Preliminary Design Review
- Mechanisms Design -

iSHELL Preliminary Design Review: Mechanisms

- Mechanisms Overview:

Layout #	***Name***	***Abbrev.***	***Type***	***# of Discrete Positions***
5	Image Rotator	IMR	Continuous Angular Position	N/A
6	Slit Mechanism	SLM	Discrete Angular Position	5 (10)
	Dekker Mechanism	(DEK)	Discrete Linear Position	4
7	Filter Mechanism	FWM	Discrete Angular Position	15
8	Spectrograph Detector Focus Stage	DET	Continuous Linear Position	N/A
9	Order Sorting Mechanism	OSM	Discrete Angular Position	10
10	Immersion Grating Mechanism	IGM	Discrete Linear Position	2
11	Cross-Disperser Mechanism	XDM	Discrete Angular Position	11
			Continuous Angular Position	N/A

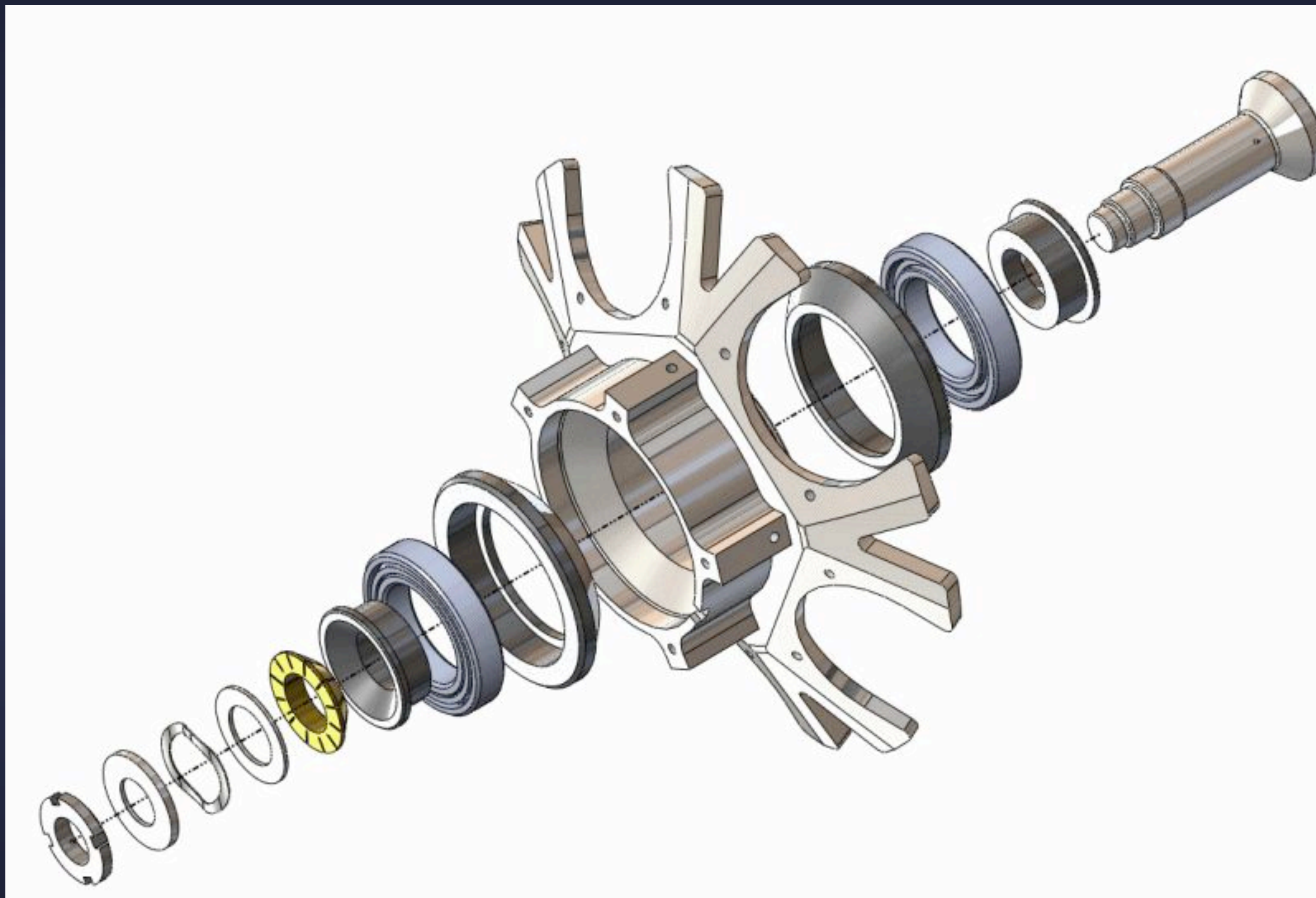
iSHELL Preliminary Design Review: Mechanisms

- High-Level Requirements:

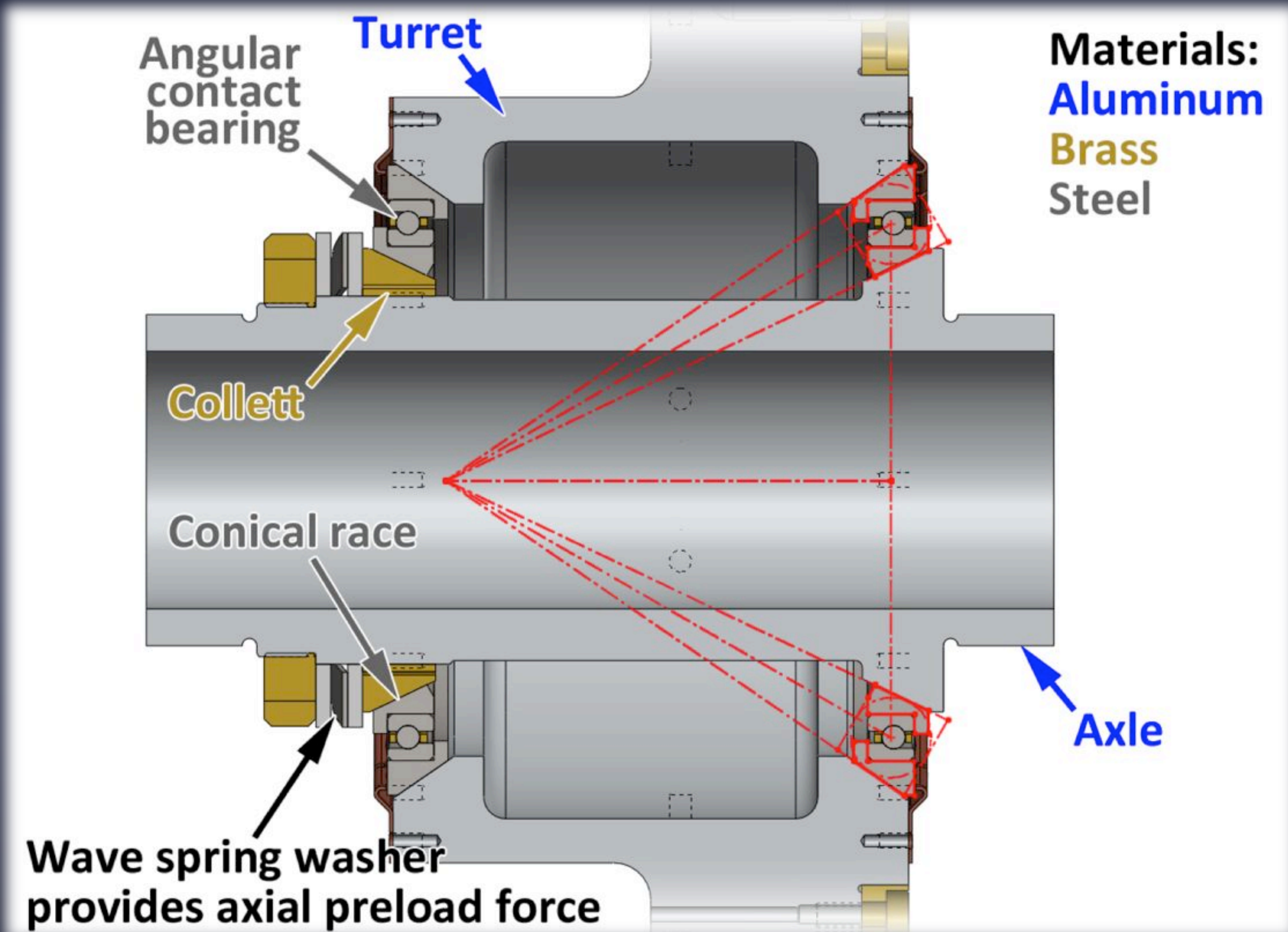
Mechanism	***Temp***	***Type***	***Range***	***Repositioning precision***	***Element size***
CB mirror	~280 K	In/out	2 positions	± 0.5 mm	Beam
Gas cell	~280 K	In/out	2 positions	± 0.5 mm	Beam
Window cover	~280 K	In/out	2 positions	± 0.5 mm	Beam
K-mirror	75 K	Continuous	> 360 degrees	± 0.1 deg on sky (1 pixel)	Beam
Slit wheel	75 K	Detent	5 positions	± 1 pixel	30 mm diameter 5 mm thick
Dekker stage	75 K	Detent	4 positions	± 1 pixel	n/a
SV filter wheel	75 K	Detent	15 positions	± 0.1 mm	25 mm diameter ~5 mm thick
Order sorter wheel	75 K	Detent	10 positions	± 0.1 mm	6 x 10 mm ~3 mm thick
IG selection mirror	75 K	In/out	2 positions	± 0.1 mm	Beam
XD wheel	75 K	Detent	12 positions	± 1 pixel (15 arcsec)	~32 x 50 mm to ~32 x 40 mm ~ 7 mm thick
XD wheel tilt	75 K	Continuous	± 5 degrees	± 1 pixel (15 arcsec)	n/a
Spectrograph focus	75 K	Continuous	± 2 mm	± 50 μm	n/a

