

# **A Cryogenic Detector Stage for Dithering Applications**

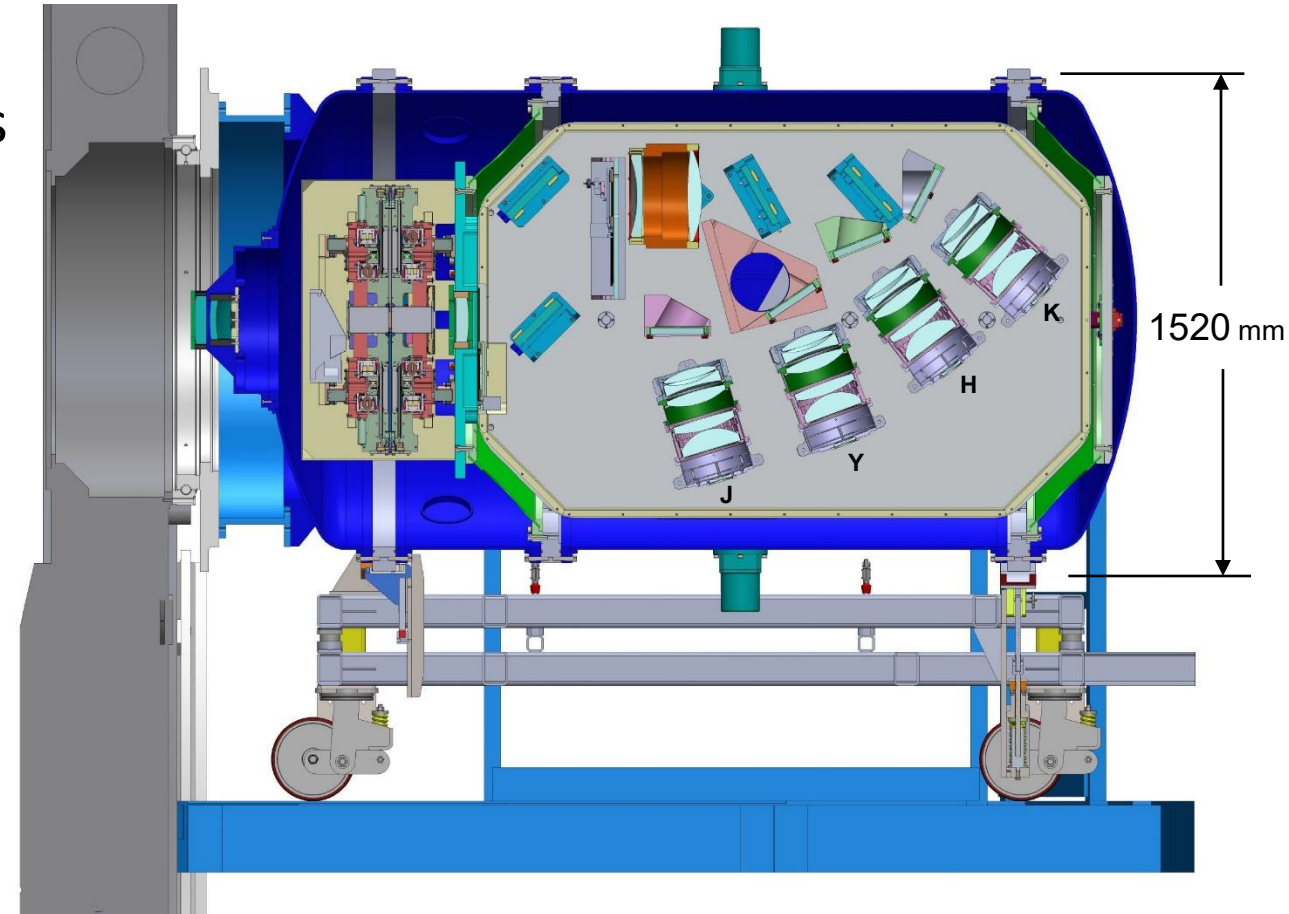
## **InfraRed Detectors in Space**

**March 11, 2026**

- Develop a precision cryogenic X-Y detector stage for a ground-based instrument to address:
  - Flexure-induced image motion
  - Under-sampled point spread functions (PSFs)

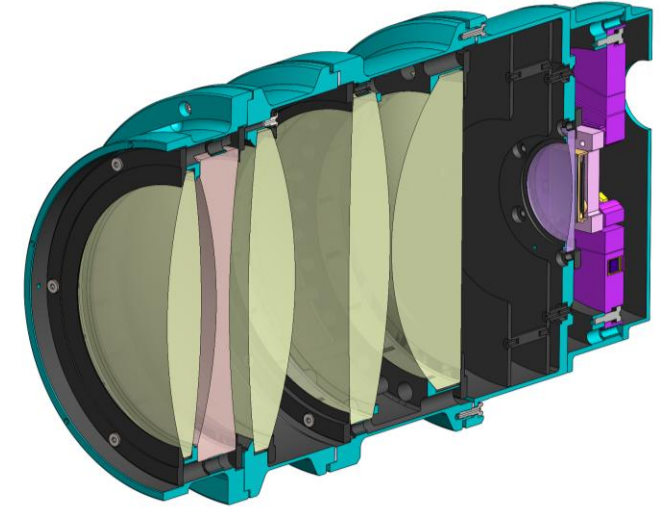
# Magellan Infrared Multi-Object Spectrograph (MIRMOS)

- MIRMOS is a large vacuum-cryogenic instrument with five science cameras
- MIRMOS is mounted at the Nasmyth focus
  - Rotator produces a gravity variant environment
- Flexure induced image motion is detrimental to spectral resolution
- Plate scale ( $0.4''/\text{pixel}$ ) undersamples Magellan's best seeing ( $0.35''$ )
- A precision X-Y detector stage solves both the flexure and sampling problems



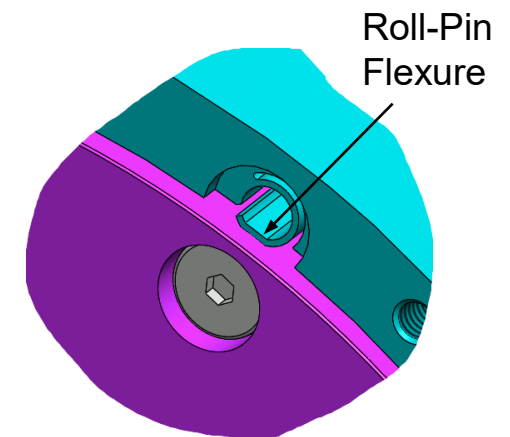
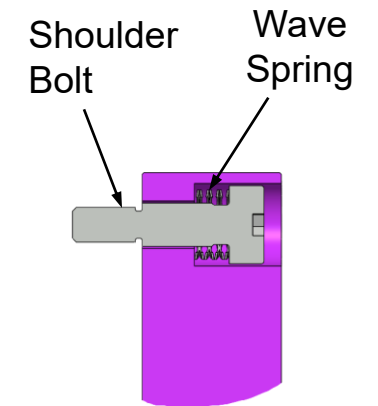
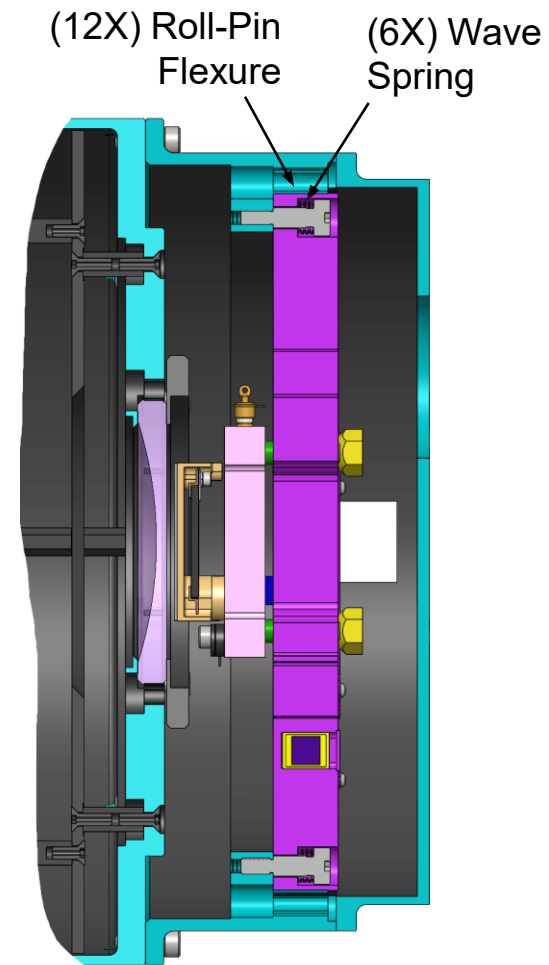
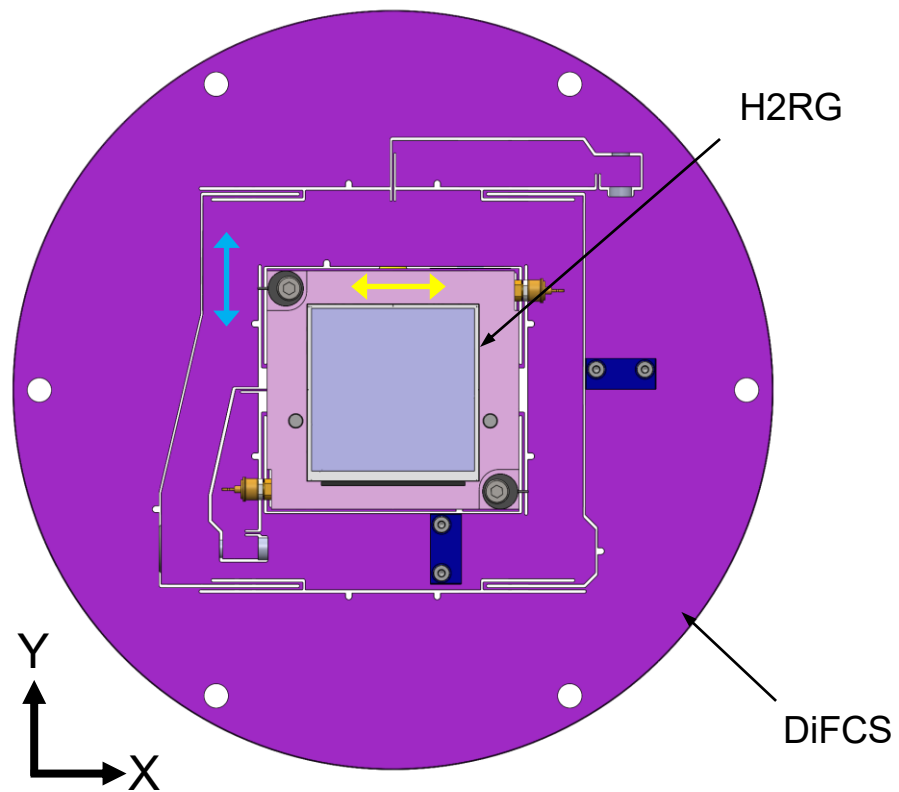
# Stage Requirements

