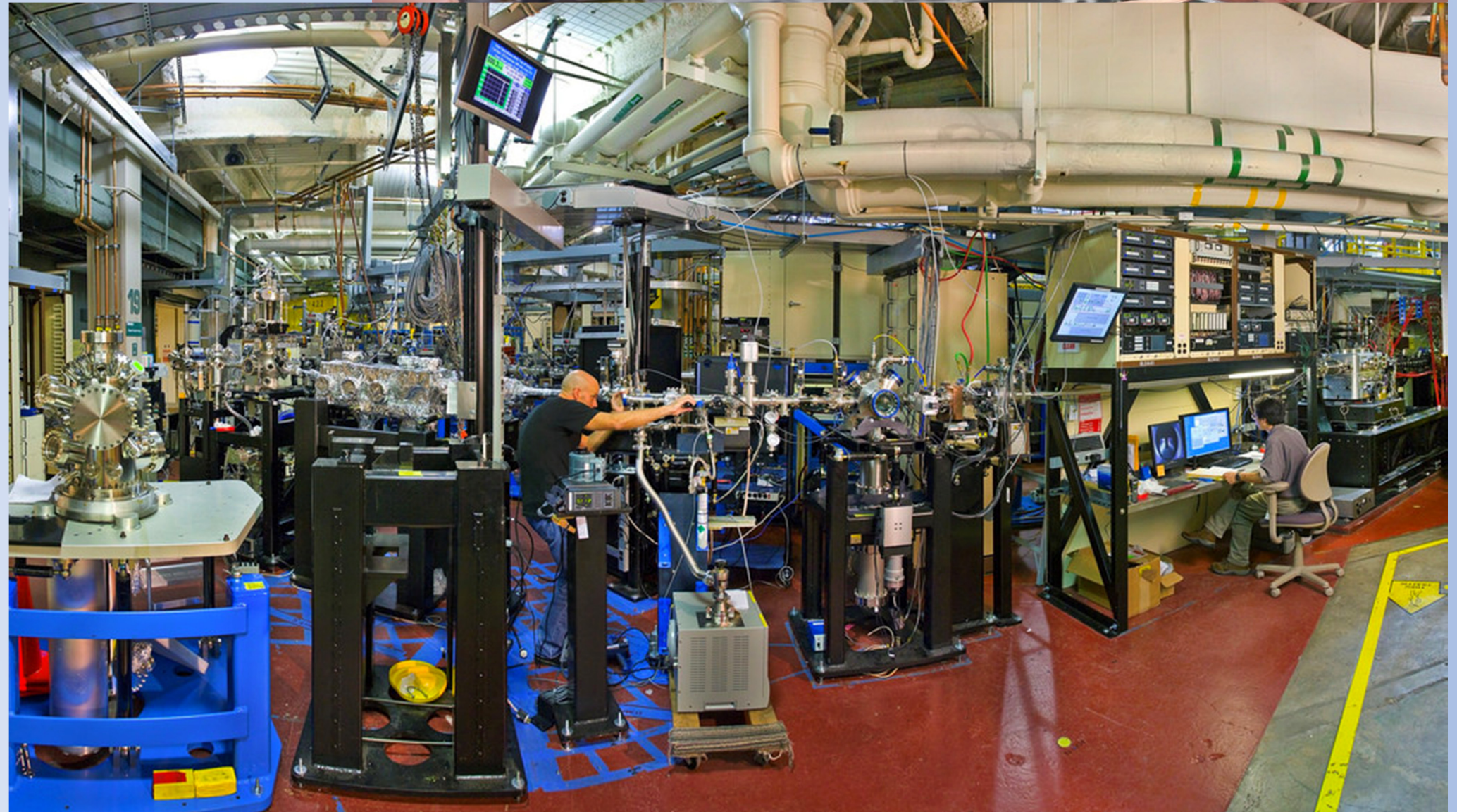
# Heat Pipes

- Thermal transfer device with a very high effective thermal conductivity in one direction.
- Commonly used in:
  - Computers
  - Cell Phones
  - Satellites



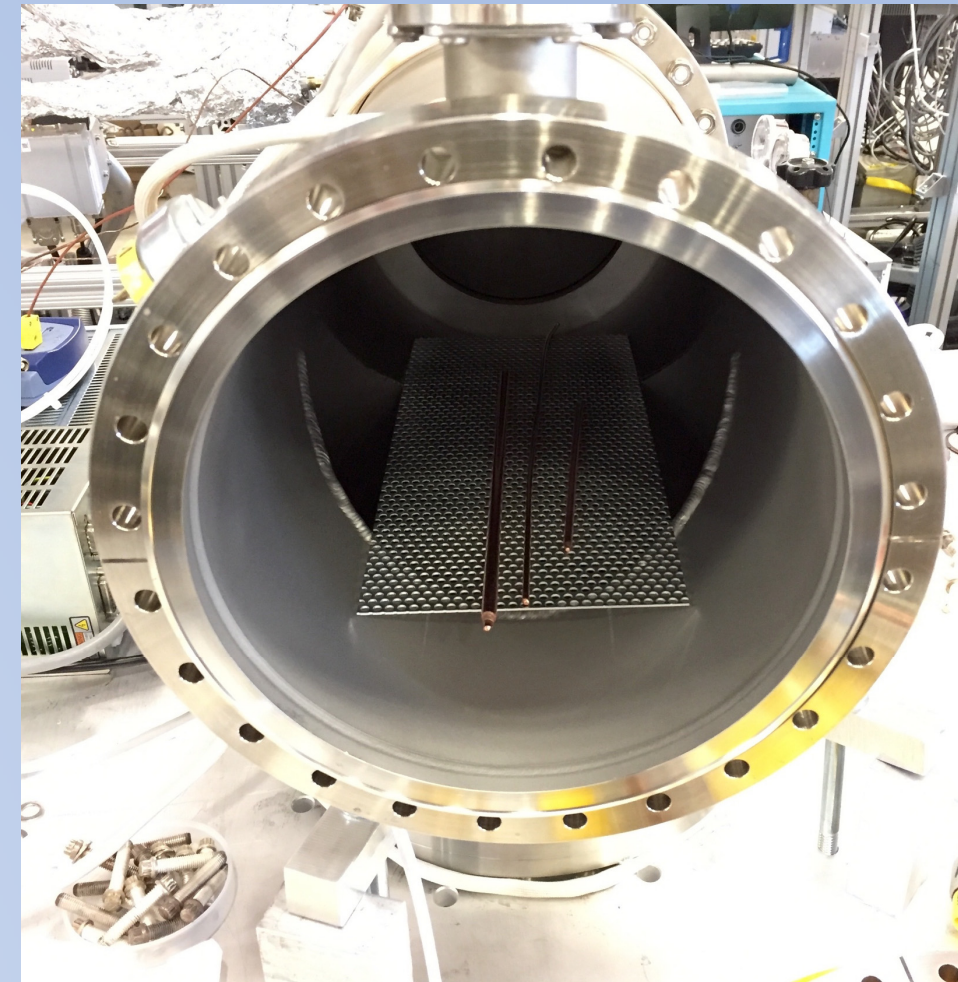
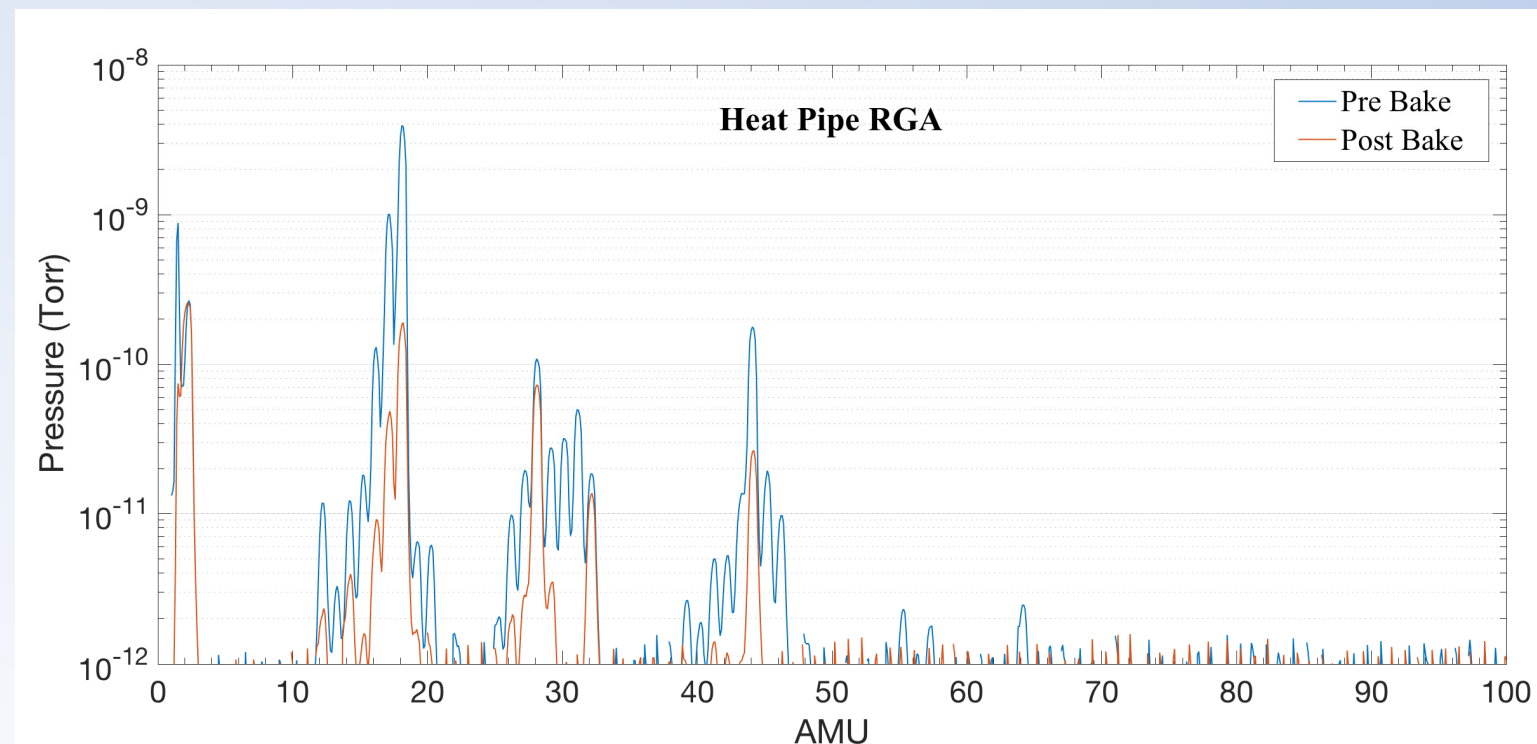
# Heat Pipes