GENERIC BEARING MOUNT

Athermal Bearing Mount

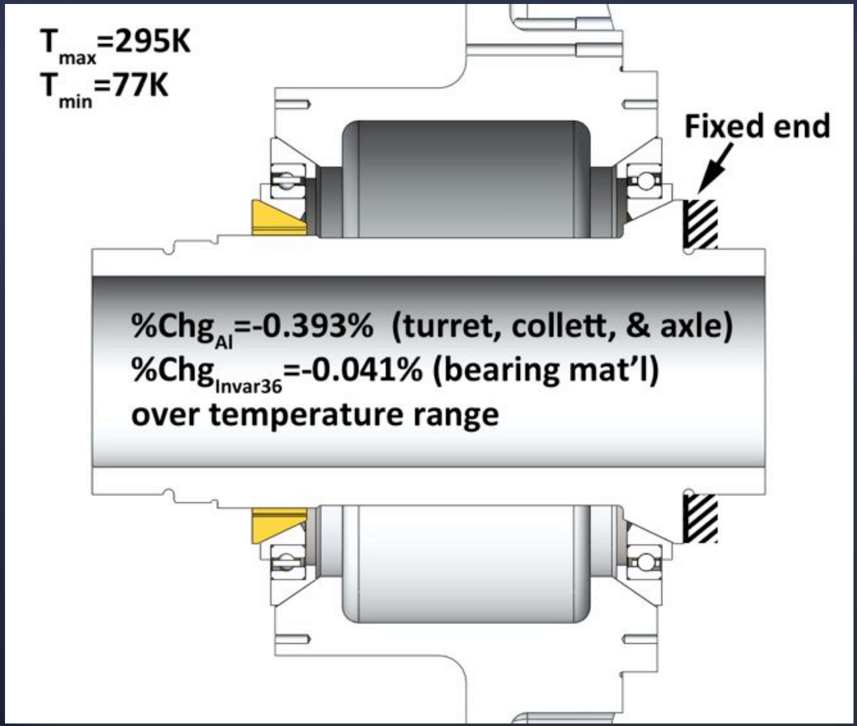


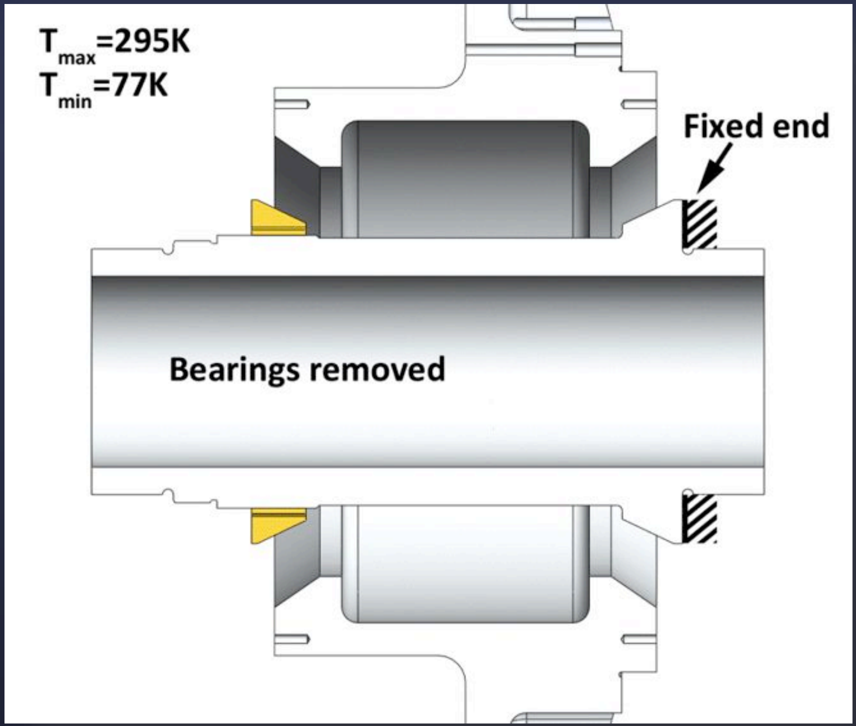
Athermal Turret Axle Design



Athermal Turret Behavior

- Components contract as turret cools from ambient to operating temperature
- Aluminum turret & axle contract/expand as a rigid body





Athermal turret axle design

- Eliminates axial & radial displacement of turret relative to axle due to CTE mismatches between steel bearings and aluminum turret during cool-down/warm-up.
- Turret/axle assembly (CTE) behaves as though it were a single material as temperature changes
- Turret remains aligned when warm or cold
- Don't need to design in "warm" bearing clearances that makes turret sloppy when warm & tight when cold

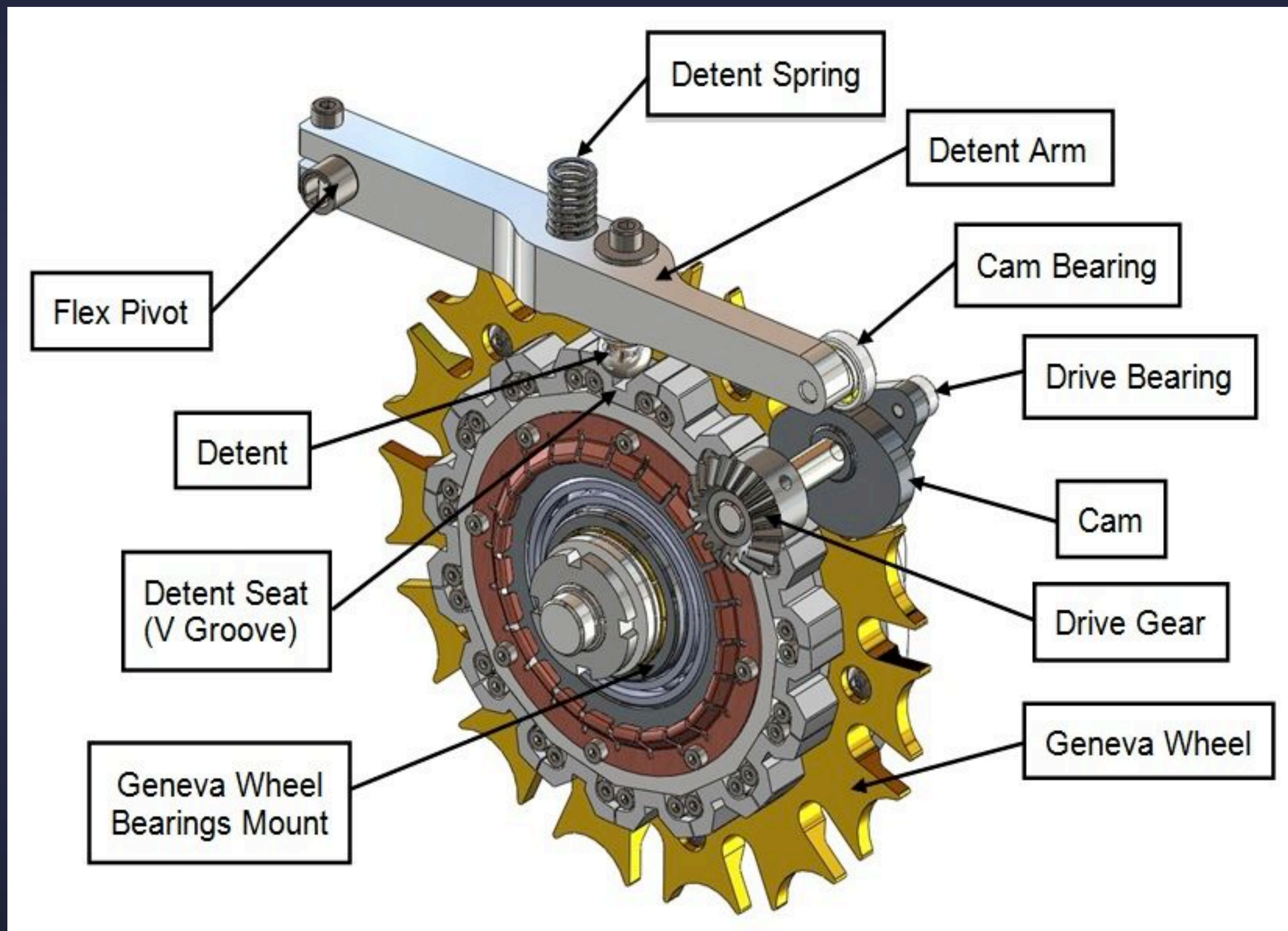
DISCRETE ANGULAR POSITION MECHANISMS (DAPM)