- Core requirements
  - Vacuum Operation:  $10^{-6}$  Torr
  - Cryogenic Operation: 120 K
  - Mechanically supports either a H2RG or CCD
  - Provides features for detector tip, tilt, and focus adjustment
  - Provides features for detector thermal control, i.e. heater and thermostat
  - Stroke:  $\sim 200$   $\mu\text{m}$
  - Resolution: sub-micron
  - Repeatability:  $\sim$  micron
  - Must be compact to minimize the size of the instrument

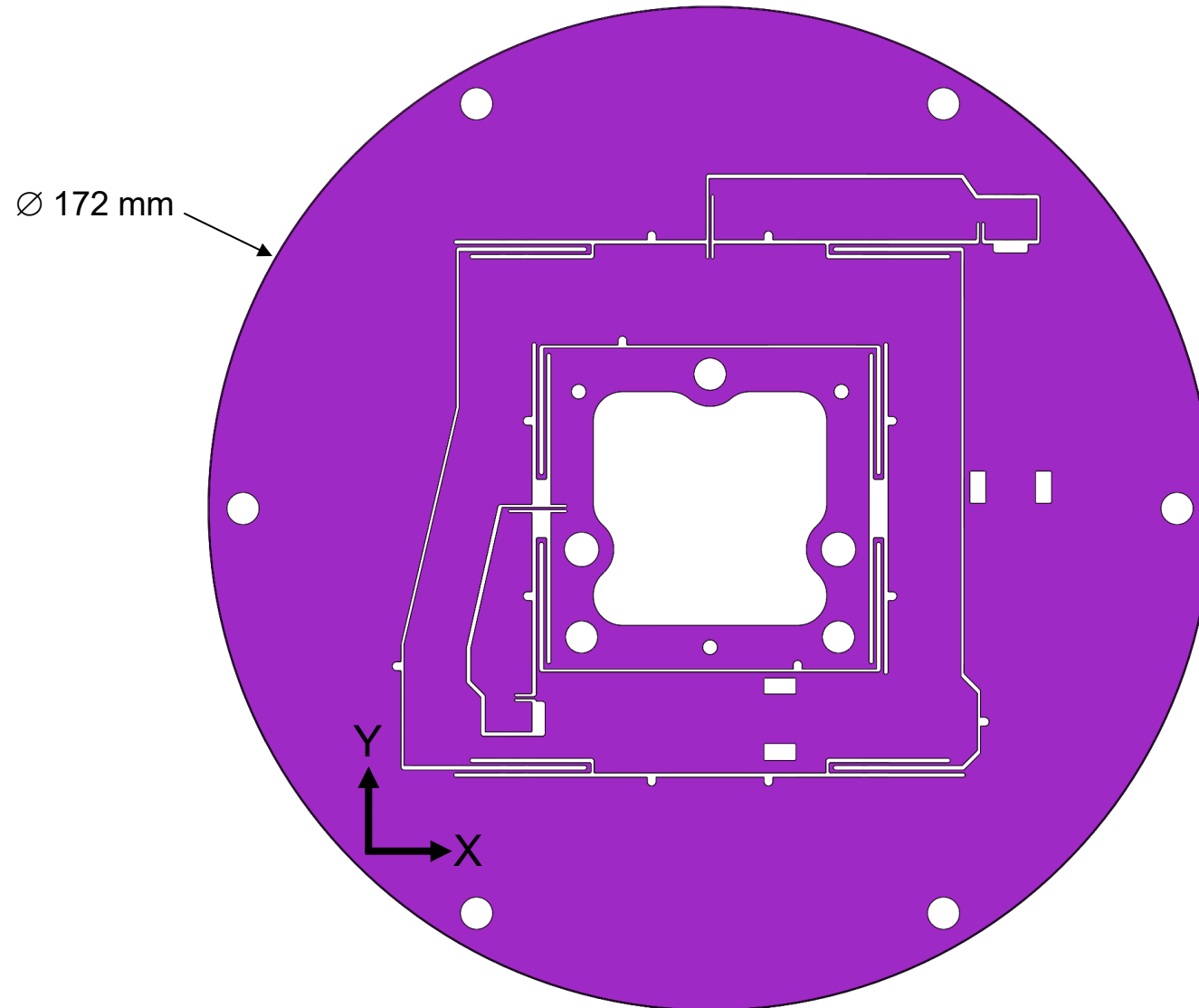


# DiFCS Camera Integration

## DiFCS Front View

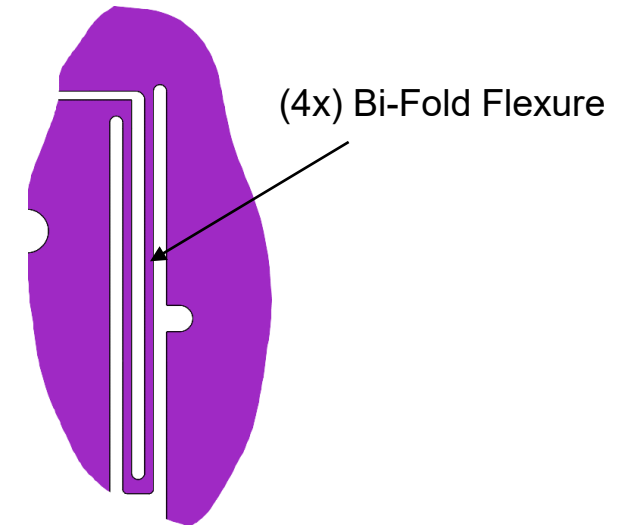
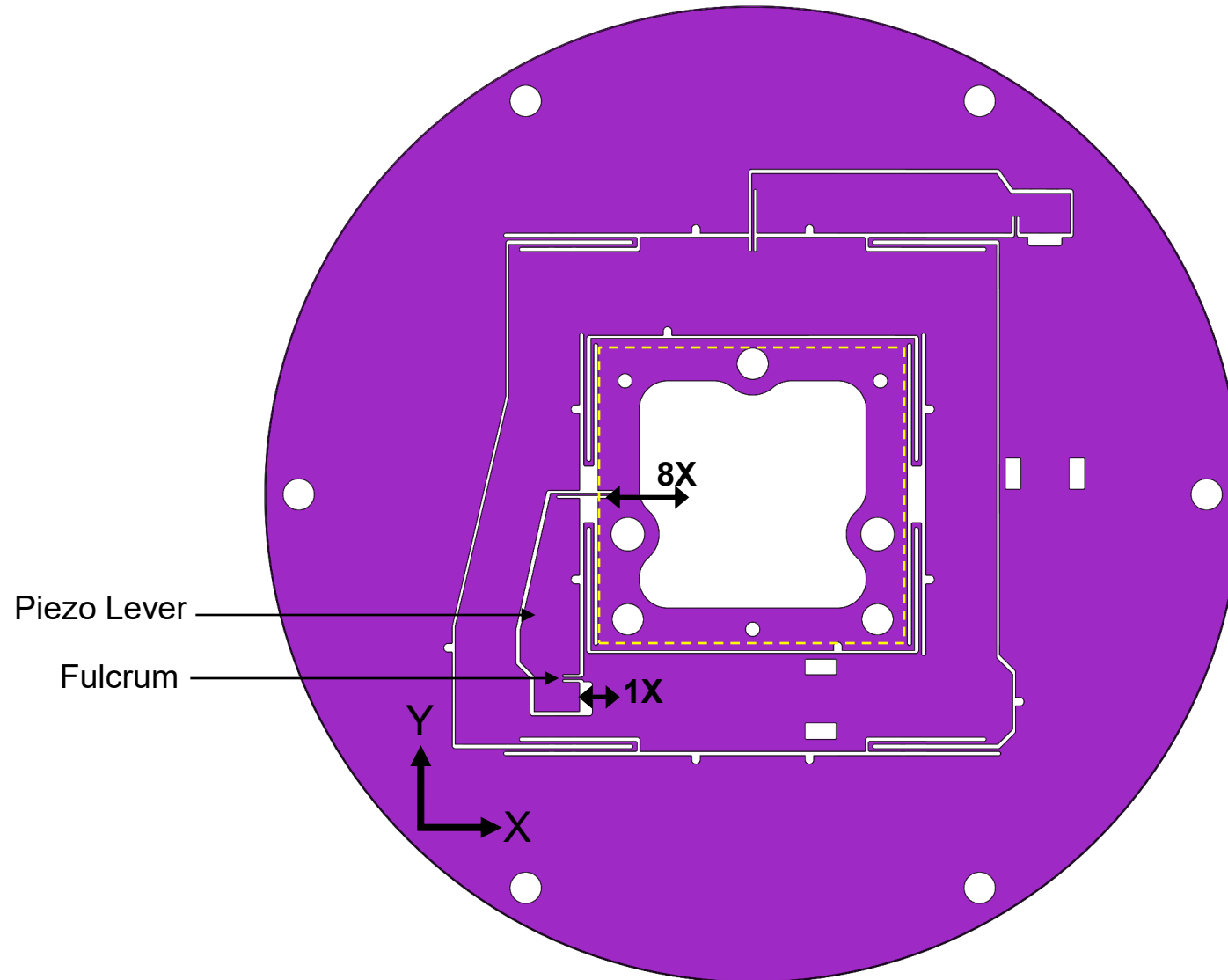