- Thermal transfer device with a very high effective thermal conductivity in one direction.
- Commonly used in:
  - Computers
  - Cell Phones
  - Satellites
- Why Not Beamlines?



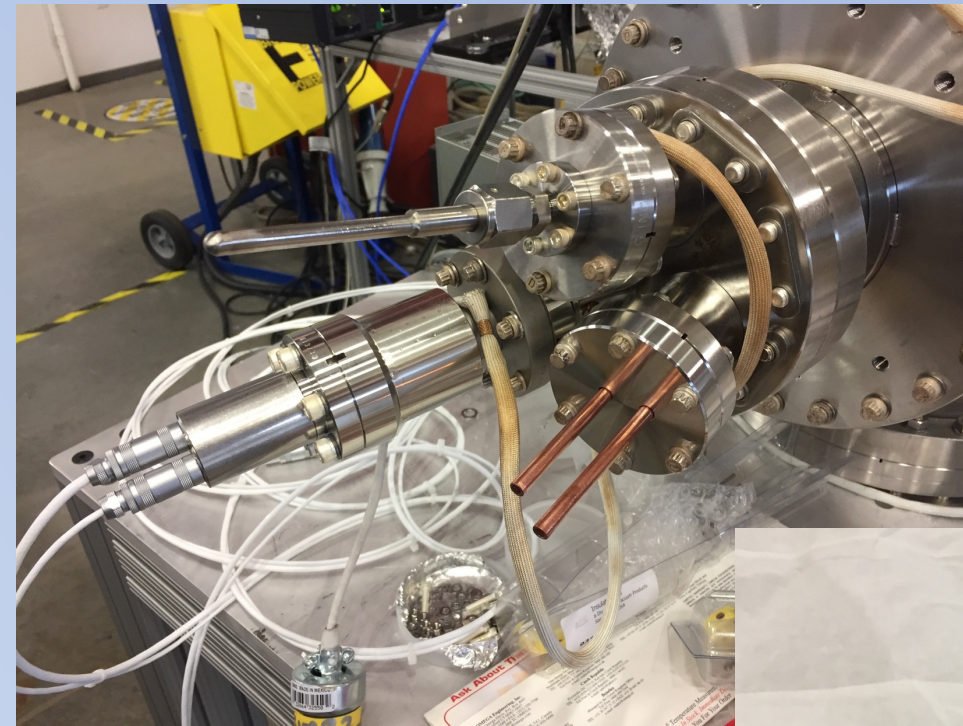
# Vacuum Compatibility

- Need to survive in UHV
- Baked at 180°C for 2-days
- Before/After RGA show clean



# Vacuum Compatibility

- Heat Pipe was sectioned and brazed onto CFF
- Baked at 180°C and leak checked
- Stopped monitoring after 5 cycles
- Left on chamber for ~2 months and 15 bake cycles