DAPM: Choice of a type of wheel

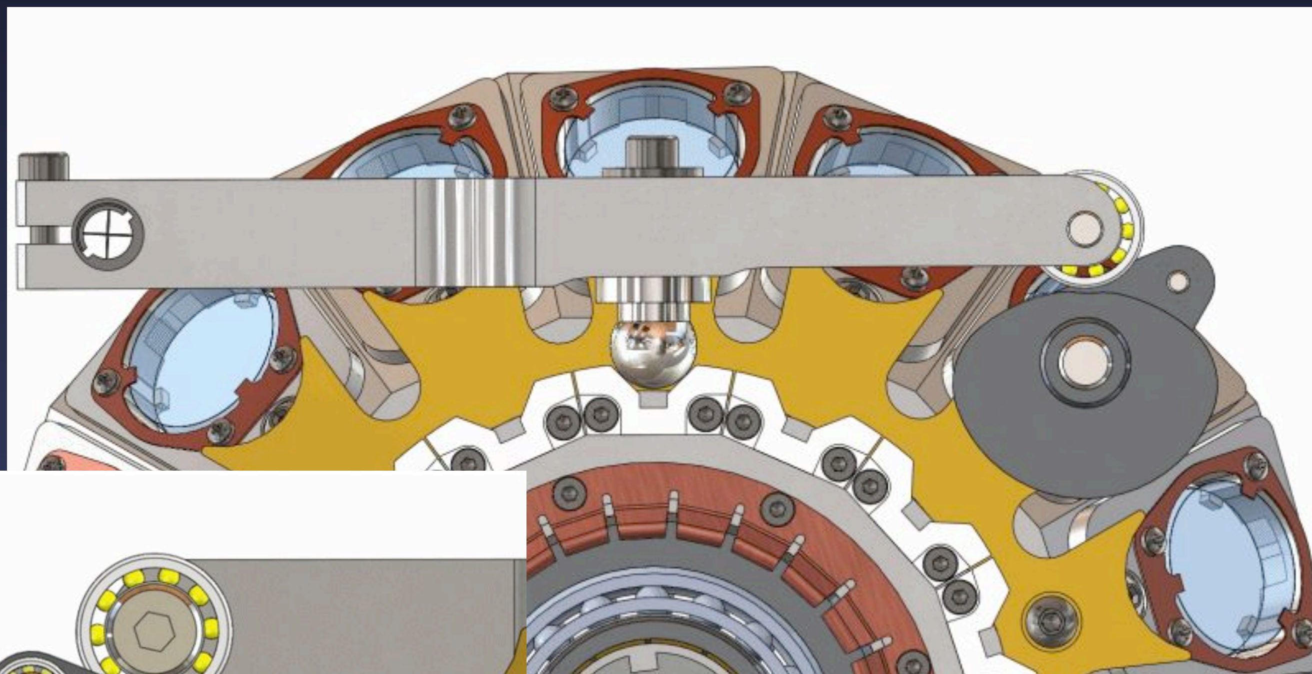
Here is a summary of the pros and cons of a Geneva drive versus a compliant worm drive:

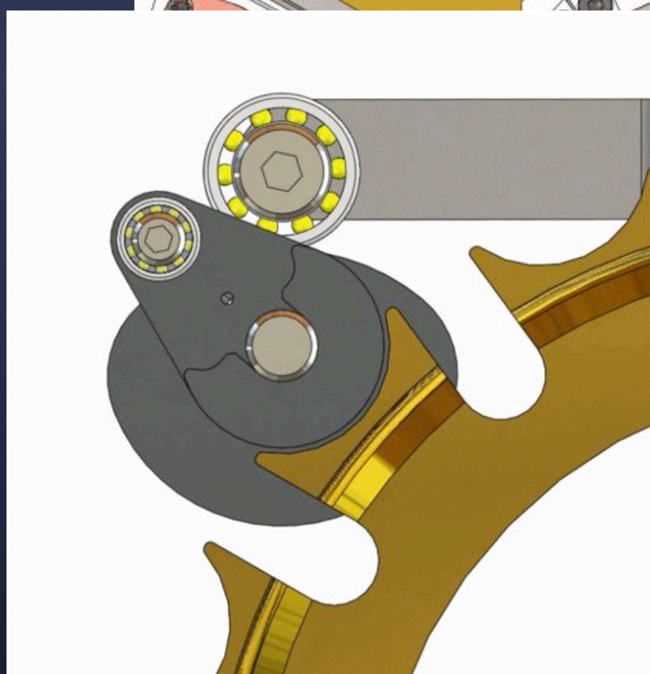
- Pro: Geneva mechanisms locate the wheel close to the required position => less detent force required
- Pro: Geneva mechanisms require less time to index than a worm drive because the reduction ration is usually less
- Con: Geneva mechanisms usually require the use of gear reduction.
- Con: due to the reduction and the use of a cam, Geneva mechanisms have more moving parts than a worm drive
- Pro: Geneva wheels are less expansive to fabricate than worm drives
- Con: Geneva mechanisms are limited in the number of discrete positions.

DAPM: The Modified Geneva



DAPM: The Modified Geneva

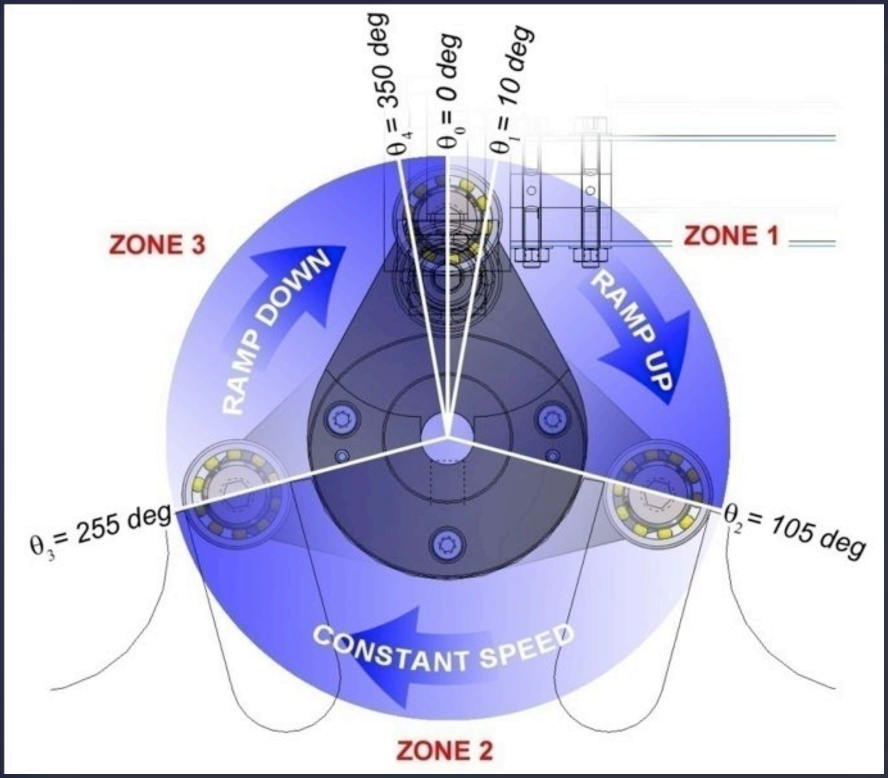




- In the detent position, the cam has a “dip” so that the detent arm is no longer in contact with the cam but only with the detent seat.
- when the drive bearing disengages from the Geneva wheel, the wheel is still held by the cam