# Nested Flexure Stage Design

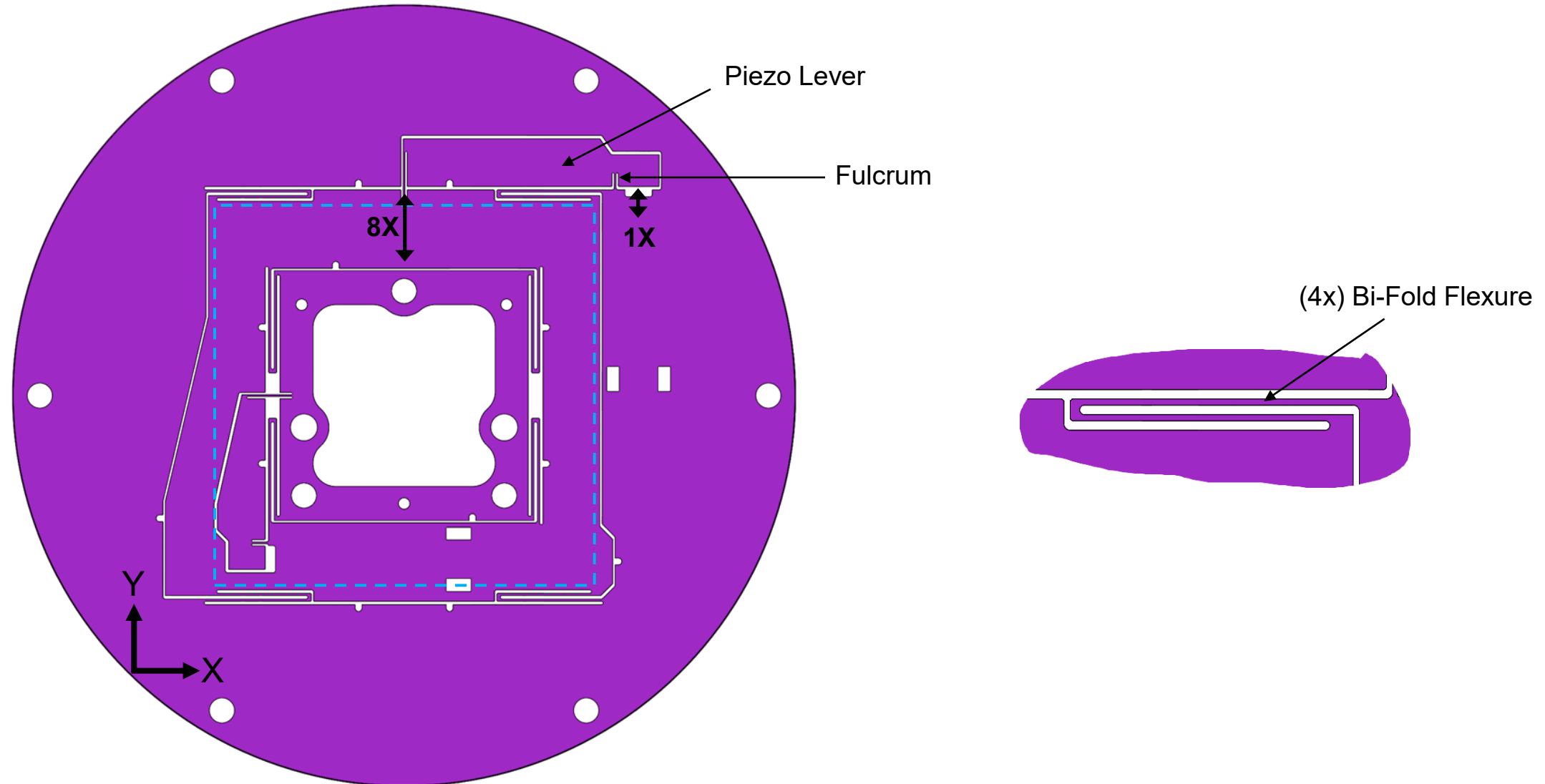


- Stage Base
  - 172 mm diameter
  - 16 mm thick
  - Titanium 6Al4V
  - Integral flexures provide backlash free motion