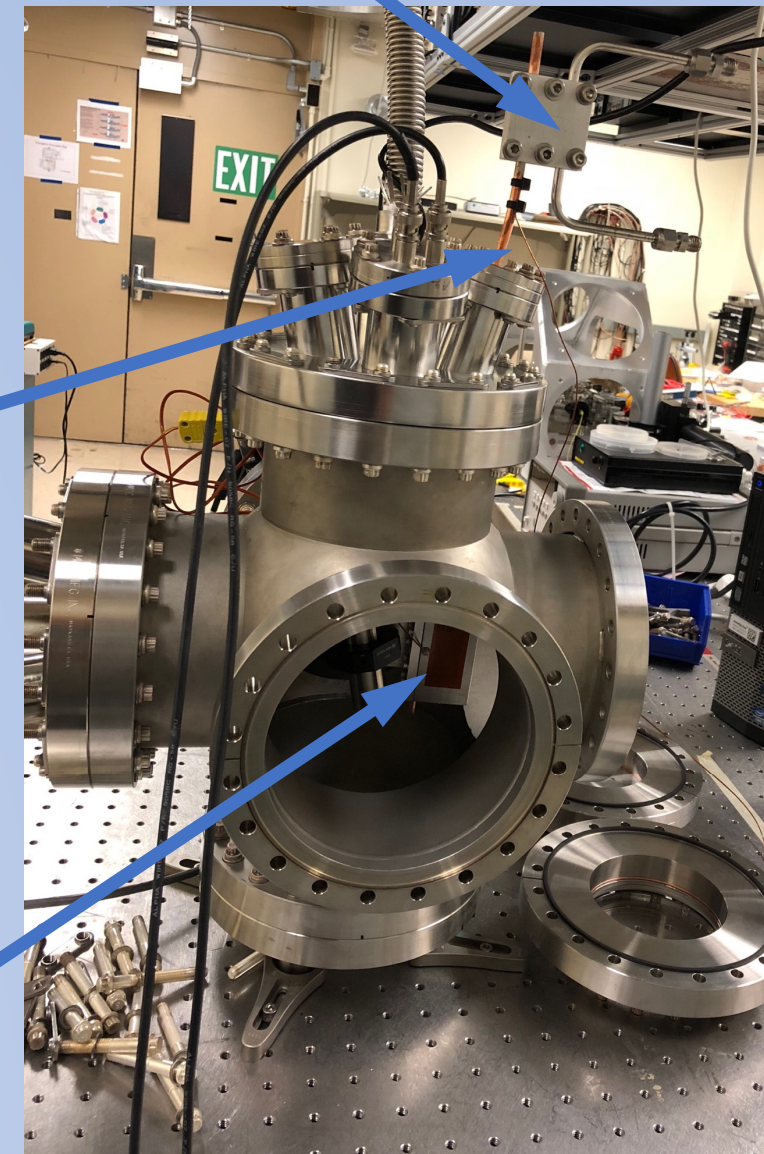
# Thermal Testing

- Does it work?
- Can we Simulate?
  
- Custom Heat Pipe on CFF
- Al Heater Block with 20W Kapton Heater
- UHV Test Chamber ( $10^{-6}$  Torr)

Cold Plate (To Chiller)

Heat Pipe

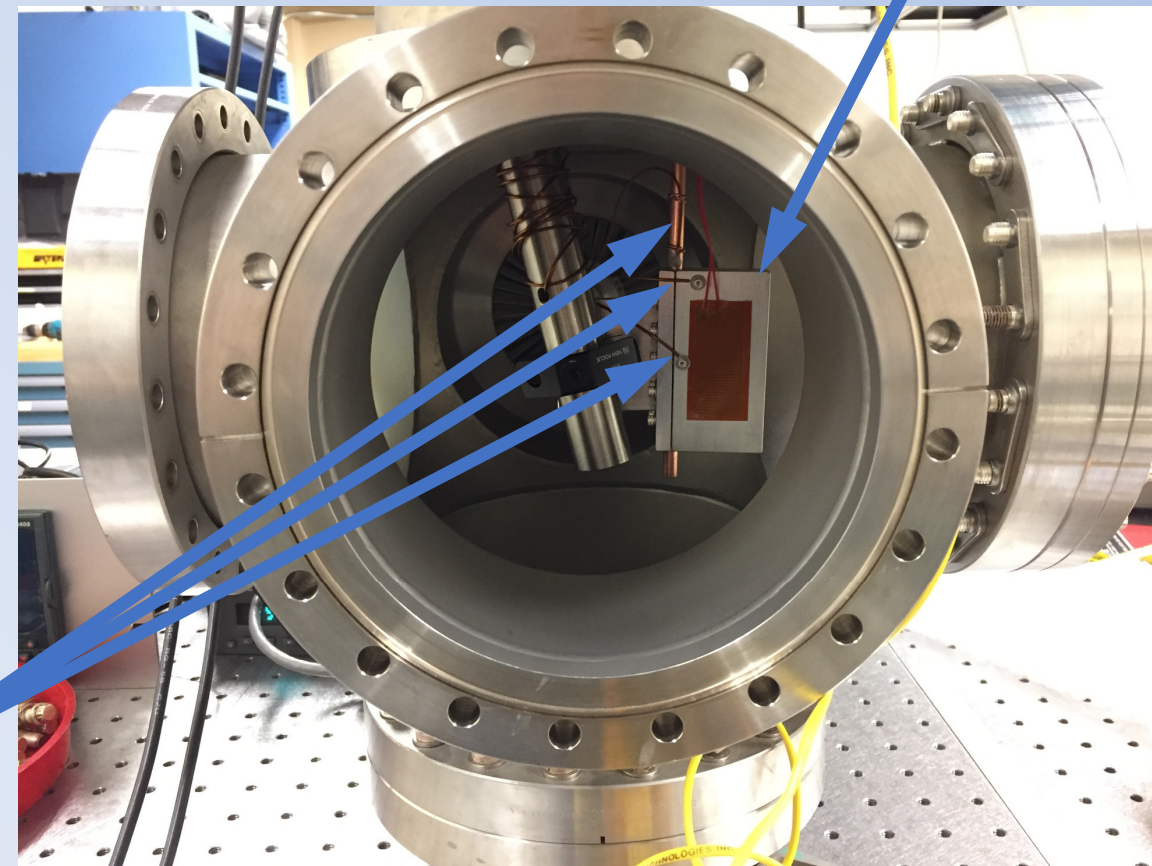
Al Heater Block



# Thermal Testing

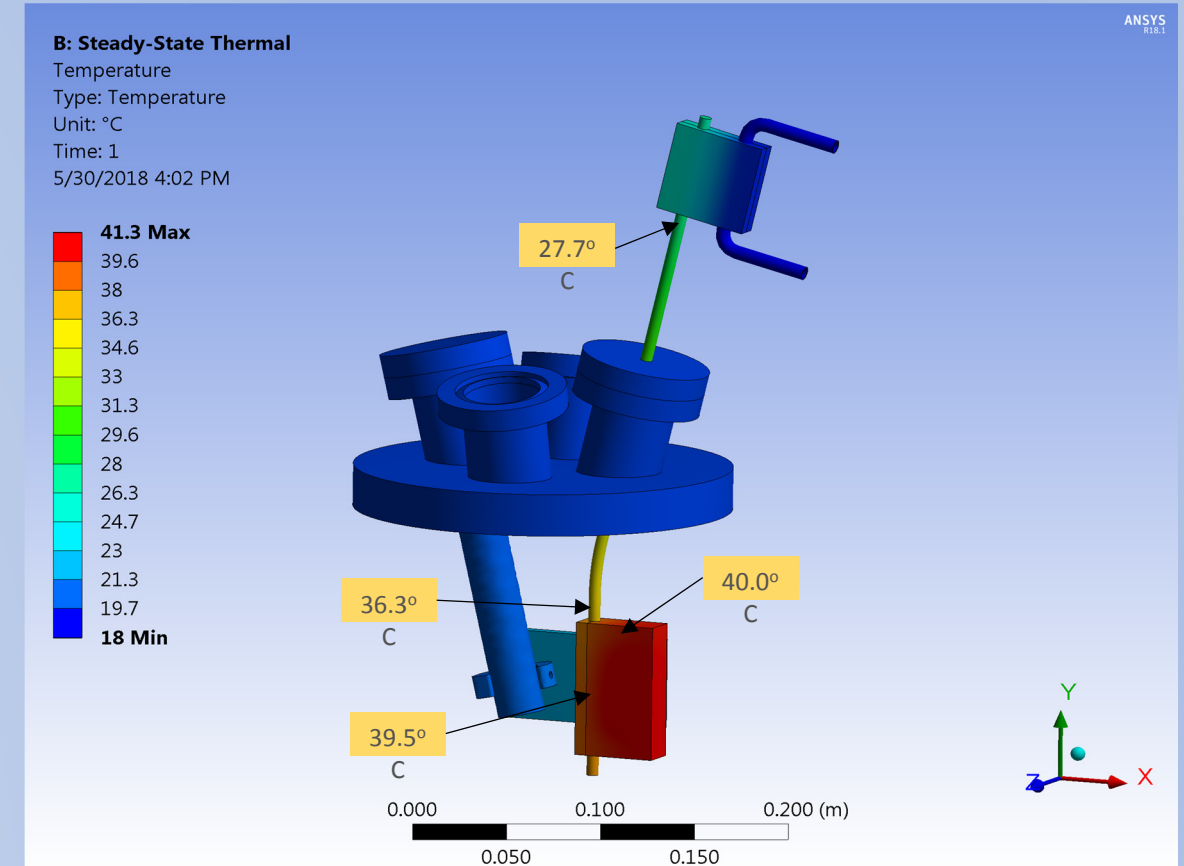
- ✓ Does it work?
- ✓ Can we Simulate?