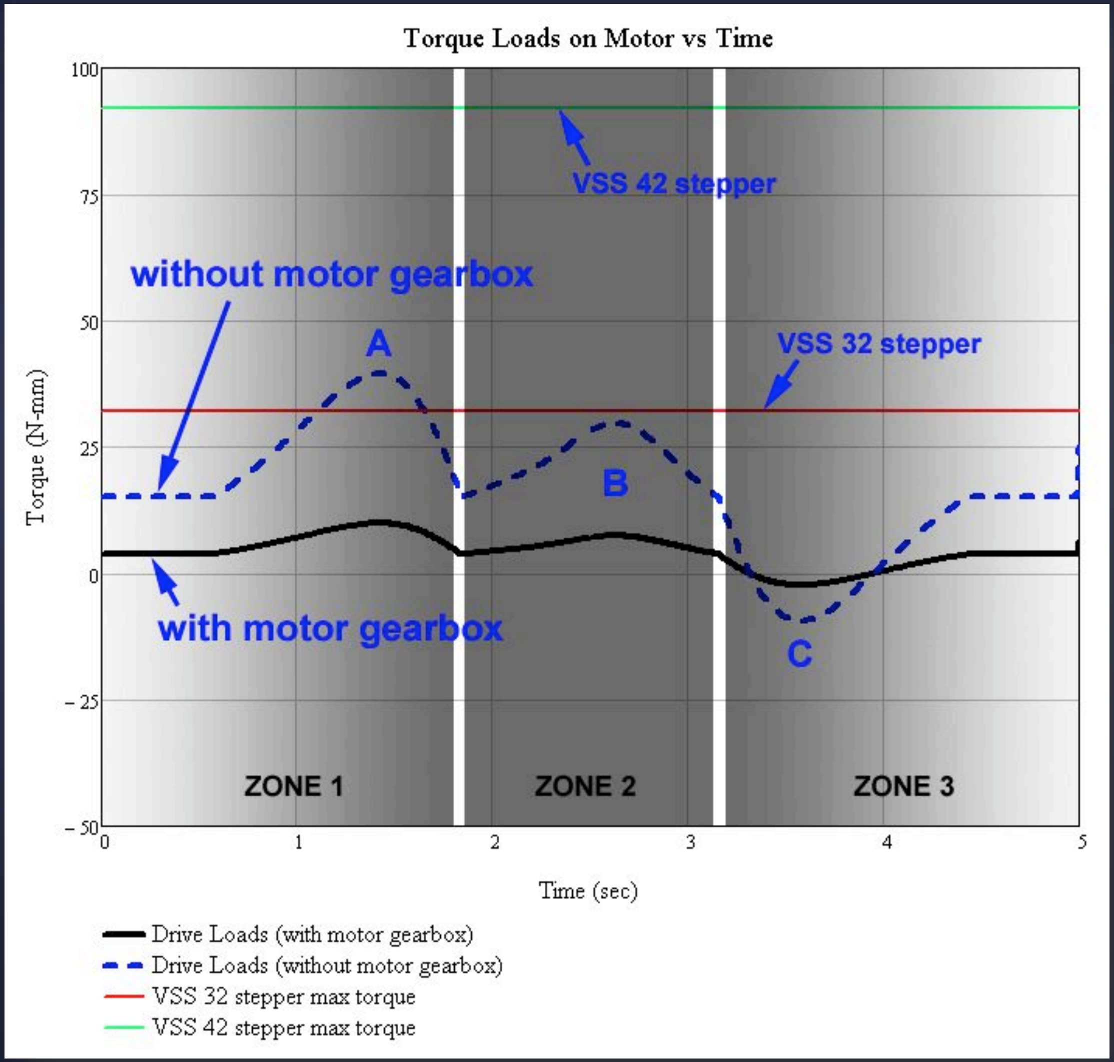
DAPM: The Modified Geneva

- Zone 1 - Ramp up
- Follower travels from fully seated position to fully disengaged position
- Zone 2 – Constant speed
- Crank engages with the Geneva slot Turret gets moved to the next position
- Crank disengages with the Geneva slot
- Zone 3 – Ramp down
- Follower lowers back down and detent seats in V-groove of the next turret position to locate turret.

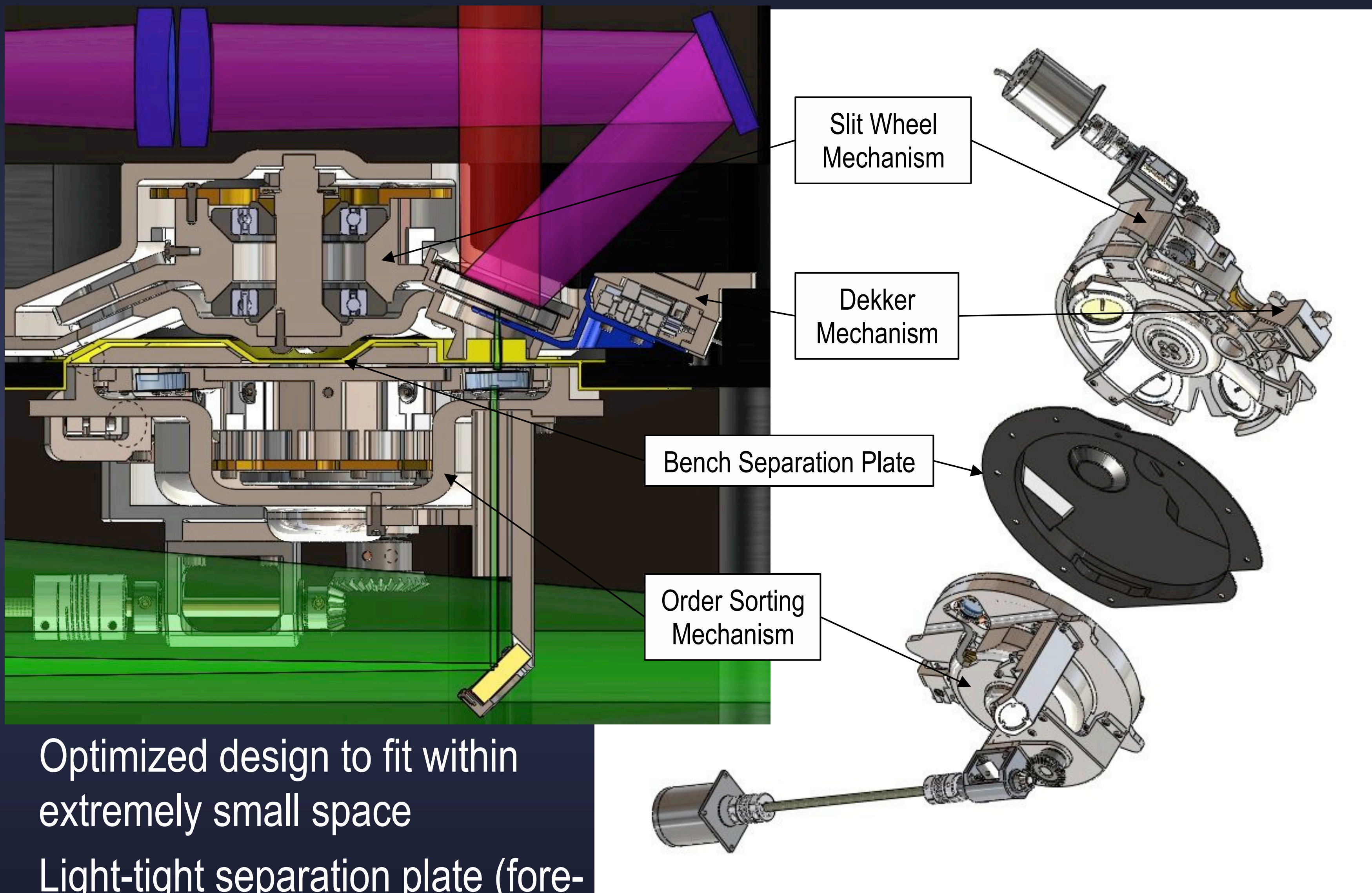


DAPM: The Modified Geneva

Geneva Drive Motor Loads For 1 Cycle:

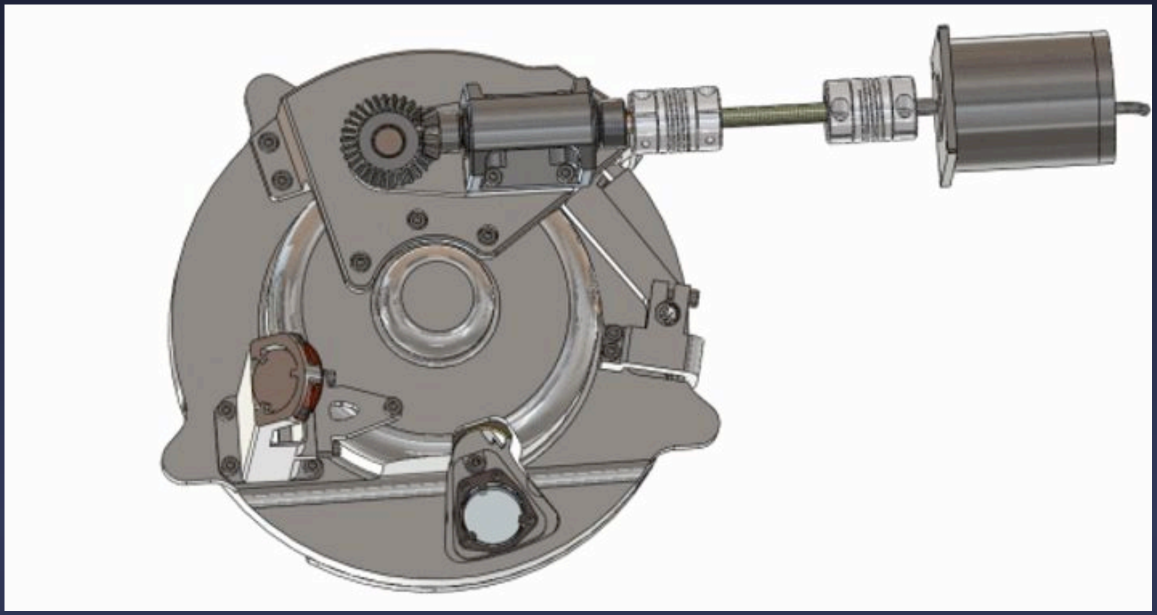


DAPM: Slit Wheel + Order Sorter

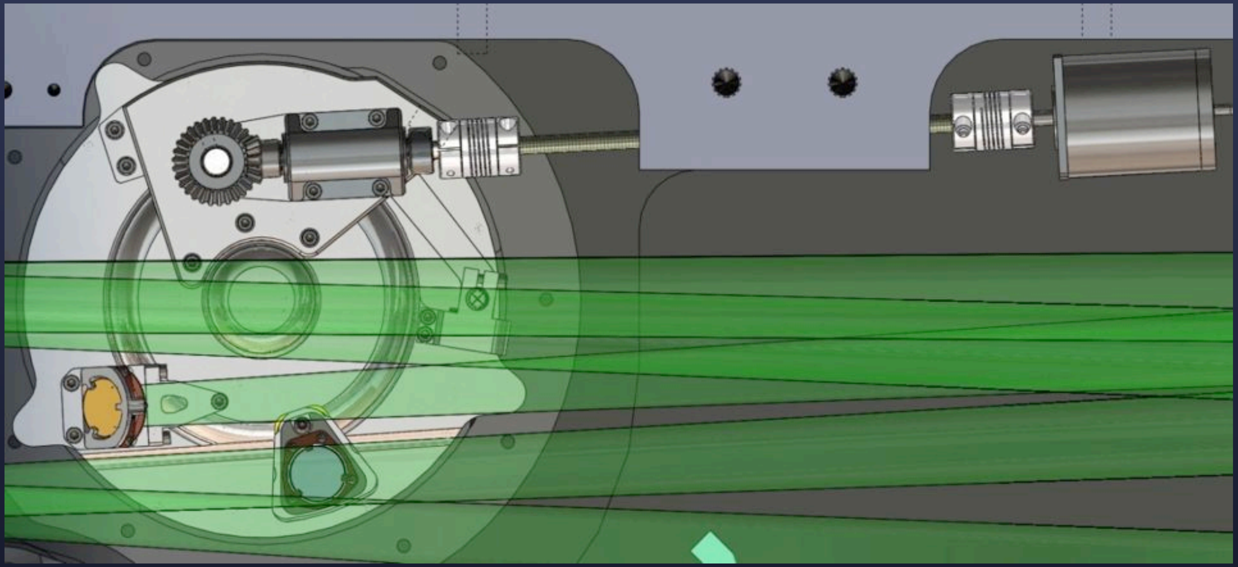


- Optimized design to fit within extremely small space
- Light-tight separation plate (fore-optics / spectrometer)

DAPM: Order Sorting Mechanism

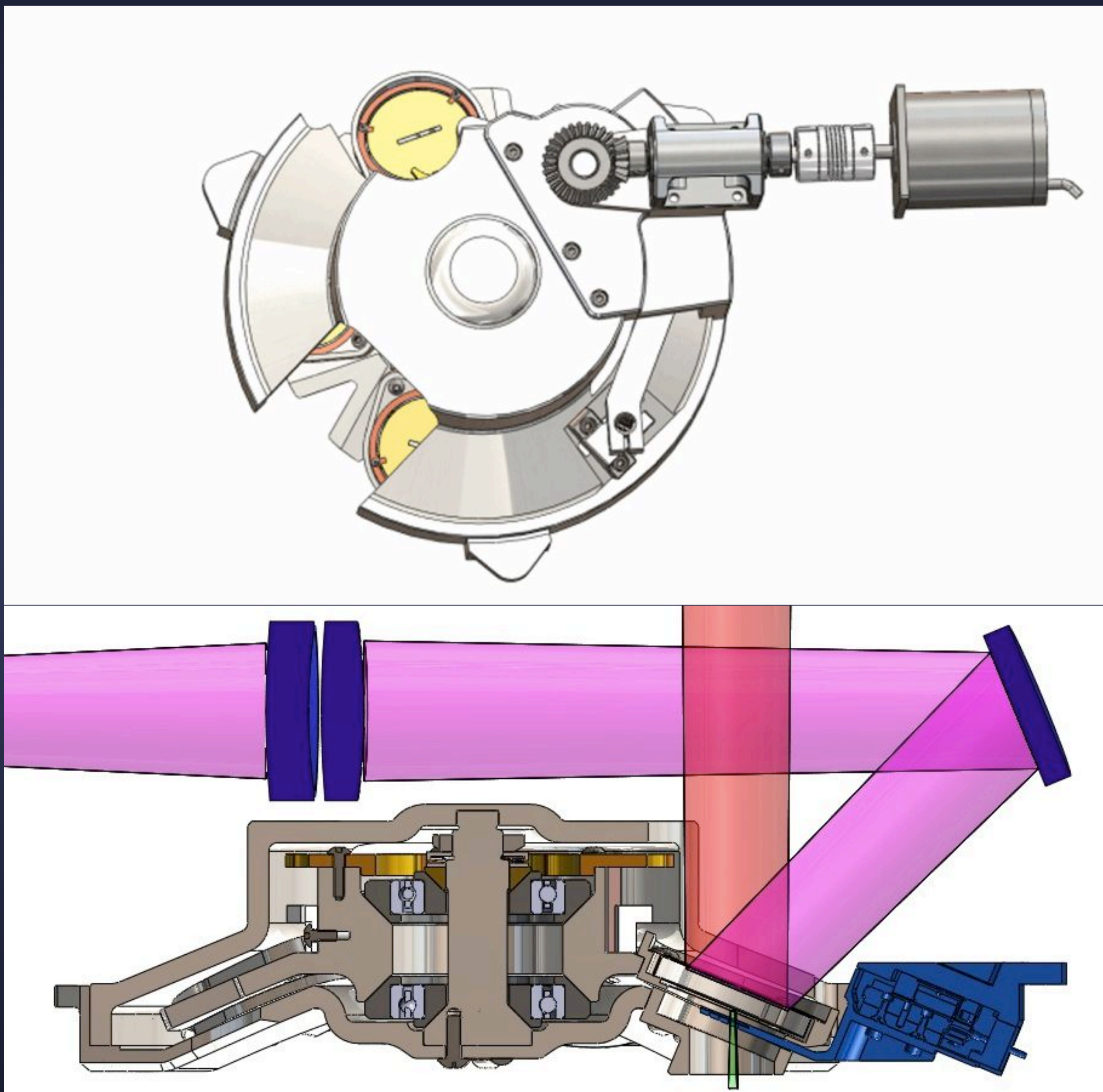


- 10 Discrete Positions
- Gearing = 2:1 ratio
- Enclosure:
  - 3-point mount (“ears”)
  - Filter Cell Access
- 45° Fold Mirror Mount



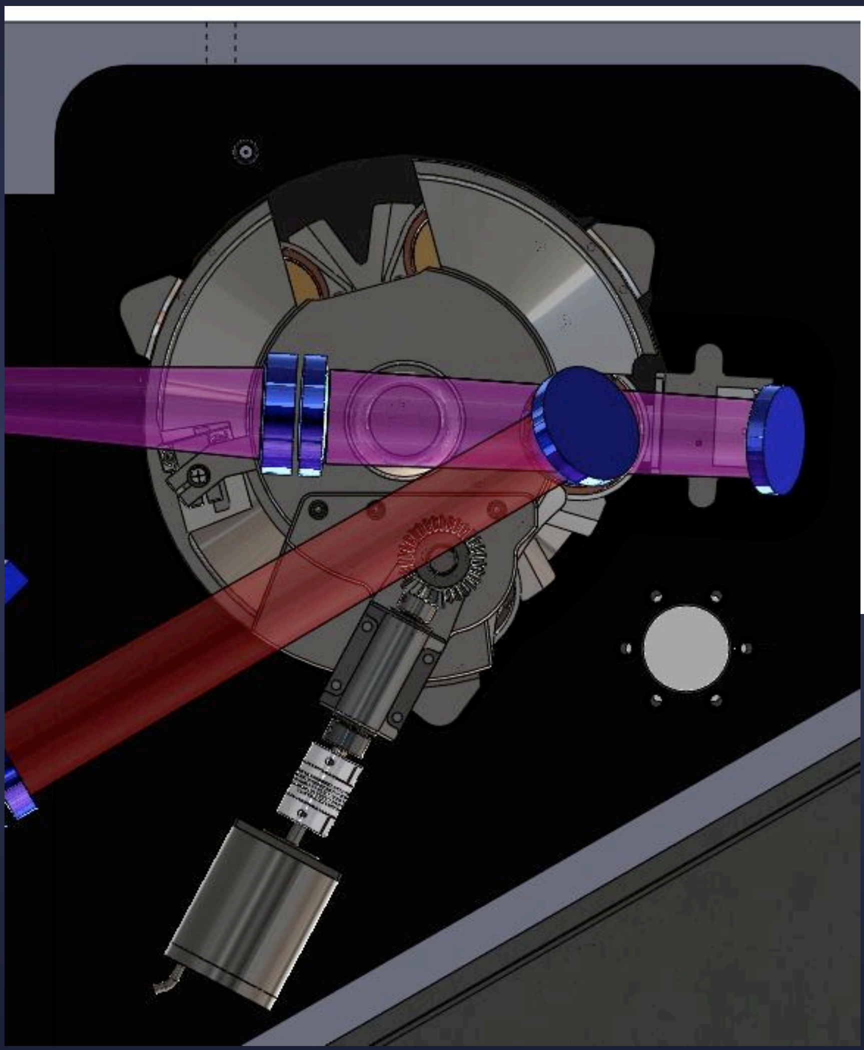
- Motor Location:
  - Easier Access
  - Light-shielding