# X-Axis Motion

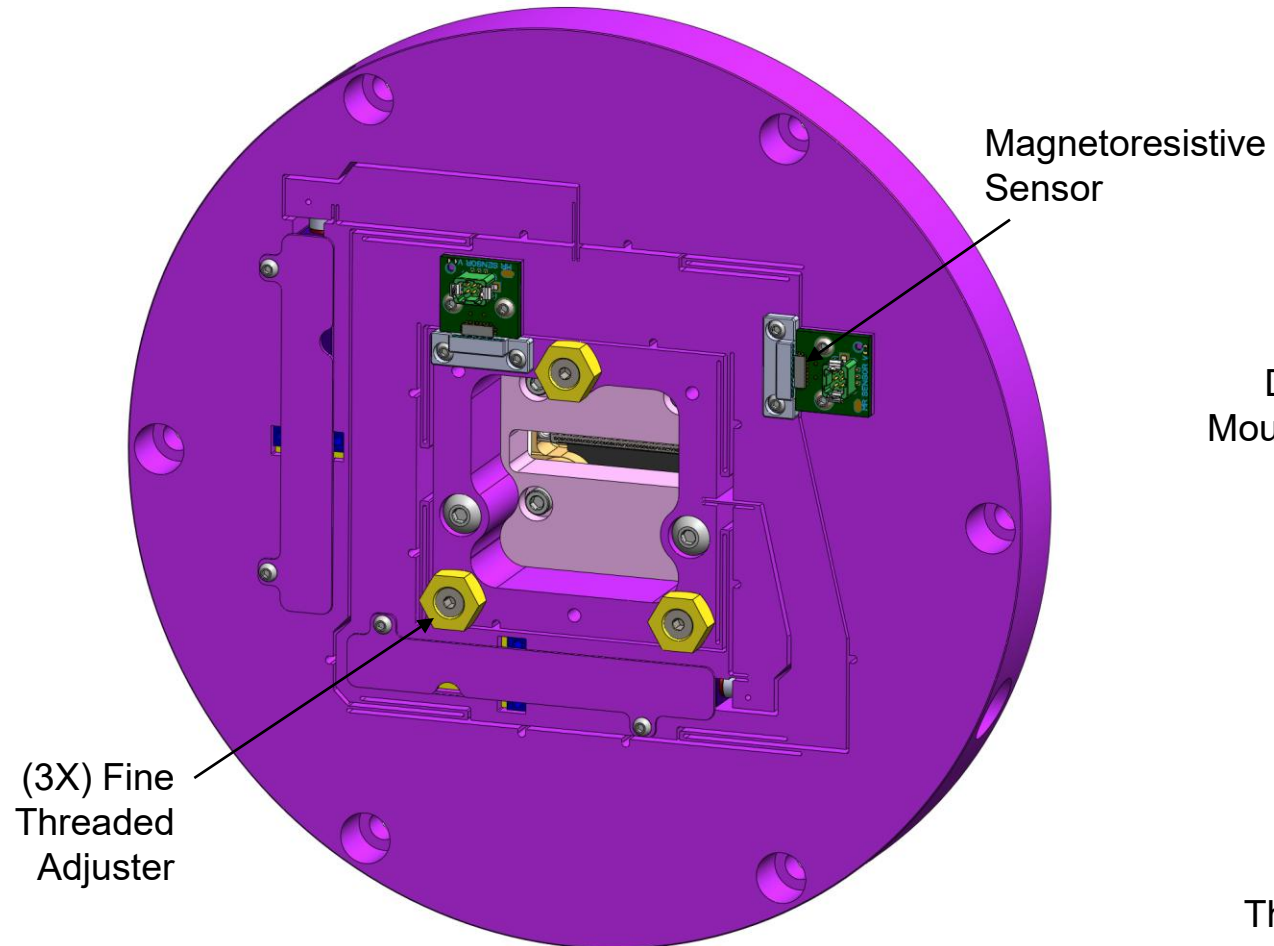


# Y-Axis Motion

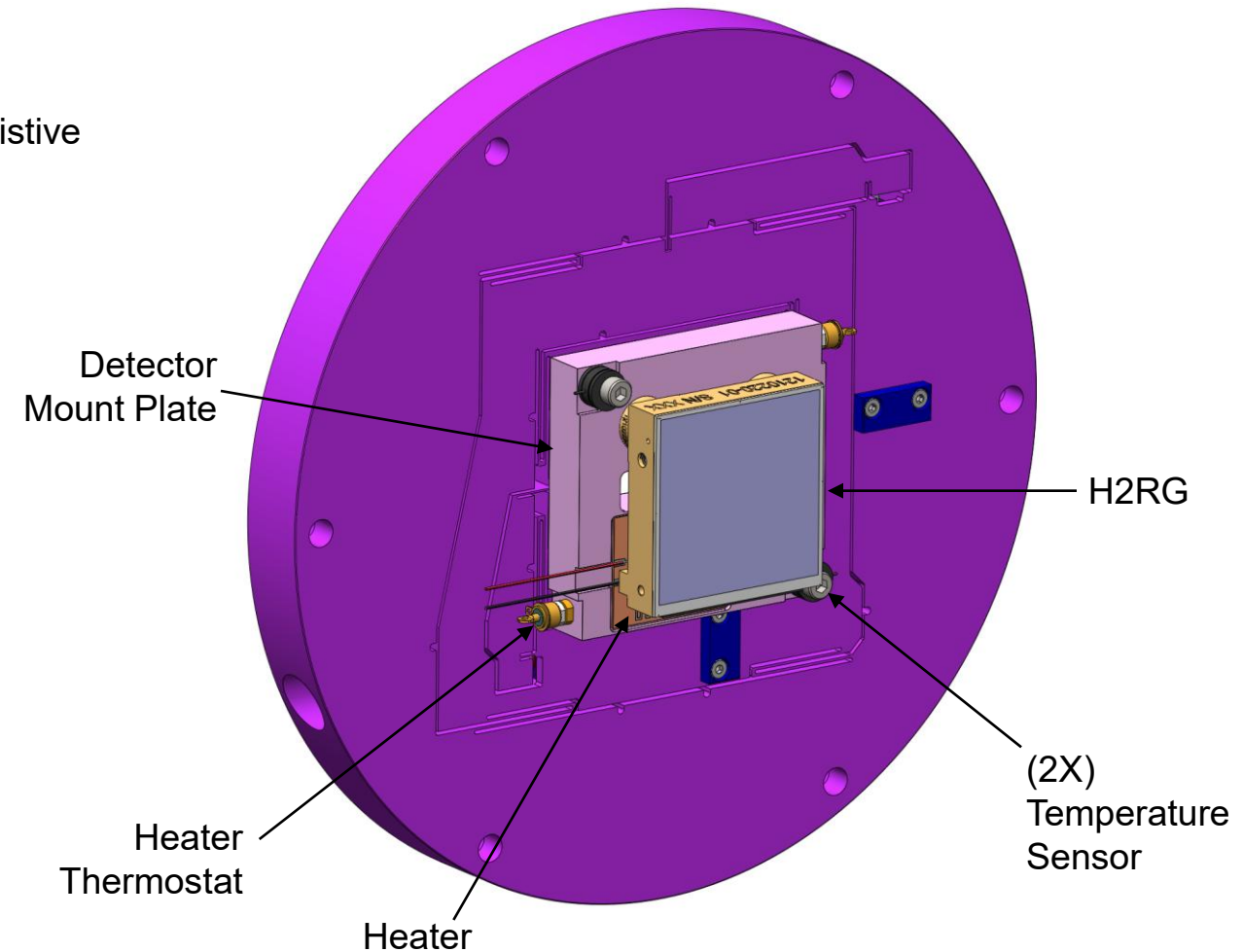




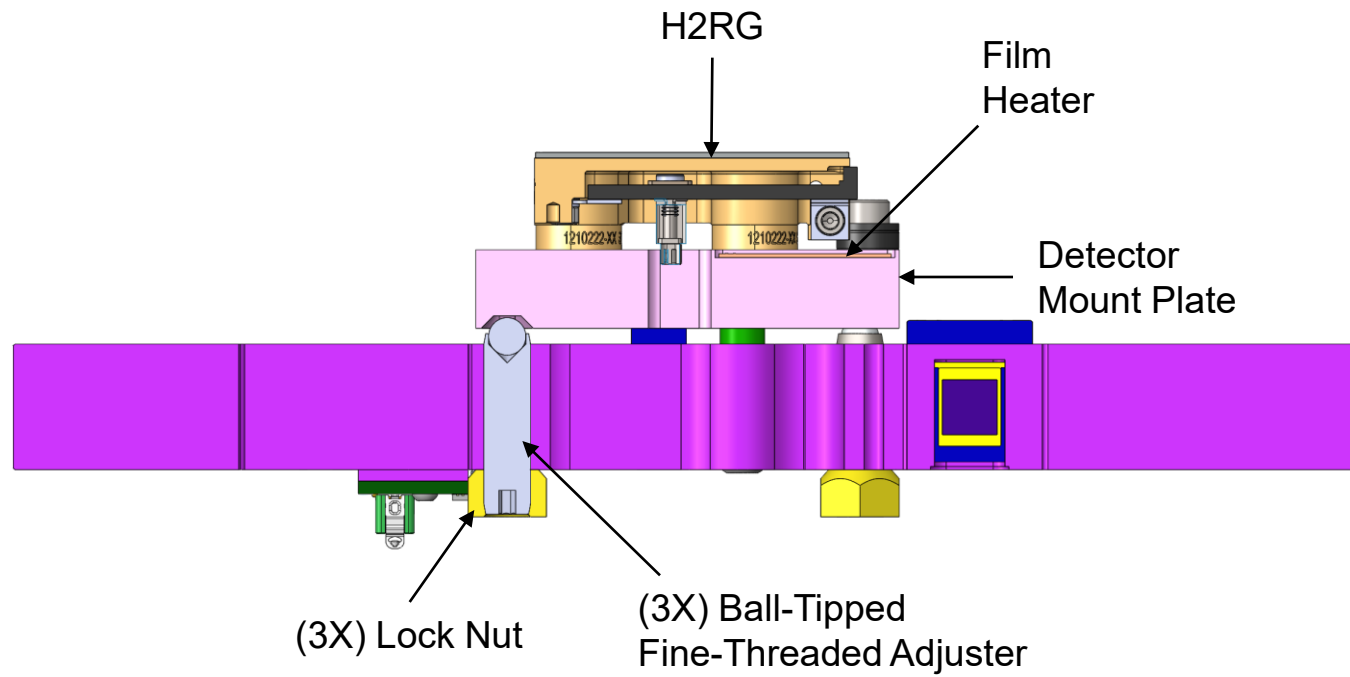
## Rear Side



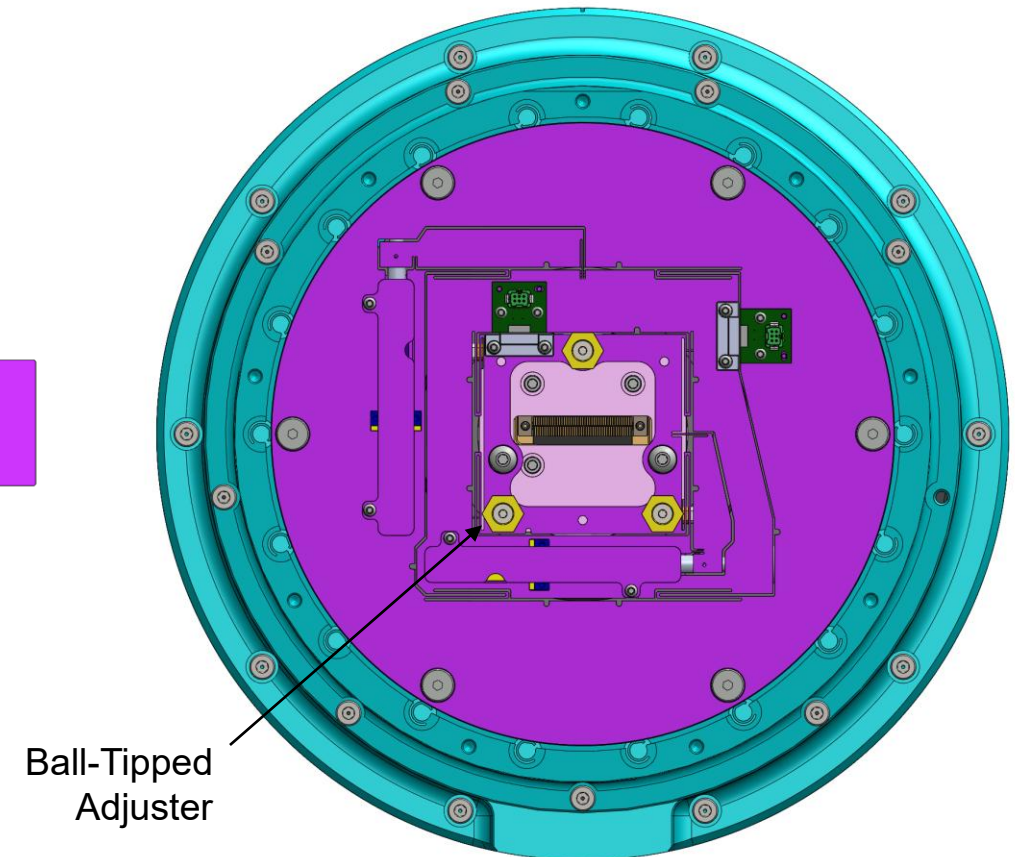
## Front Side



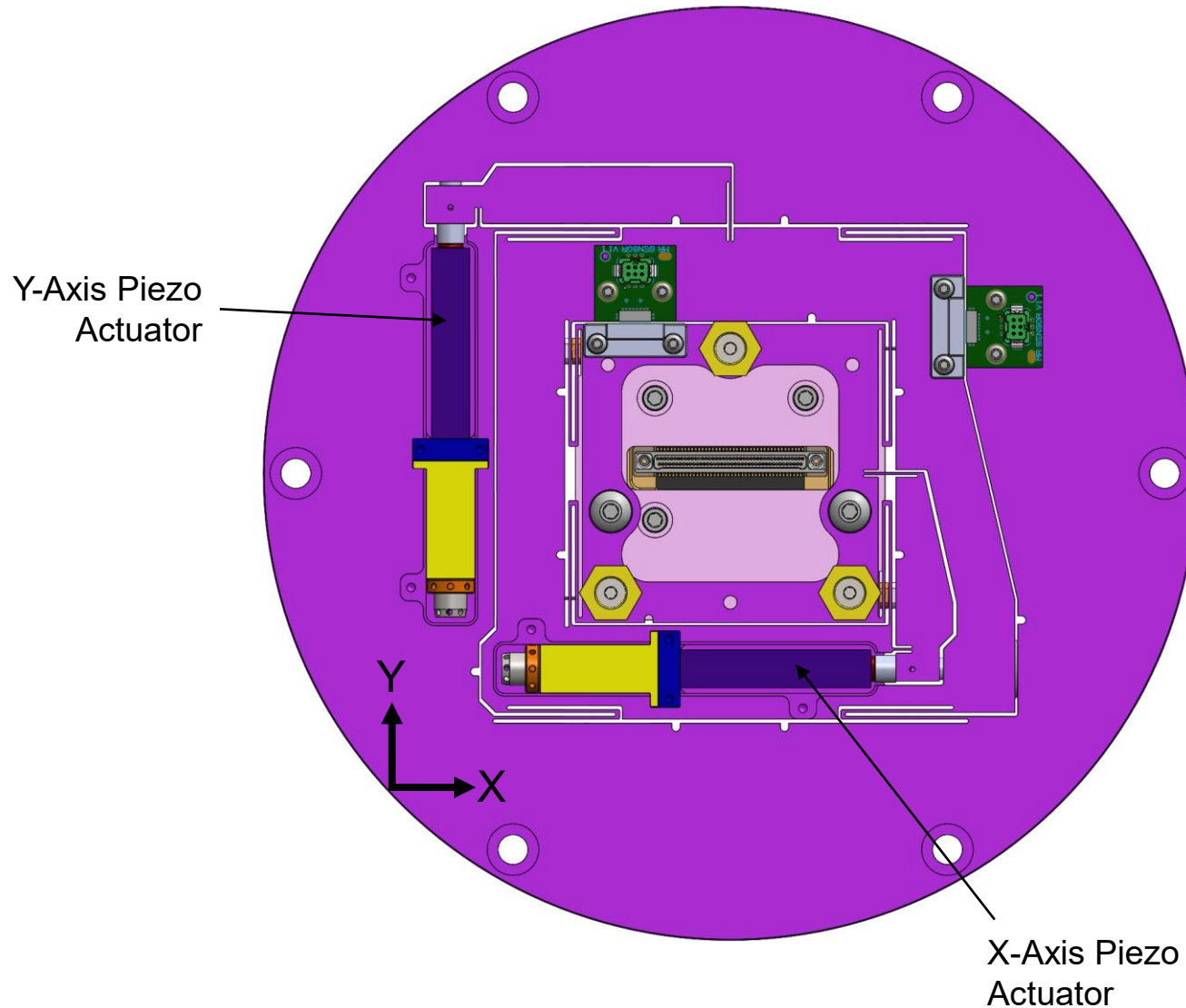
# Tip/Tilt/Piston Adjustment



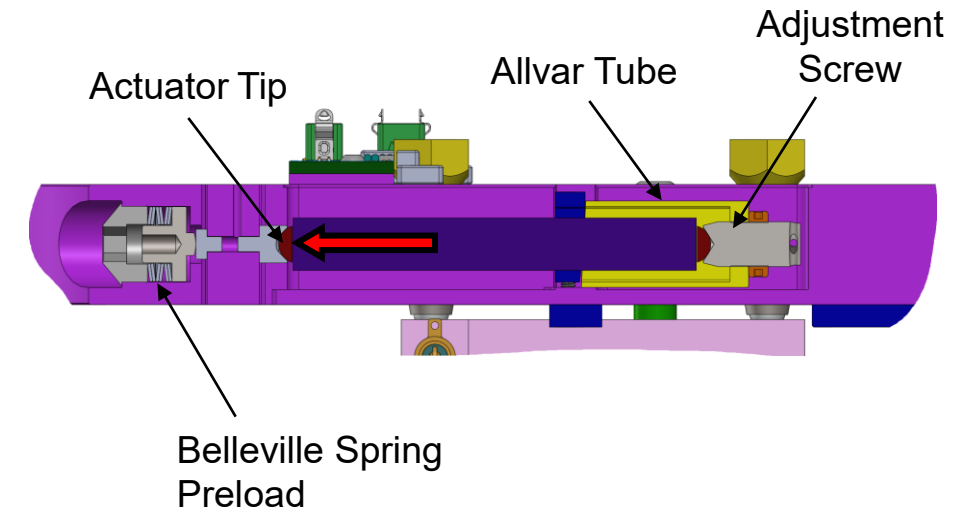