Temperature	FEA	Measured
T1 – Al Block	39.5 °C	45.6°C
T2 – Al Block	40.0 °C	44.7°C
T3 – HP Base	36.3 °C	37.1°C
T4 – HP Top	27.7 °C	25.8°C



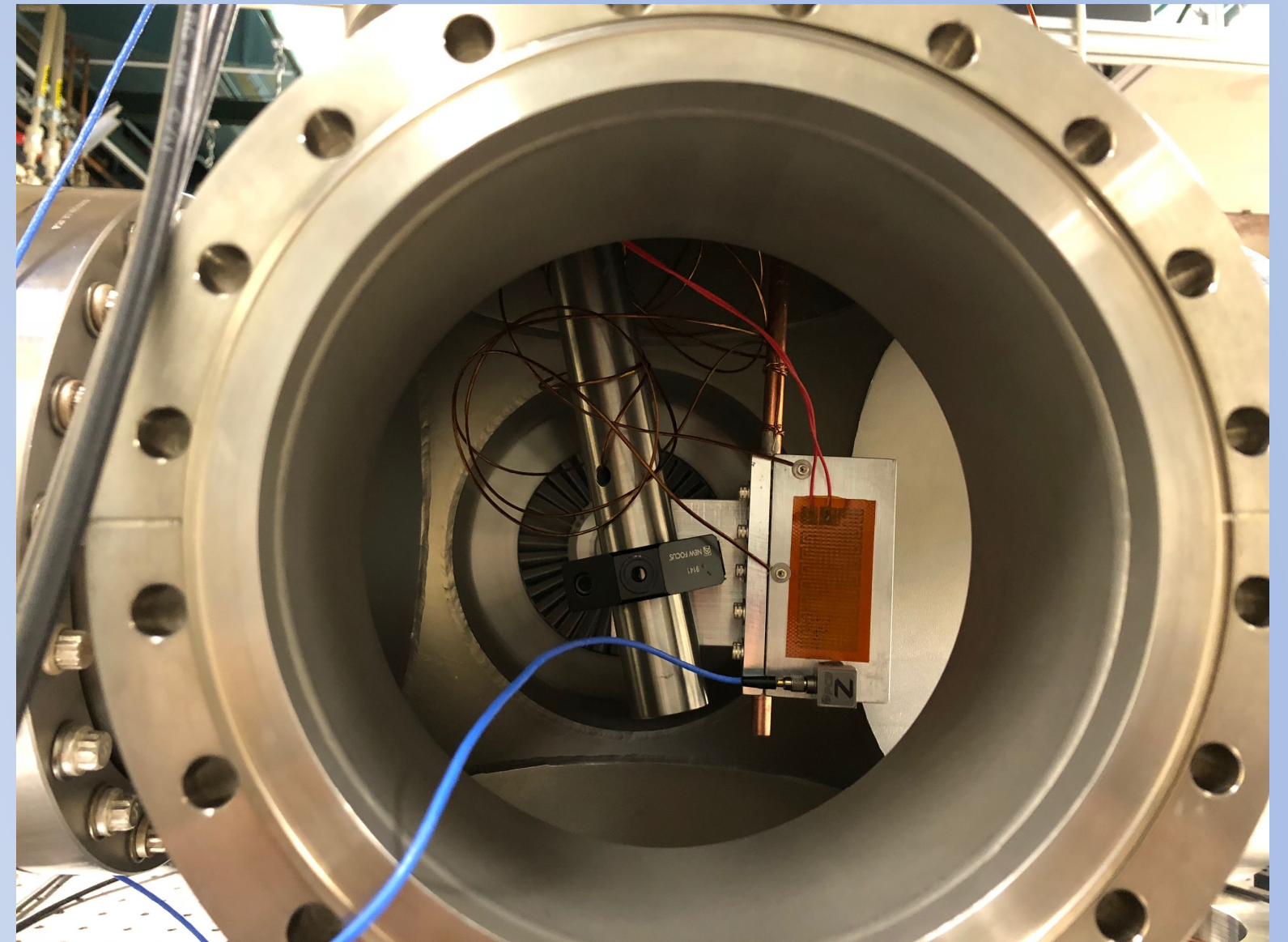
Heater Block

Thermocouples



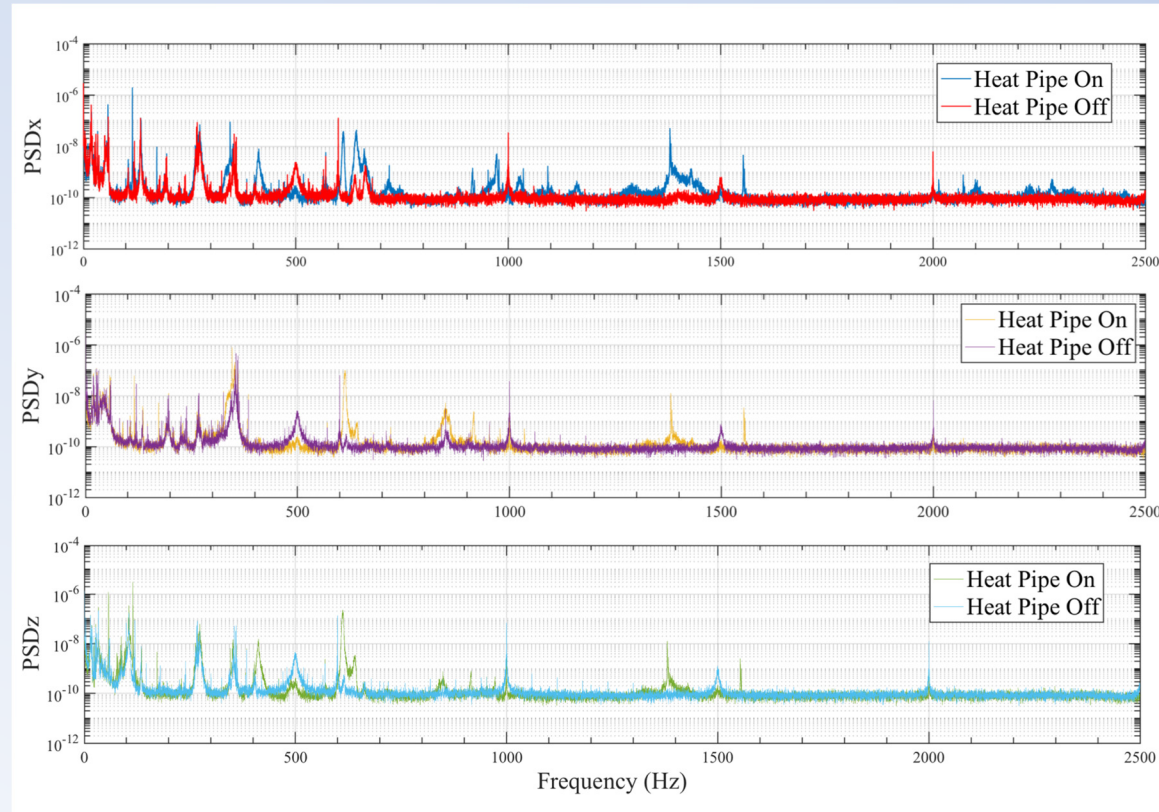
# Vibration Reduction

- Measure vibrations on Heater Block and Cold Plate
- Directly Couple Water to Heater Block