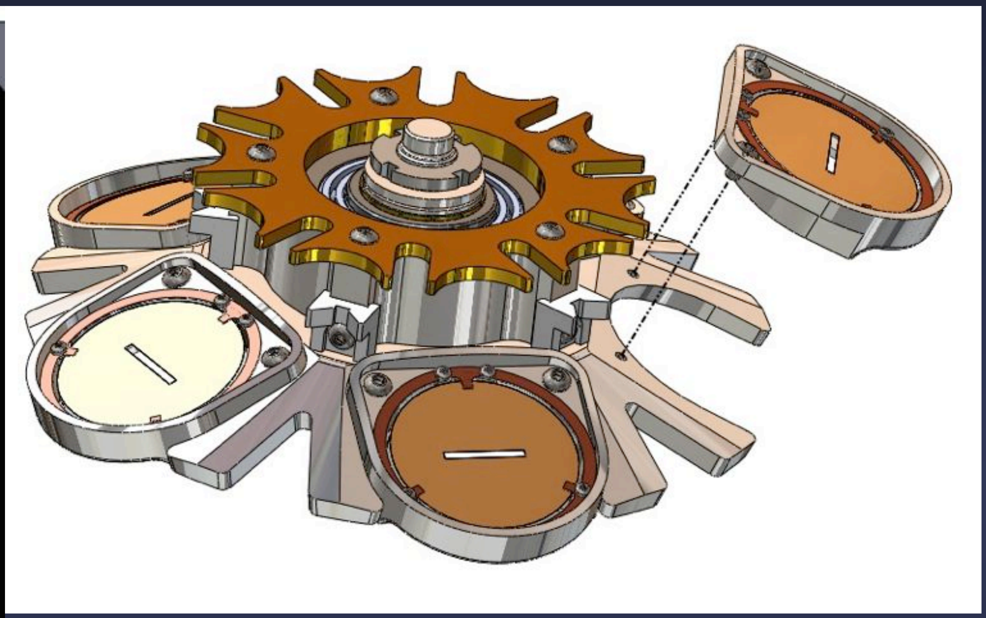
DAPM: Slit Wheel Mechanism



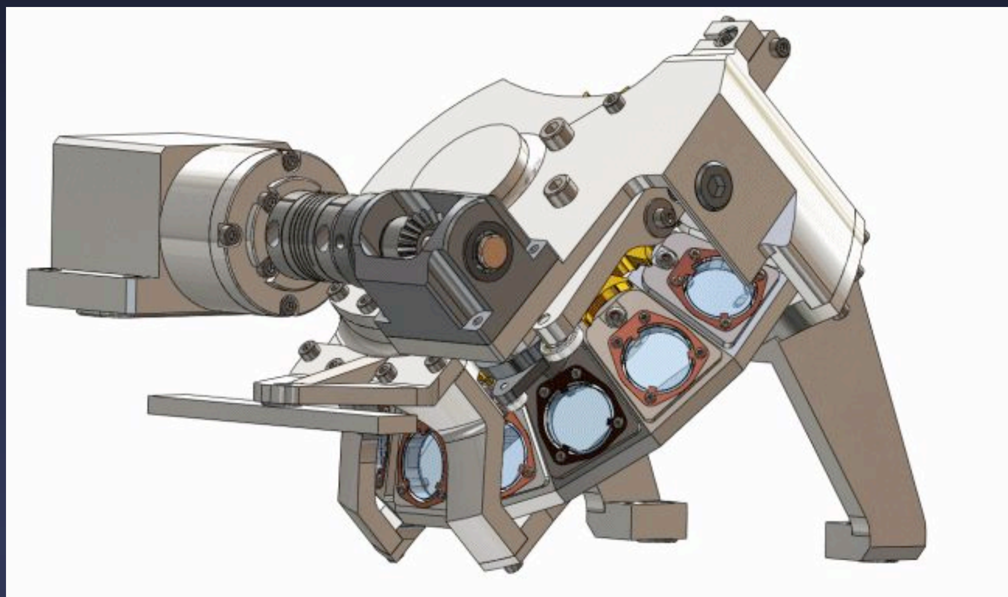
- 5 (10) Discrete Positions
- Gearing = 2:1 ratio
- Enclosure:
  - 3-point mount ("ears")
  - Slit Mirror Cell Access
- "light seal" around the Dekker mask.
- 22.5deg conical turret -> axle // to OSM axle

DAPM: Slit Wheel Mechanism

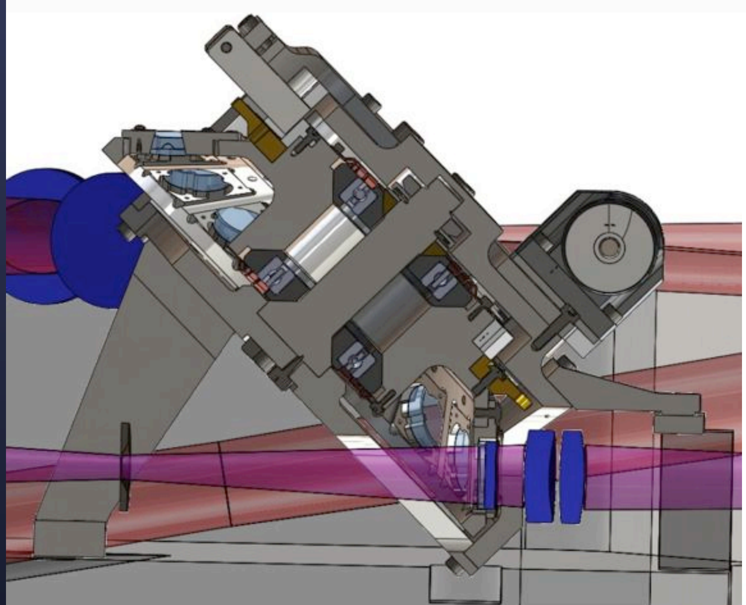


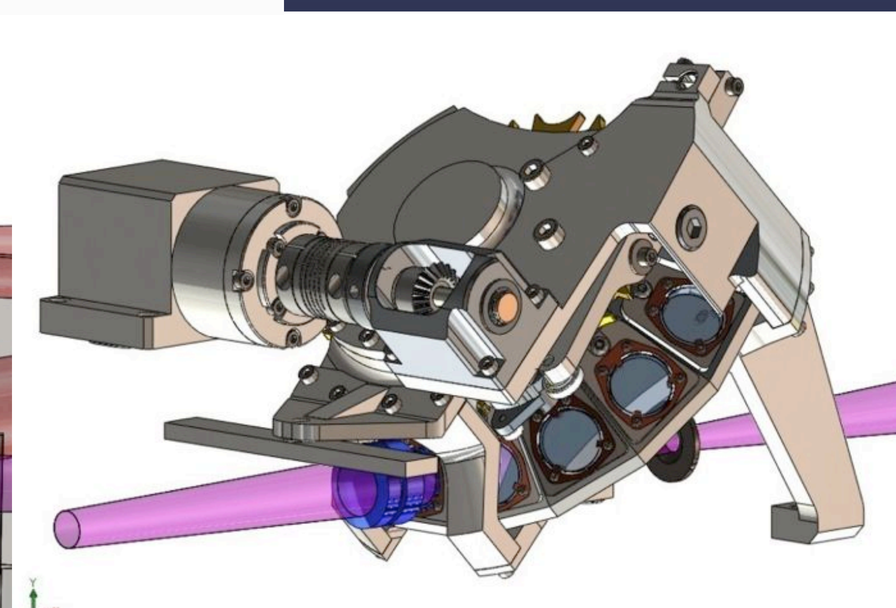


DAPM: Filter Wheel Mechanism

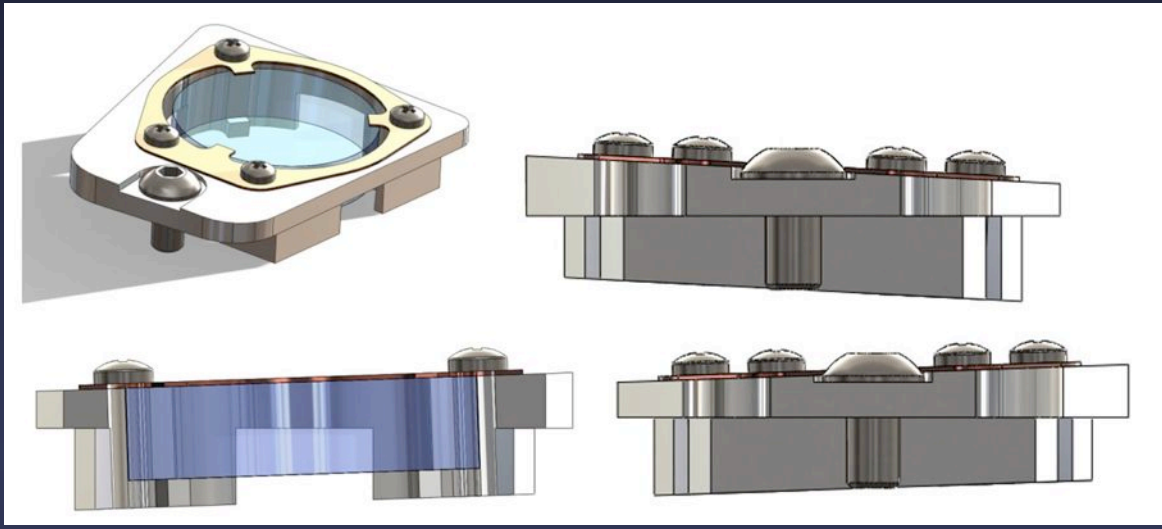


- 15 Discrete Positions
- Gearing: 1:1 Bevel + 4:1 Phytron Planetary Gear
- 45deg Turret for optimized space usage
- Light-tight Motor Mount