## Camera Rear View



# Piezo Actuators and Mounting

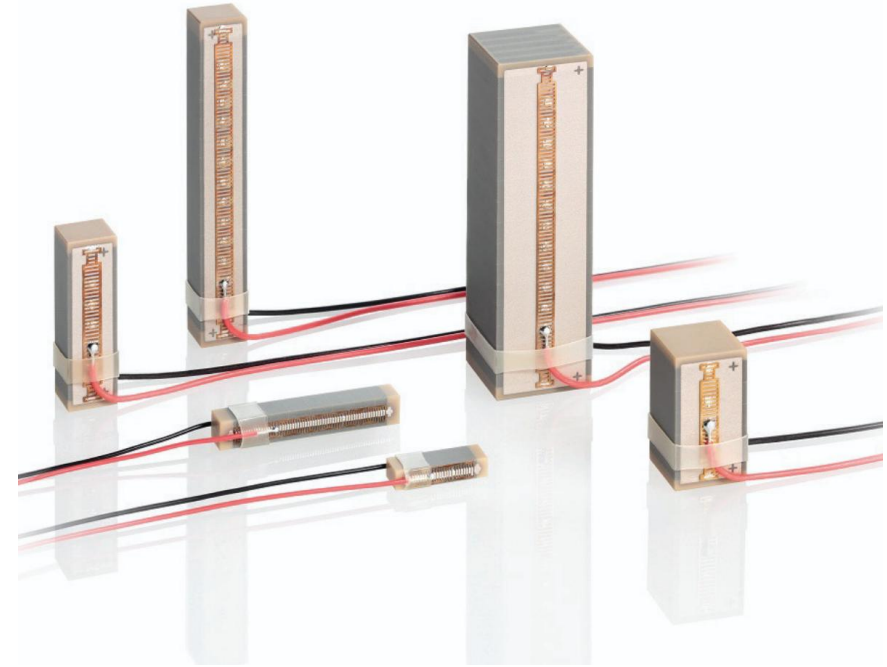


**Piezo: Section View**



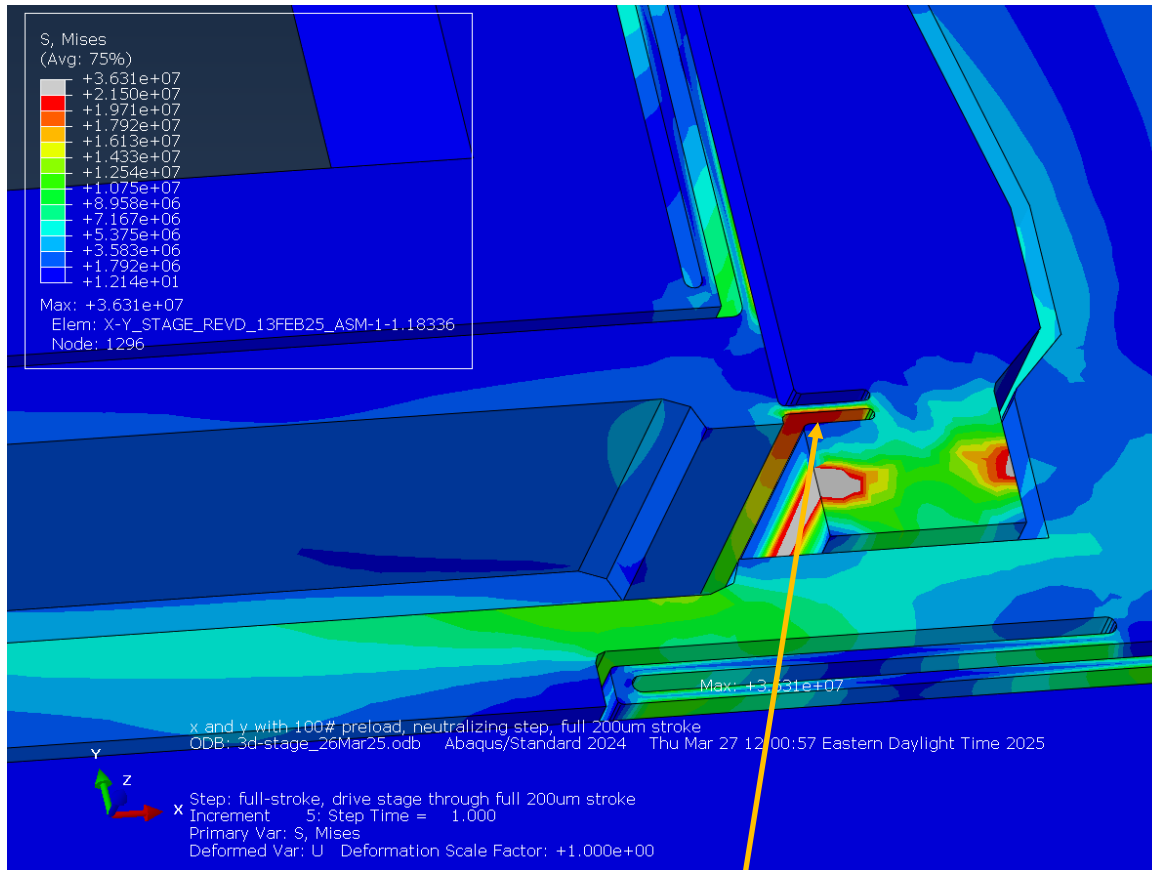
# Piezo Element

- Physik Instrumente (PI)
- PICMA PiezoAktor 7x7x54 mm
- -20 to 120 V Piezo (Ambient)
  - -100 to 100 V at cryo
- 56  $\mu\text{m}$  stroke at max voltage (Unipolar - Ambient)
  - $\sim 36 \mu\text{m}$  stroke for bipolar operation (cryo)