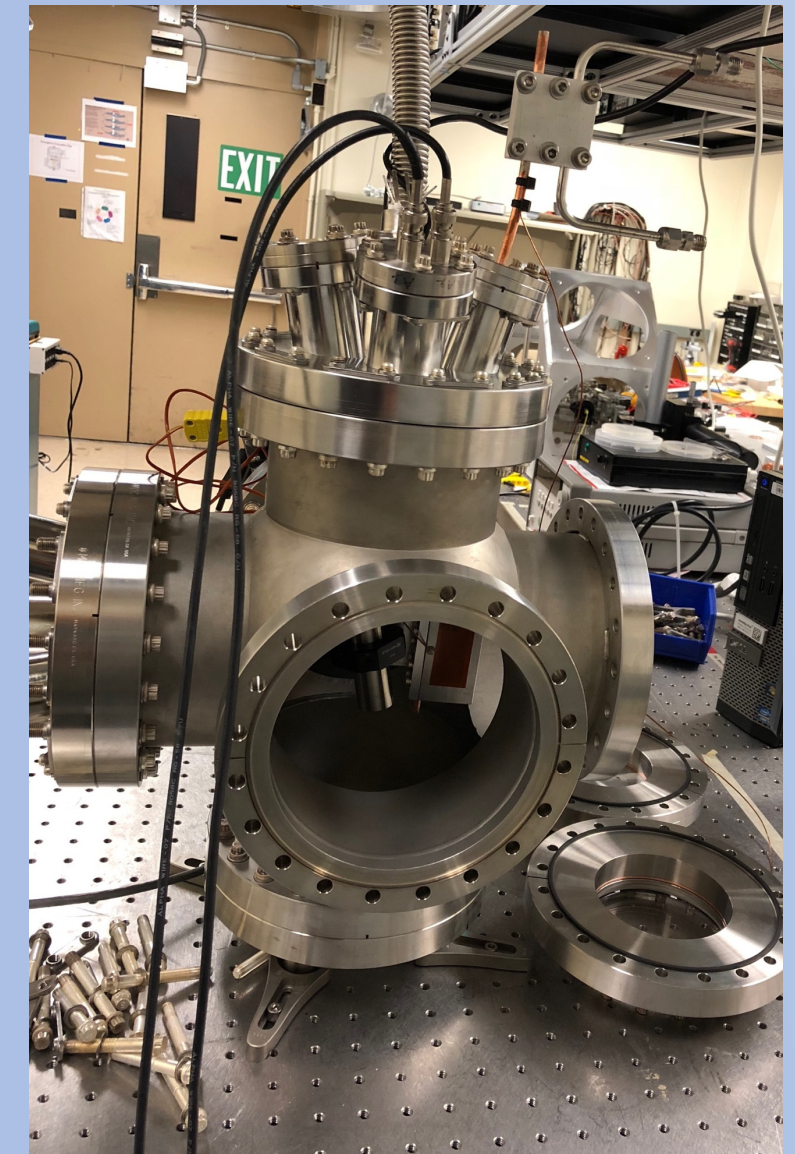
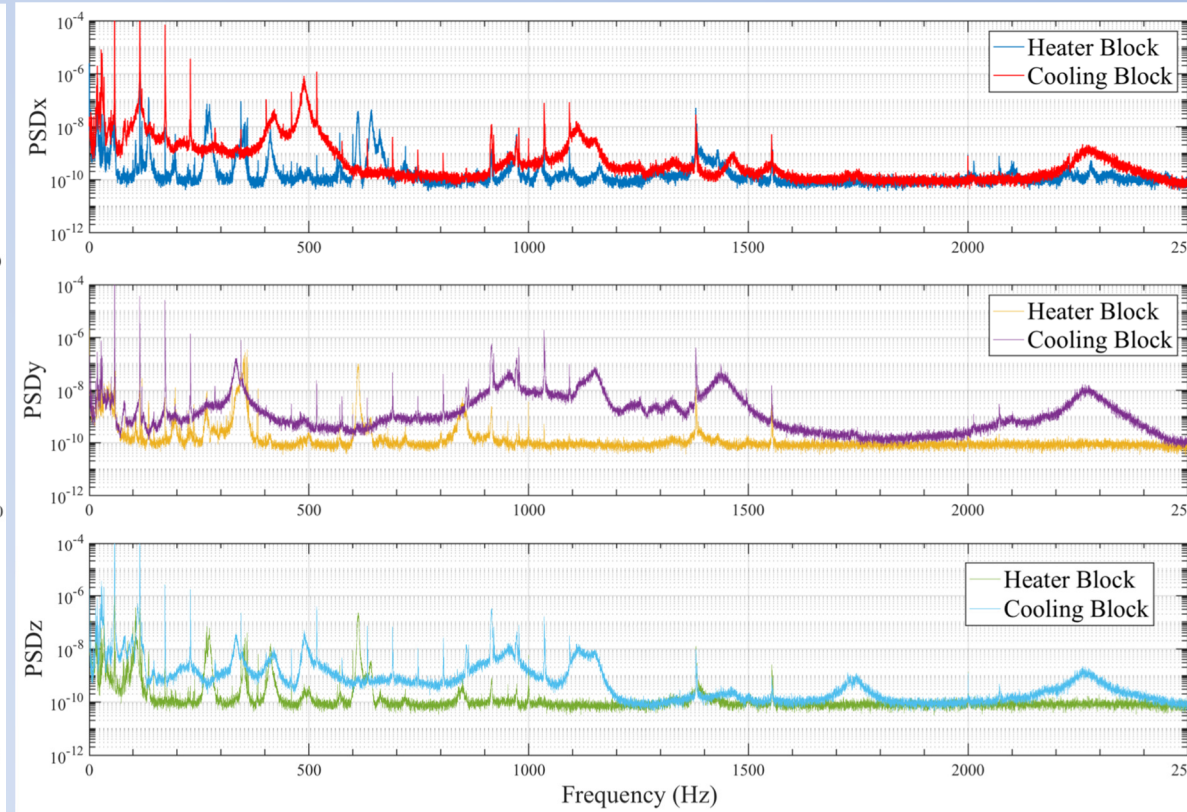