# Performance: Stress and Out-of-Plane Displacement

## Von Mises Stress



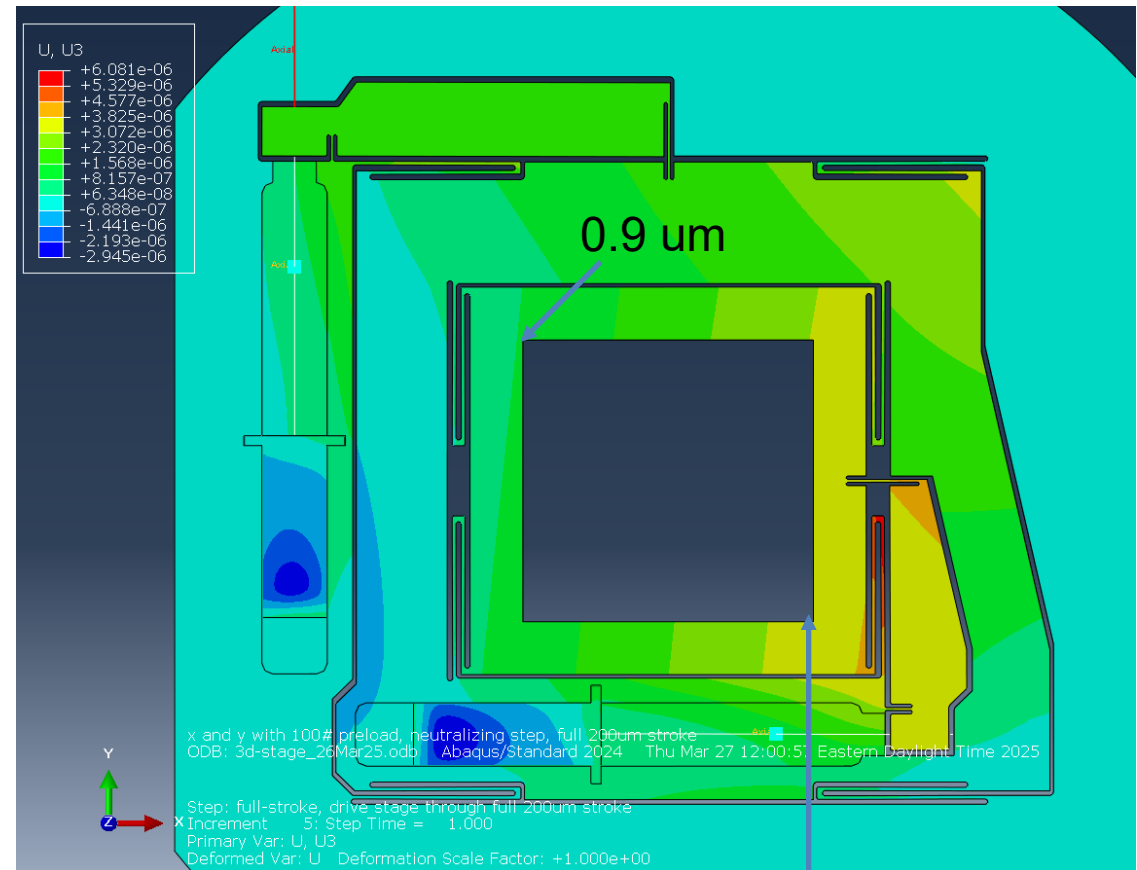
**Ti-6AL-4V Gr5 annealed:**

Yield=880MPa

UTS=950MPa

21 MPa

## Out-of-Plane Motion (200 um stroke X and Y)

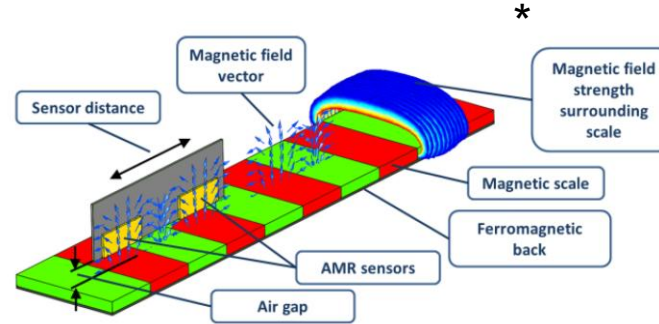
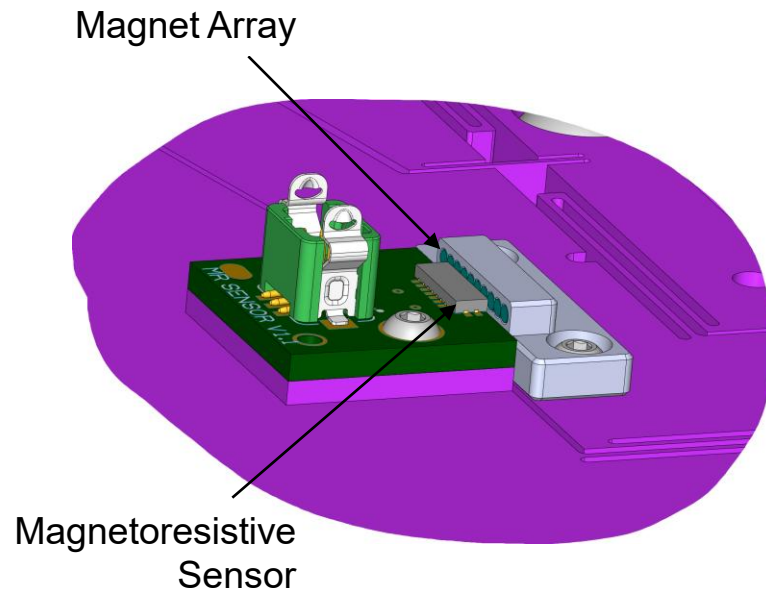


3.4 um

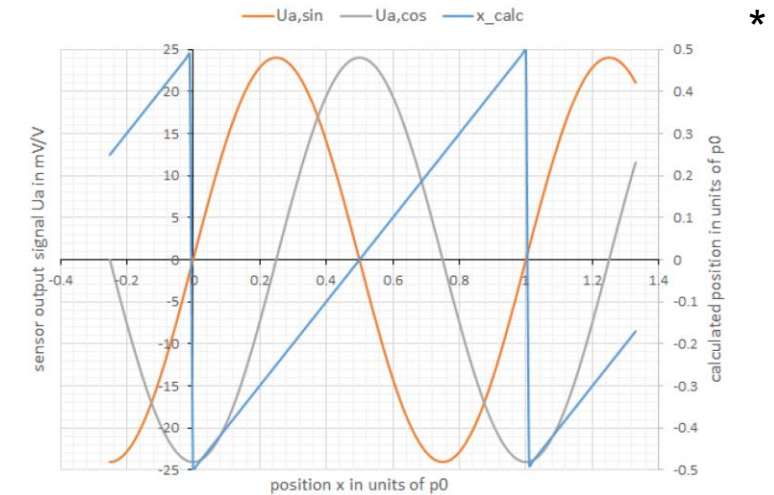
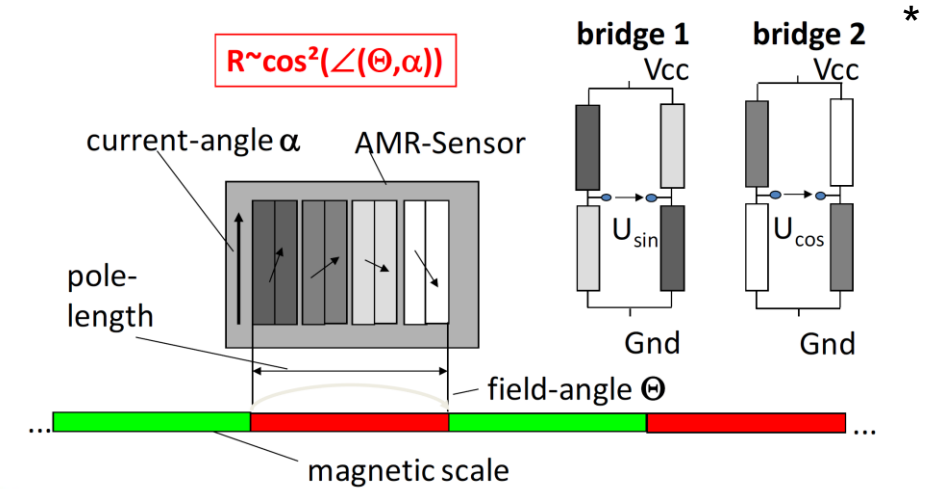


# Magnetoresistive Sensor At Cryogenic Temperature

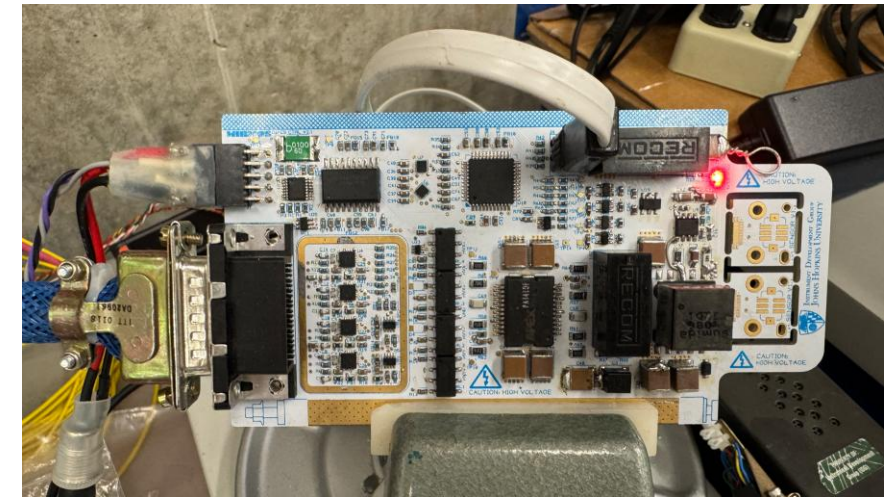
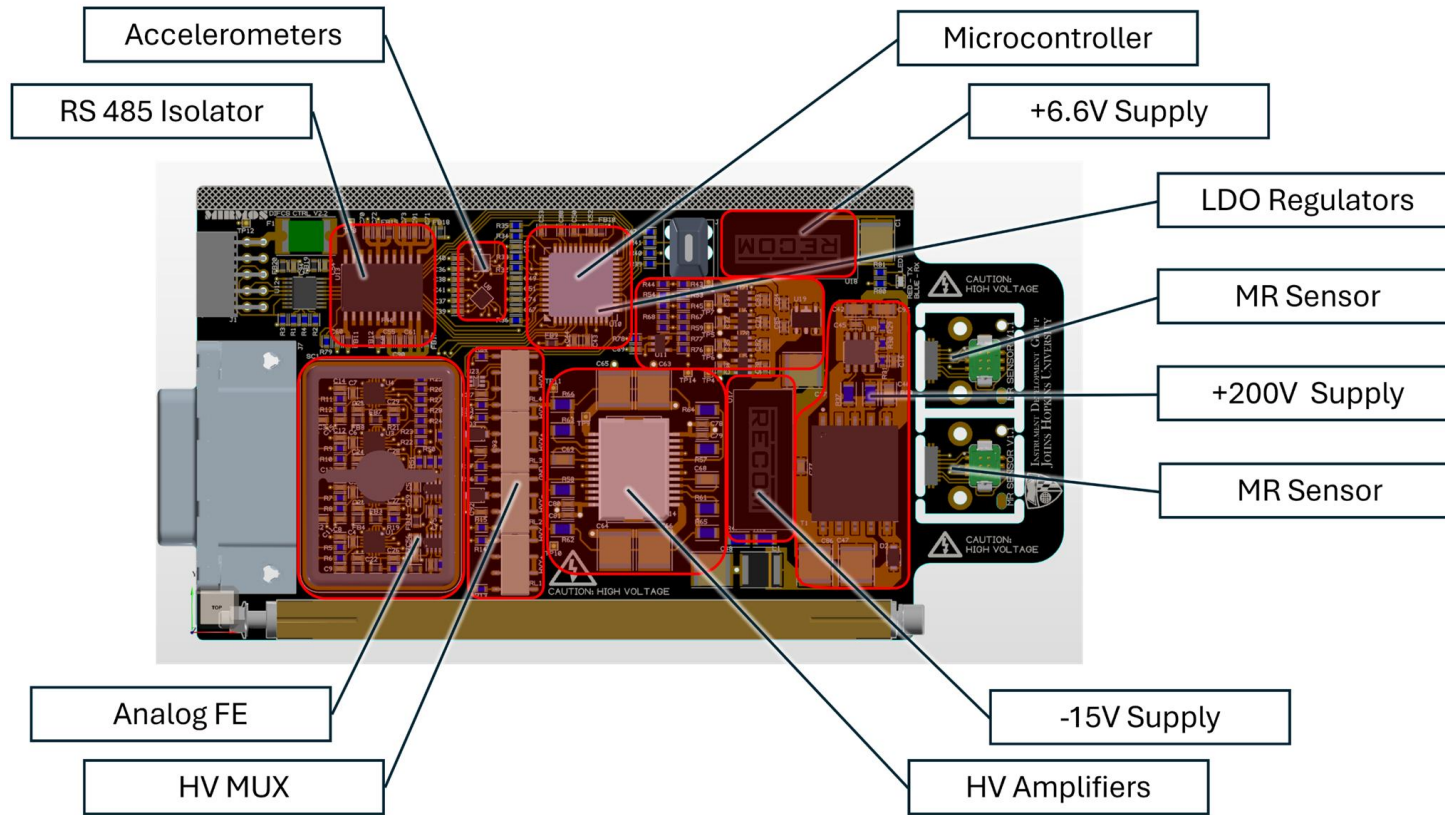
- Magnetoresistive sensor does work at cryogenic temperature
- Reduced resistance (~40%) is not a concern given the Wheatstone bridge configuration