# Vibration Reduction

## Heat Pipe Water Flow On vs. Off

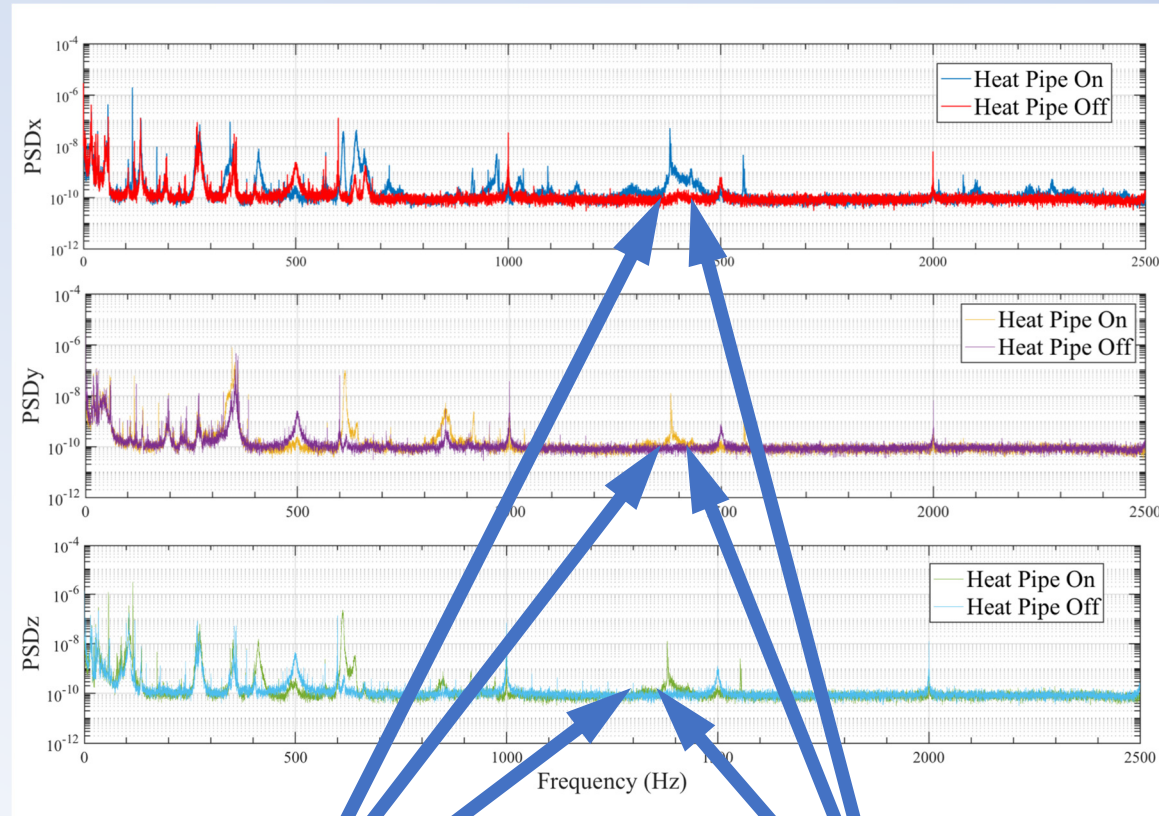


## Water Flow On Cold Plate vs. Heater Block

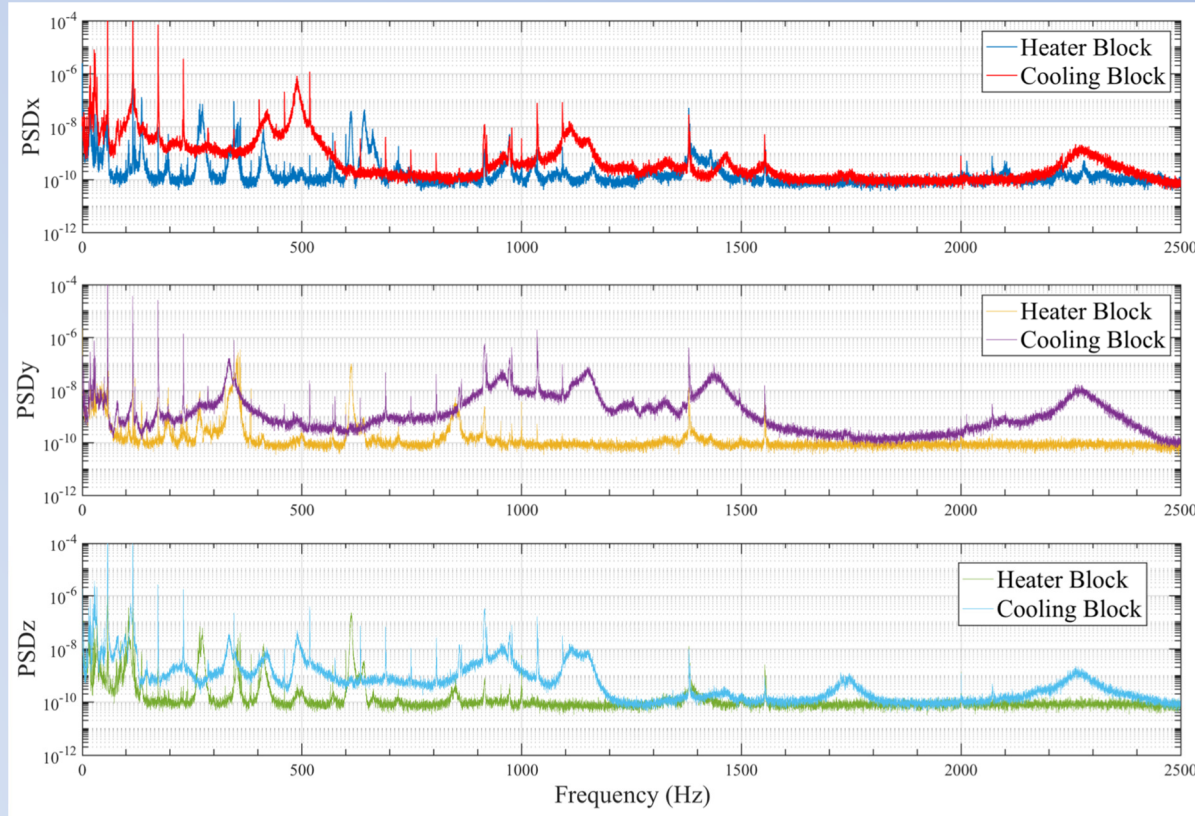


# Vibration Reduction

## Heat Pipe Water Flow On vs. Off

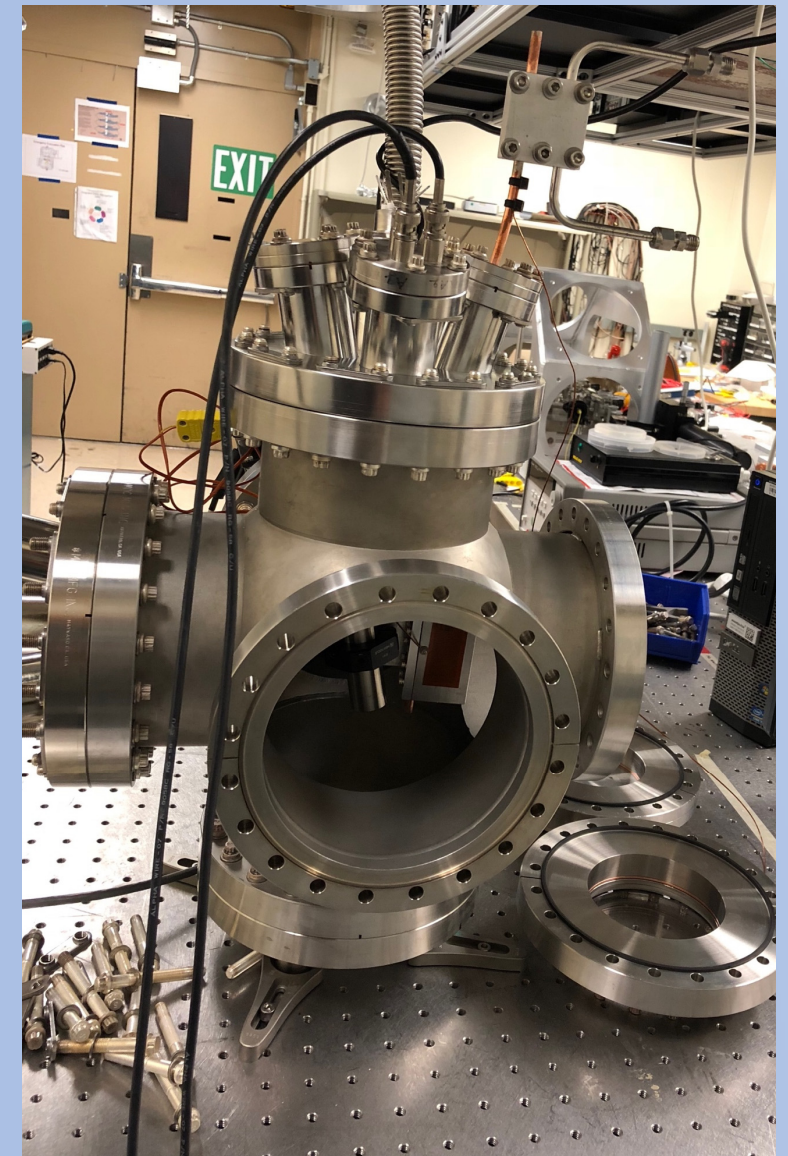


## Water Flow On Cold Plate vs. Heater Block



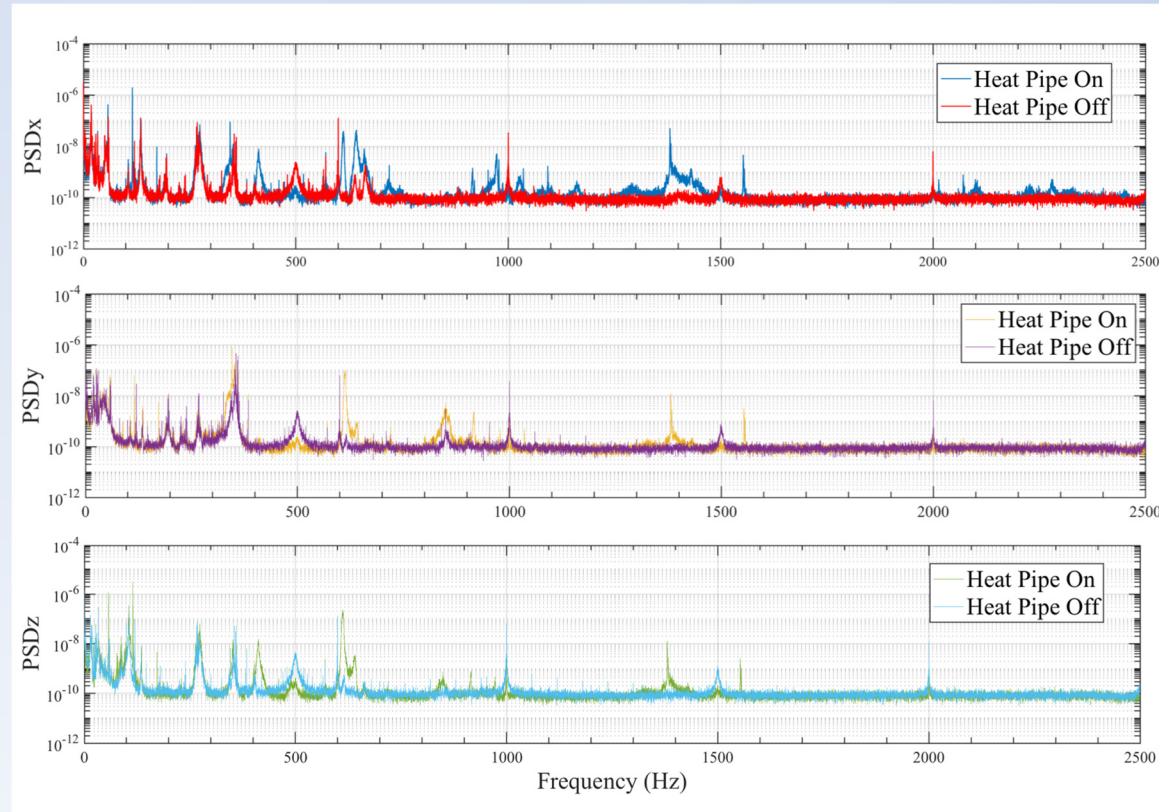
Flow On

Flow Off