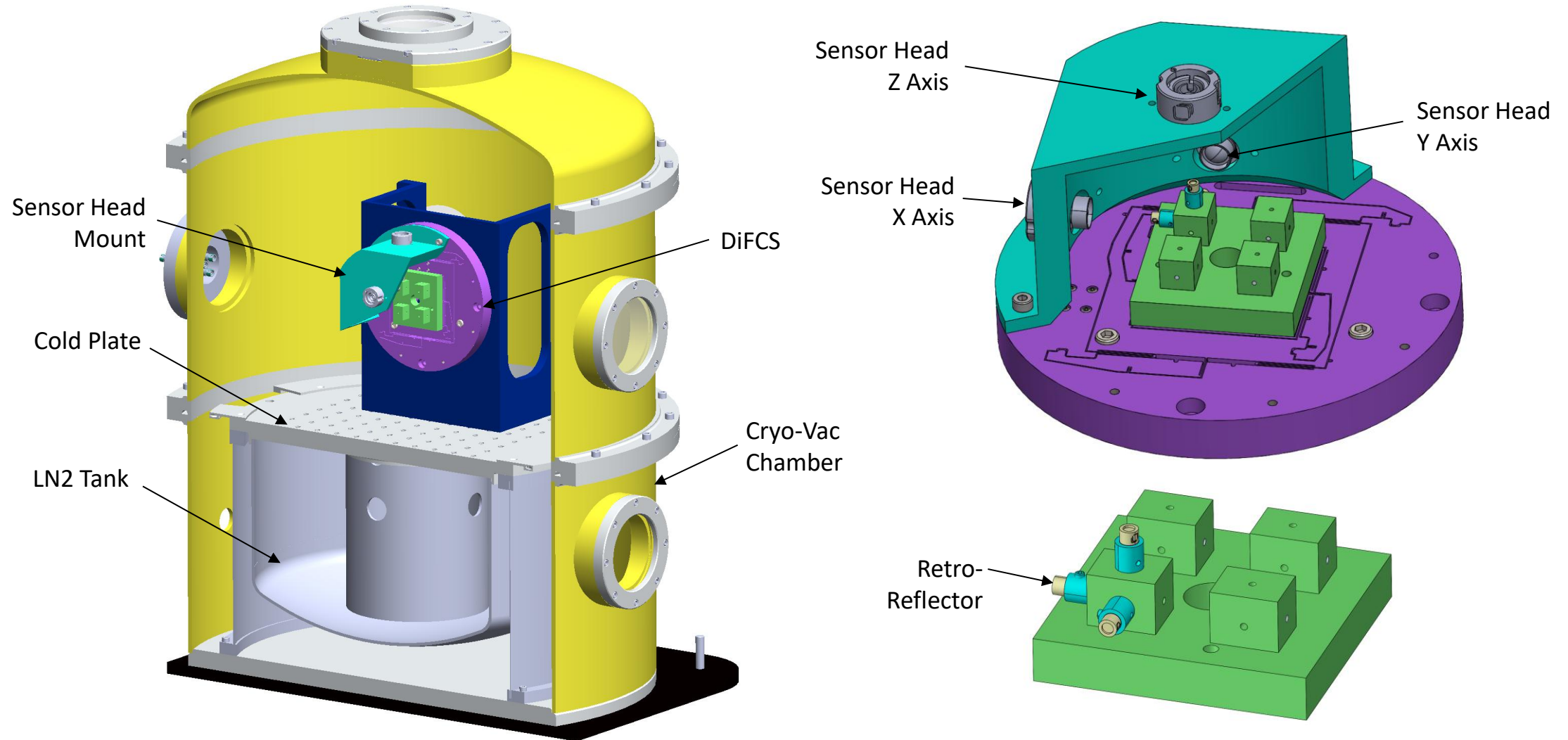
$$x = \frac{p_0}{\pi} \cdot \tan^{-1} \left( -\frac{U_{a,sin}}{U_{a,cos}} \right)$$