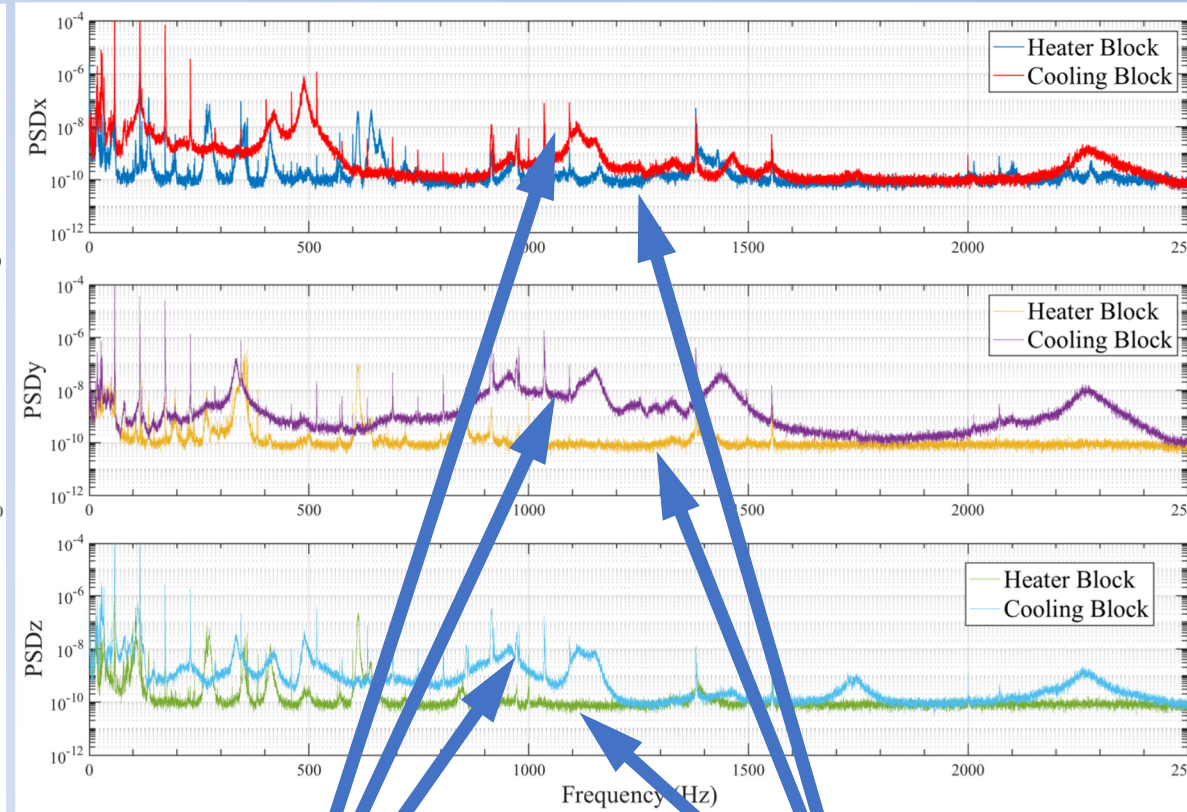


# Vibration Reduction

## Heat Pipe Water Flow On vs. Off

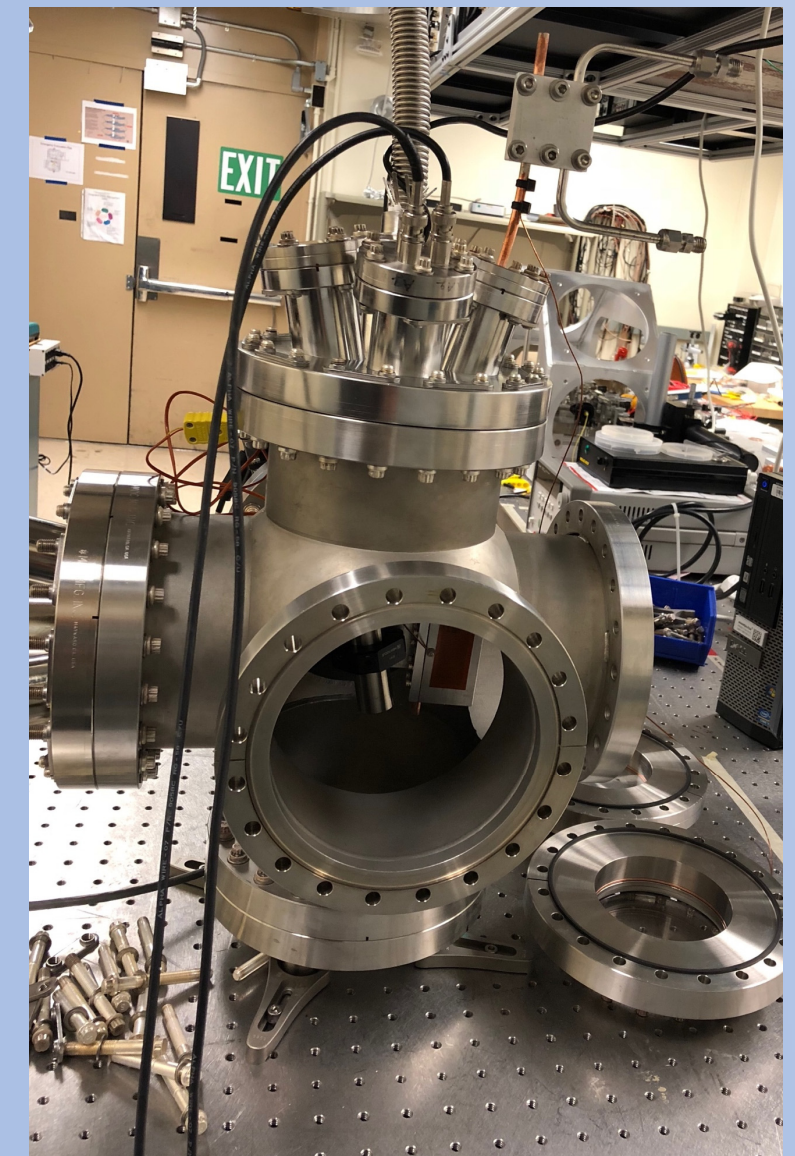


## Water Flow On Cold Plate vs. Heater Block



Cold Plate  
(Water Input)

Heater Block



# Vibration Reduction

- Heat Pipe dampens/isolates vibrations from cooling water
- Greatly reduced compared to direct coupling

## Direct Coupling vs. Heat Pipe

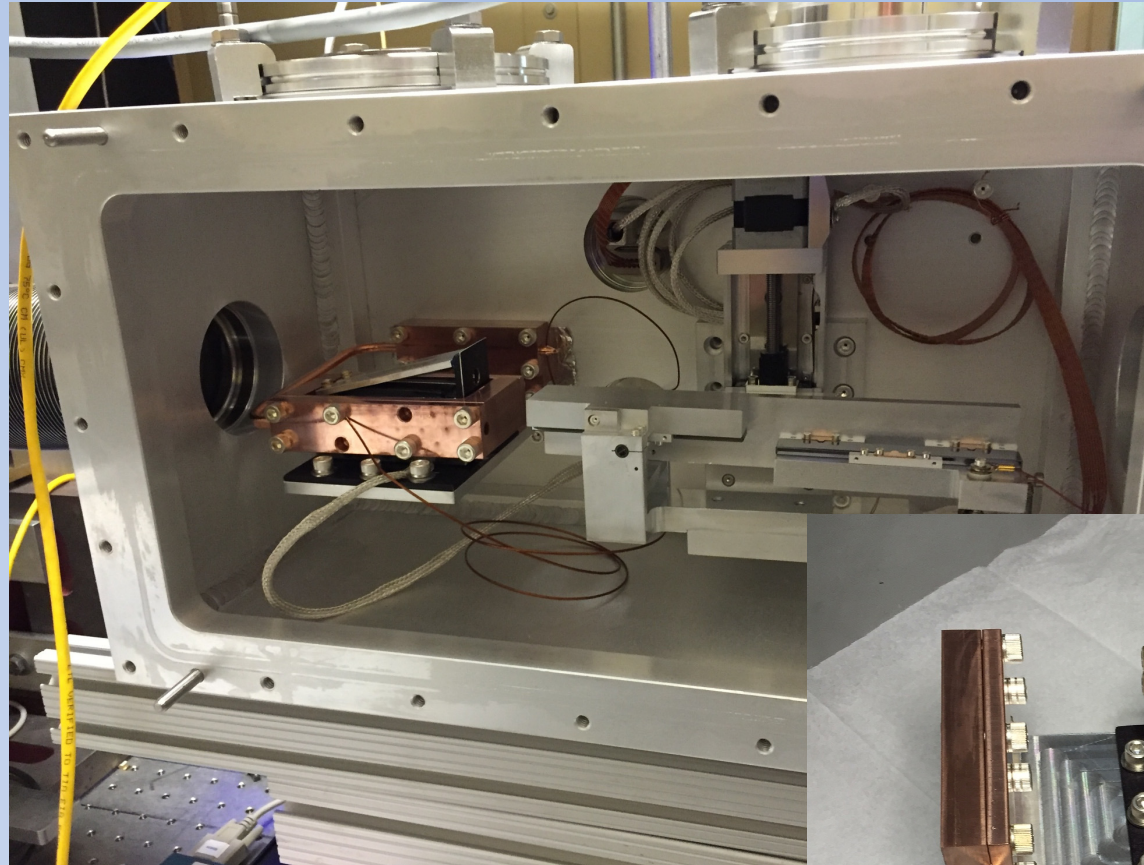
Directly Coupled



Heat Pipe

# Practical Usage

- ALS Beamline 5.3.1
  - Tender X-Ray Beamline
- Electromagnetic laser shutter for endstation (<10ms)
  - Electromagnetic shutter
  - Overheats w/out cooling
- Use Heat Pipe instead of water line



- Merci de votre attention!
- Thank You for your attention!



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