# DiFCS Custom Controller

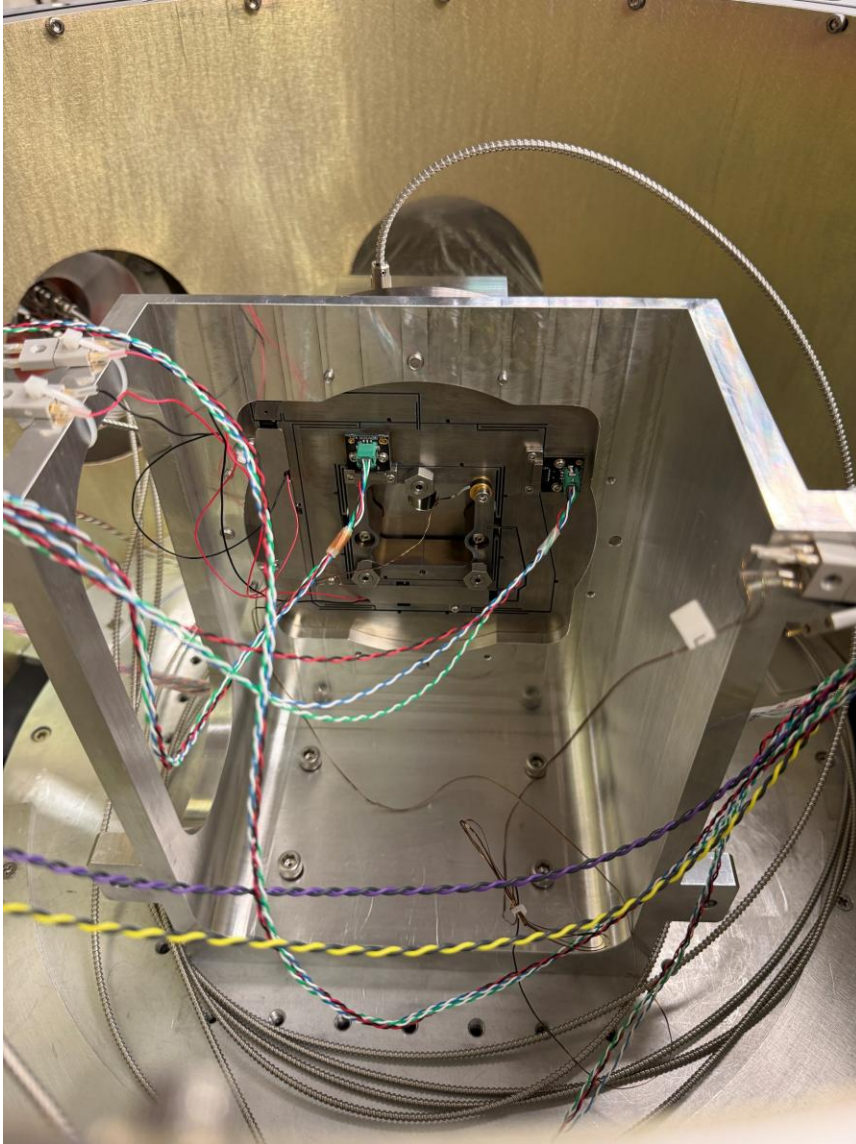


# DiFCS Cryogenic Performance: Test Setup

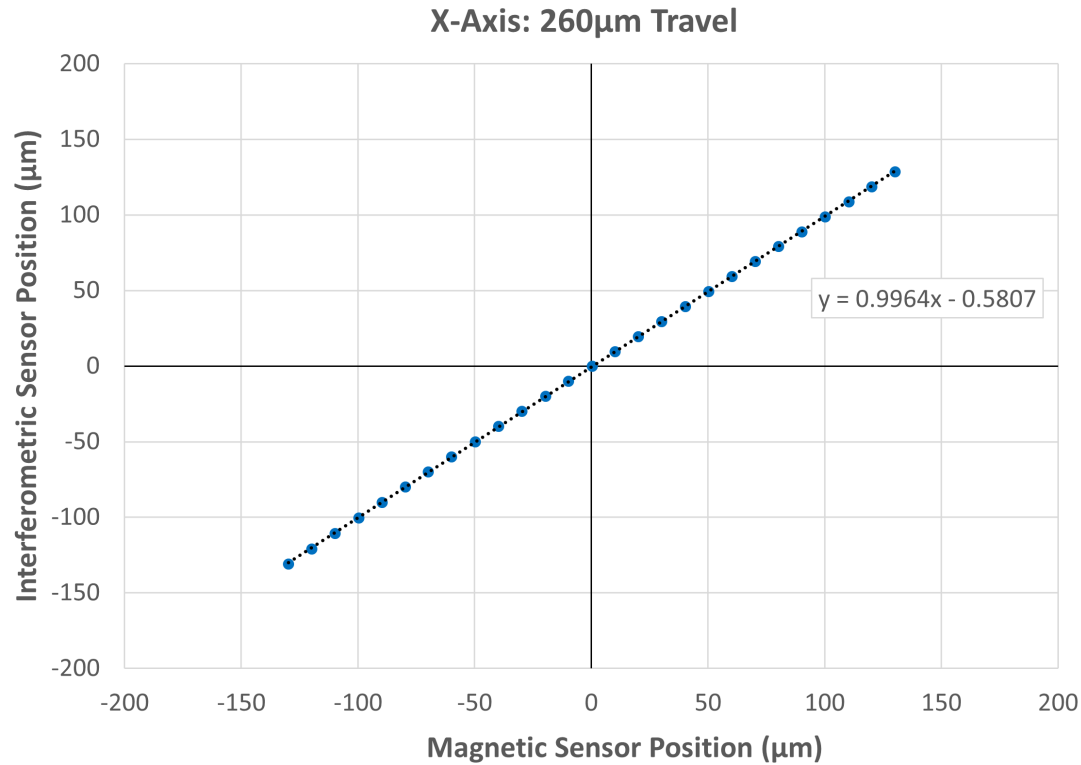




# Test Setup Photos

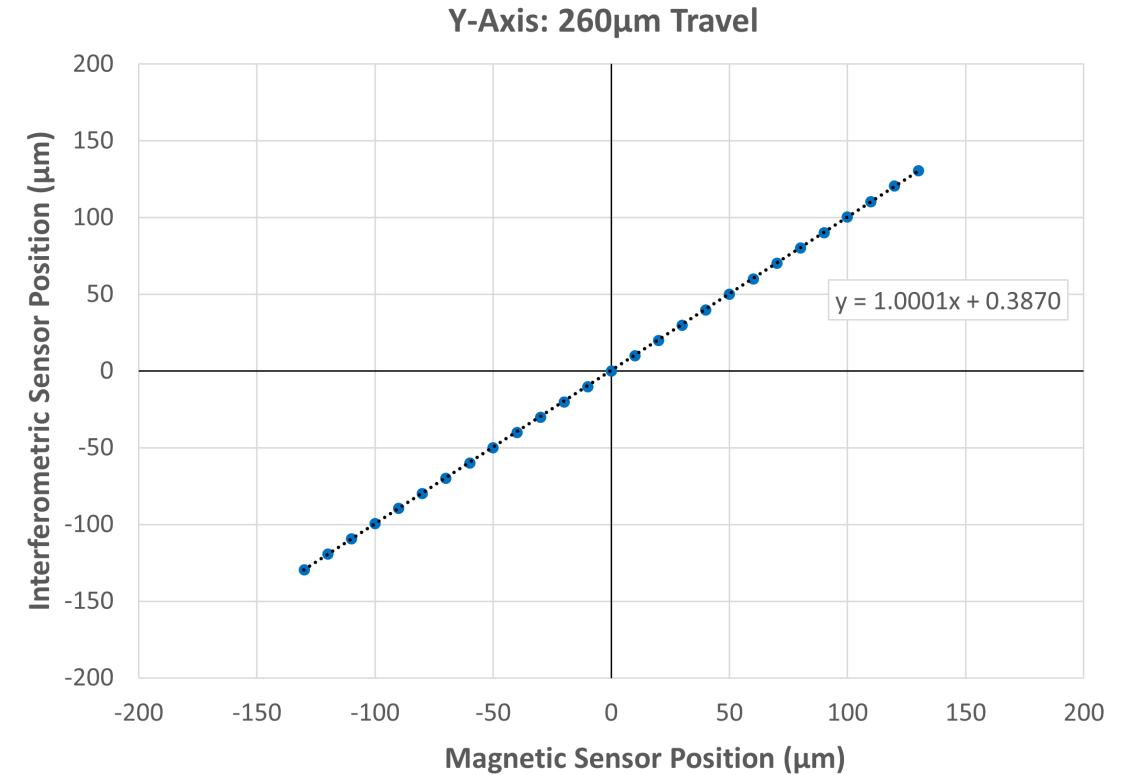


# Performance: 10 um Dither Precision



**X-Axis**

| Slew #     | P-V (260 μm) | RMS (260 μm) | RMS (200 μm) | slope         |
|------------|--------------|--------------|--------------|---------------|
| 1          | 1.55         | 0.53         | 0.45         | 0.9952        |
| 2          | 1.69         | 0.73         | 0.57         | 0.9953        |
| 3          | 1.63         | 1.26         | 1.14         | 0.9948        |
| 4          | 1.53         | 0.86         | 0.64         | 0.9964        |
| <b>AVG</b> | <b>1.60</b>  | <b>0.85</b>  | <b>0.70</b>  | <b>0.9954</b> |

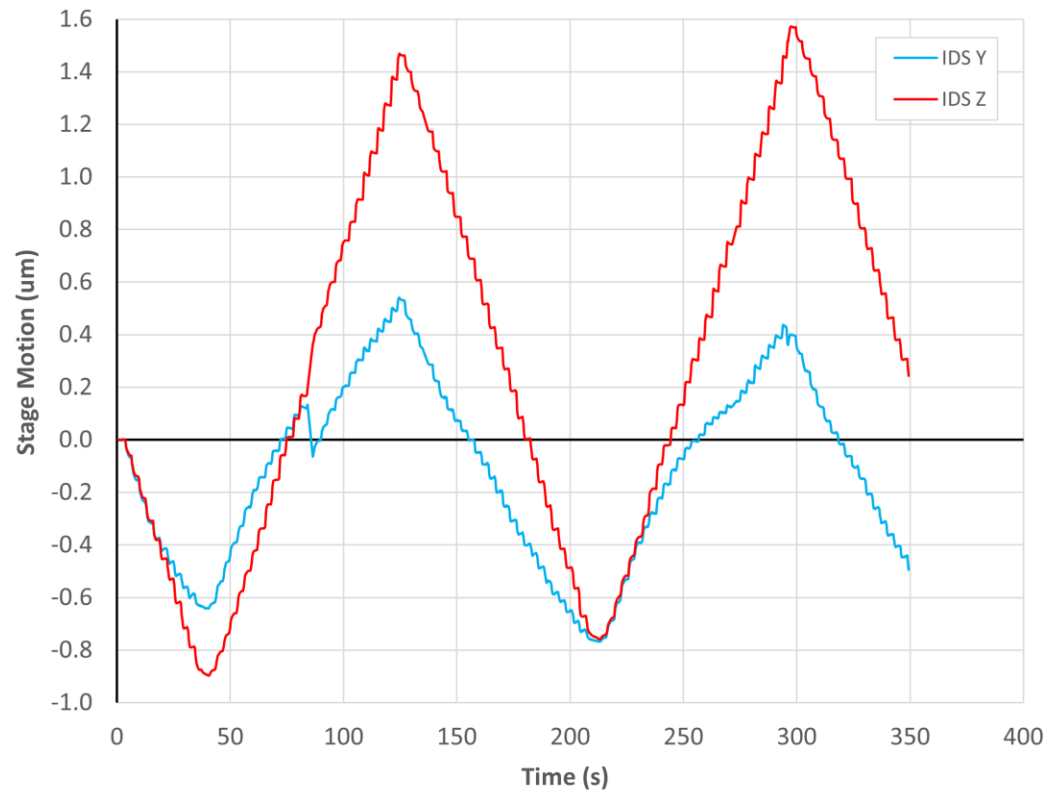


**Y-Axis**

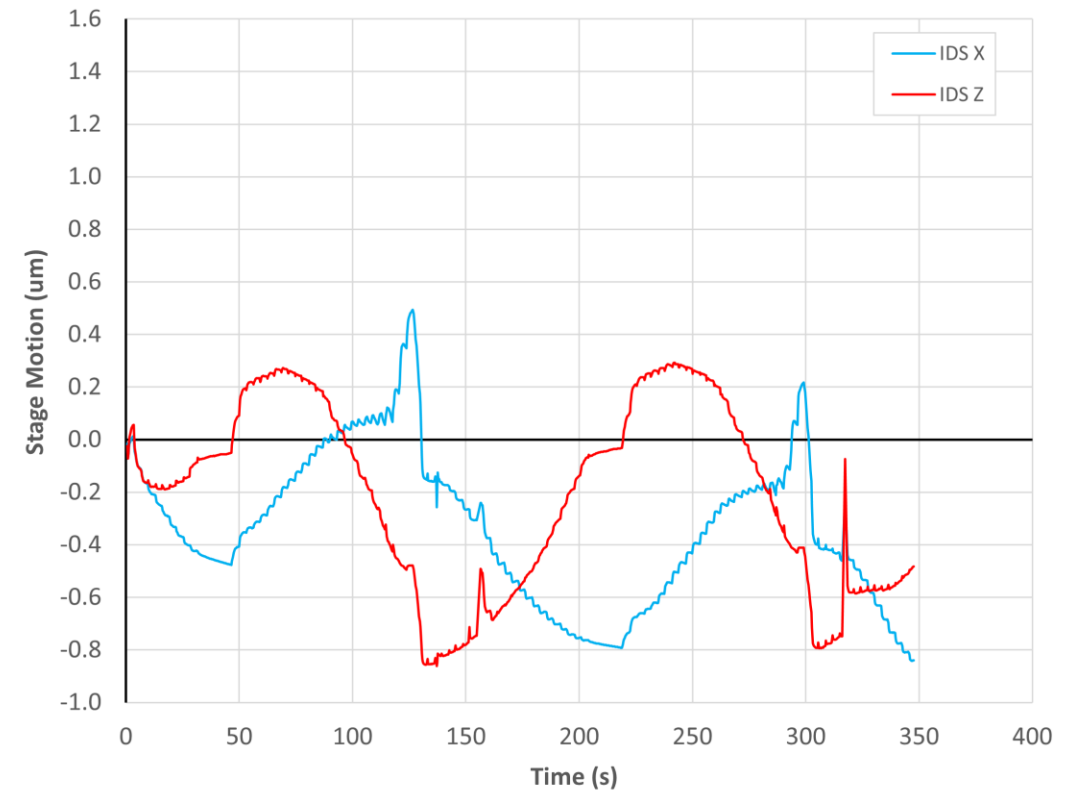
| Slew #     | P-V (260 μm) | RMS (260 μm) | RMS (200 μm) | slope         |
|------------|--------------|--------------|--------------|---------------|
| 1          | 0.77         | 0.22         | 0.18         | 0.9982        |
| 2          | 0.95         | 0.39         | 0.25         | 0.9991        |
| 3          | 0.91         | 0.30         | 0.28         | 0.9967        |
| 4          | 0.99         | 0.48         | 0.33         | 1.0001        |
| <b>AVG</b> | <b>0.90</b>  | <b>0.35</b>  | <b>0.26</b>  | <b>0.9985</b> |

# Performance: Out-of-Plane Motion

Parasitic Motion from X-Axis



Parasitic Motion from Y-Axis



- Magnetoresistive sensors shown to work at cryogenic temperature
  - Produce micron-level accuracy at cryogenic temperature
- Preliminary DiFCS cryogenic performance has been evaluated
  - 300  $\mu\text{m}$  range of motion
  - Micron-level PID-controlled accuracy
  - Very low parasitic motion consistent with FEA