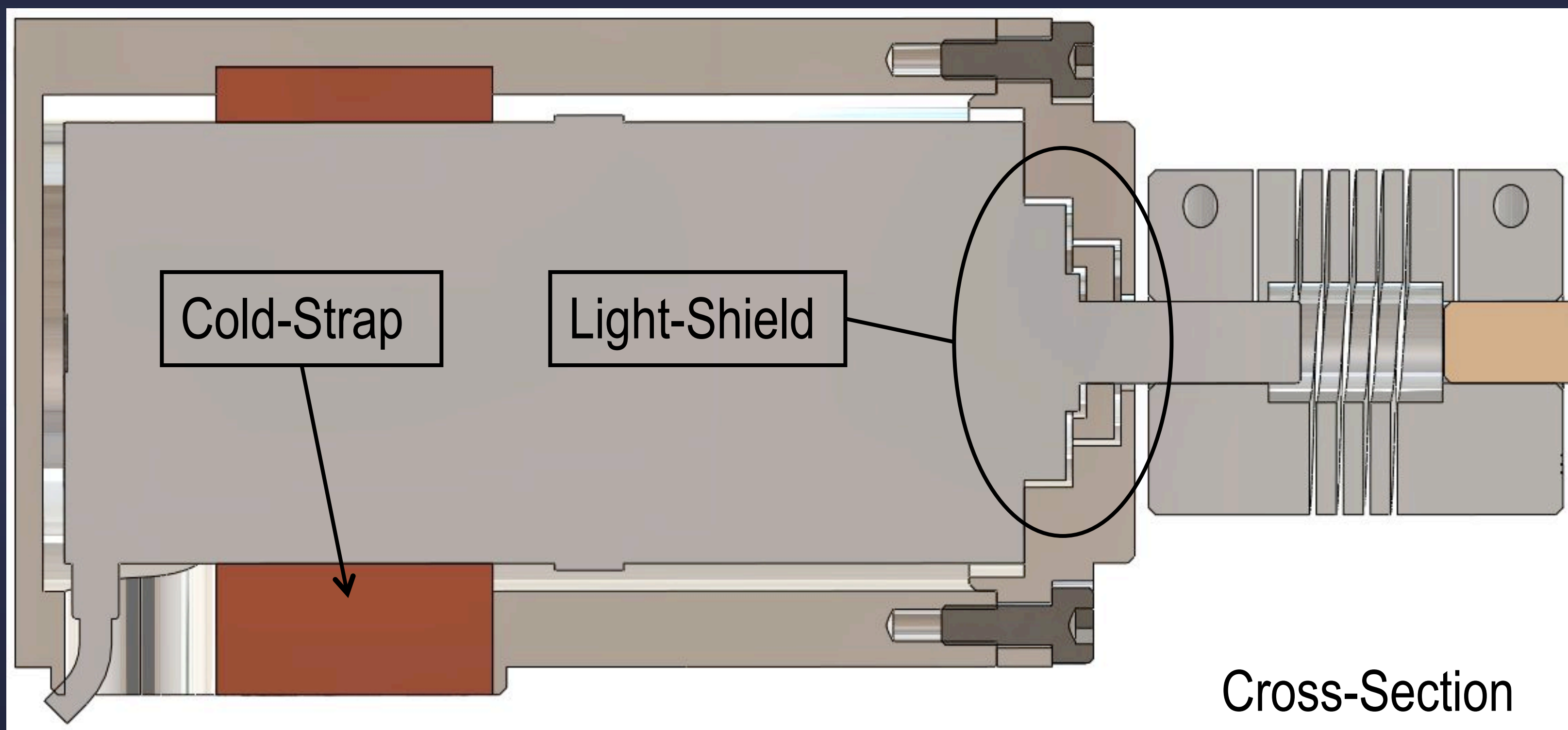
DAPM: Filter Wheel Mechanism



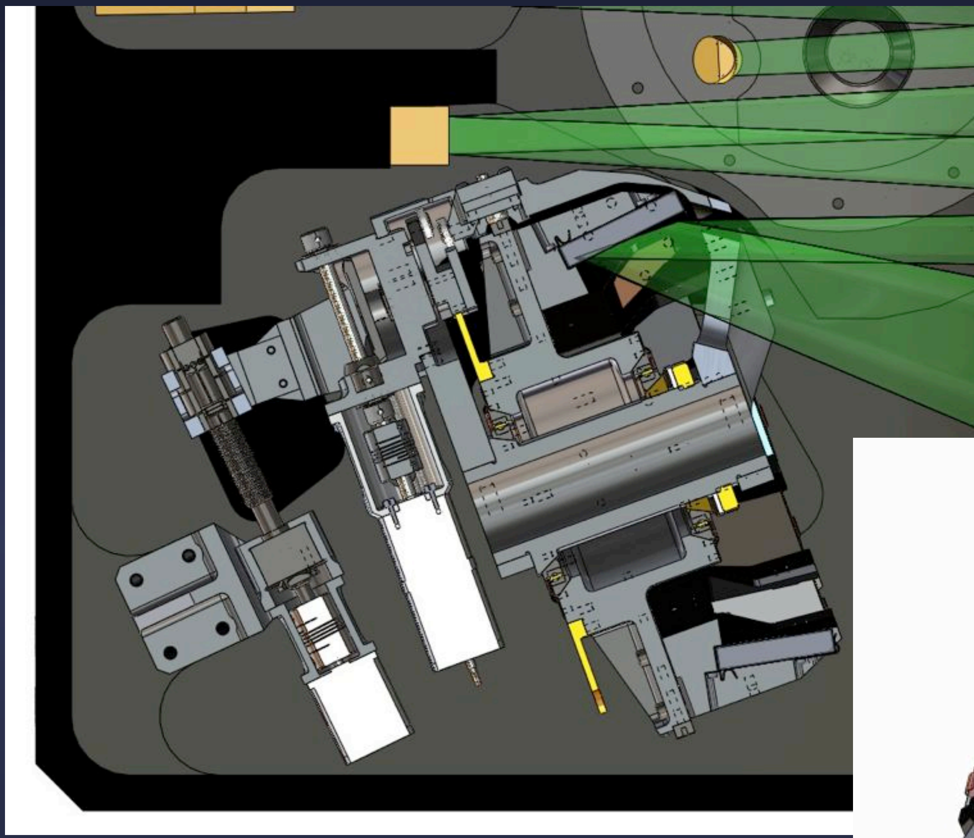
- Filter Cells Facilitate swap/replacement of filters
- 3-point support = Statically Determinate
- 2 different Cells with 2 different angles (Ghost)

DAPM: Filter Wheel Mechanism

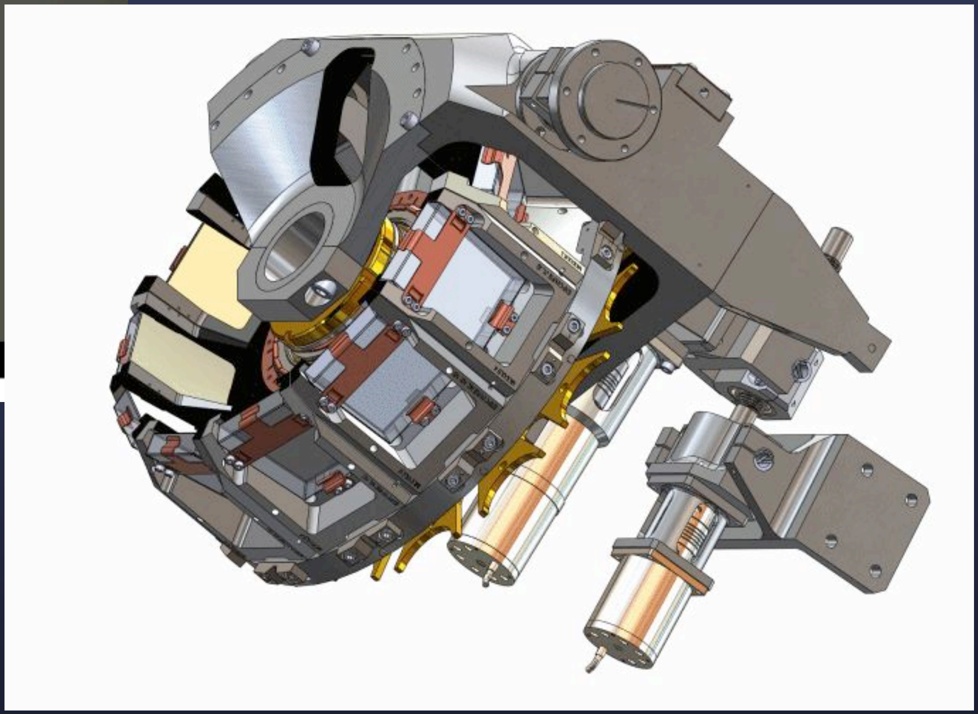
Motor Mount Concept:



DAPM: Cross-Disperser Mechanism

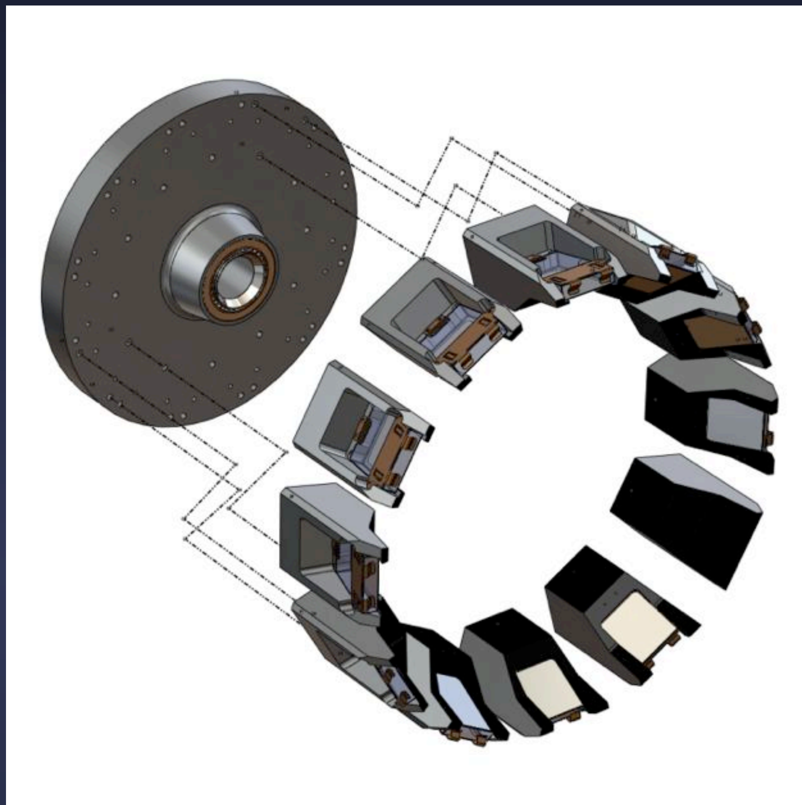


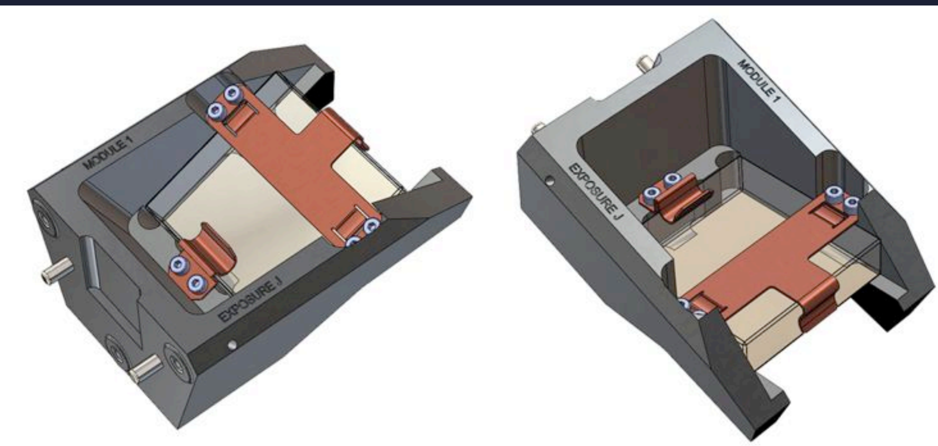
- 12 Discrete Positions (+ Tilt)
- Gearing: 3:1 Bevel +
  4:1 Phytron Planetary Gear



- Grating angle to wheel optimized to reduce overall diameter while clearing the bearings mount

DAPM: Cross-Disperser Mechanism



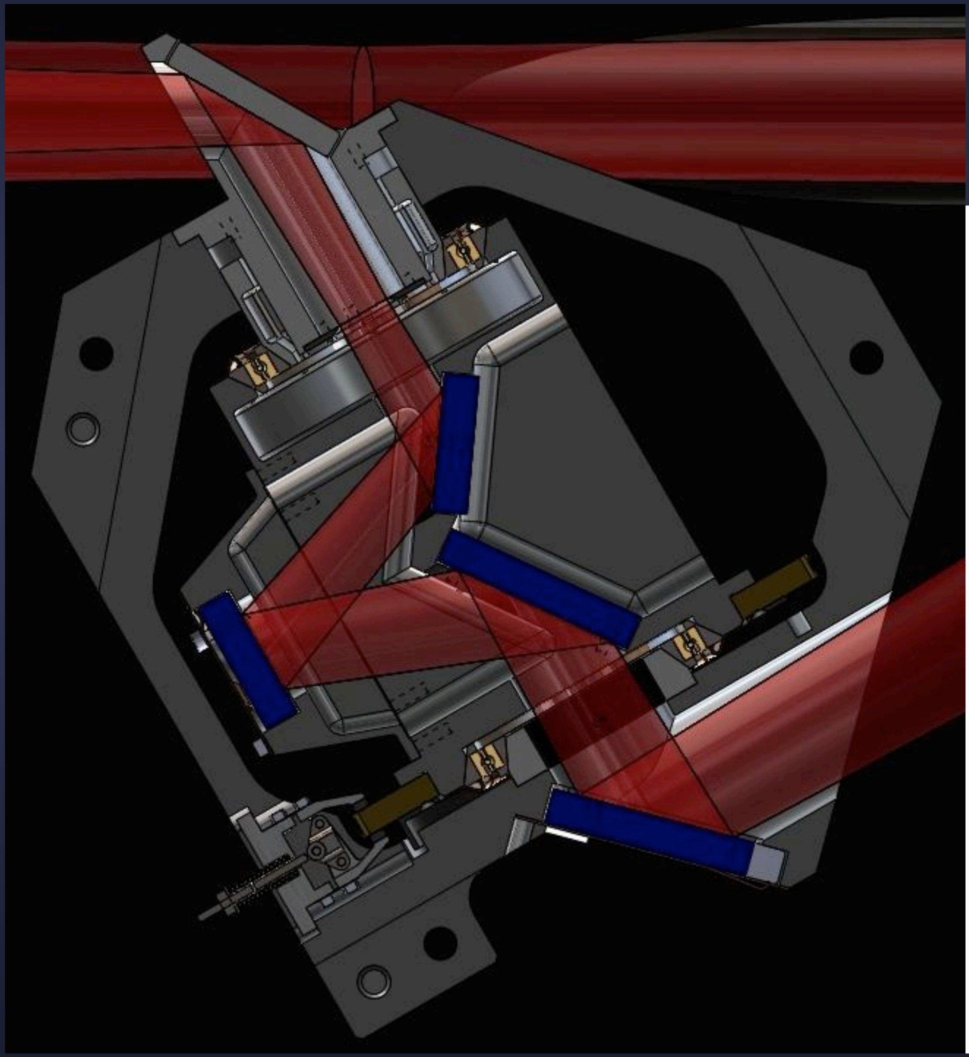


- Gratings are mounted in removable modules
- Optics modules are unique but are machined from identical blanks.

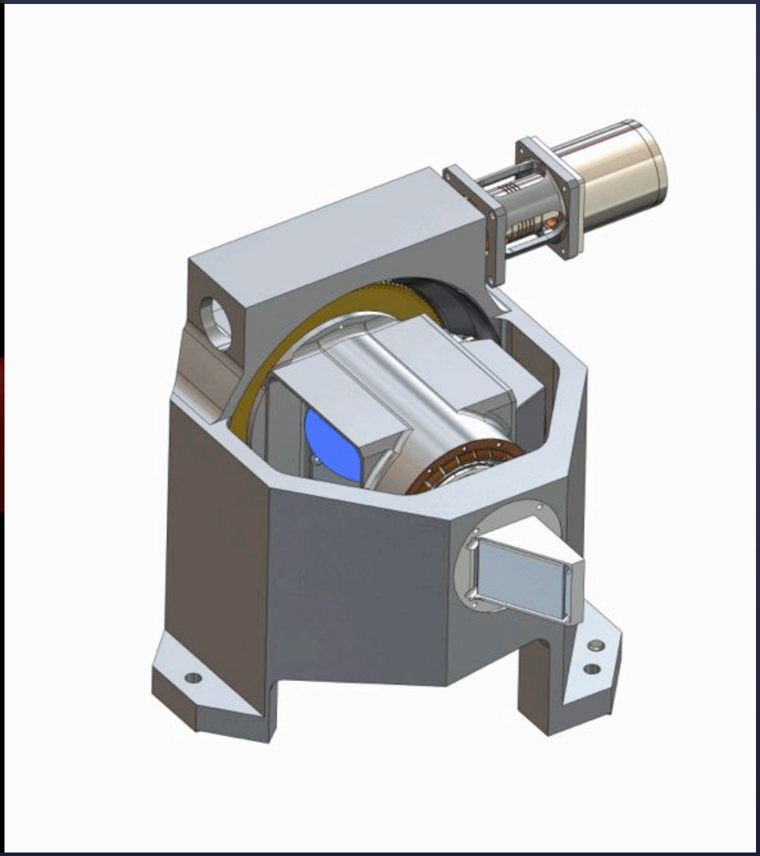
- Each grating is mounted in a module with mounting features that fully support the grating without over constraining it.
- The grating modules have no provisions for tip/tilt adjustment. One-time adjustments may be necessary by machining optics mounting surfaces.

CONTINUOUS ANGULAR POSITION MECHANISMS (CAPM)

CAPM: Image Rotator

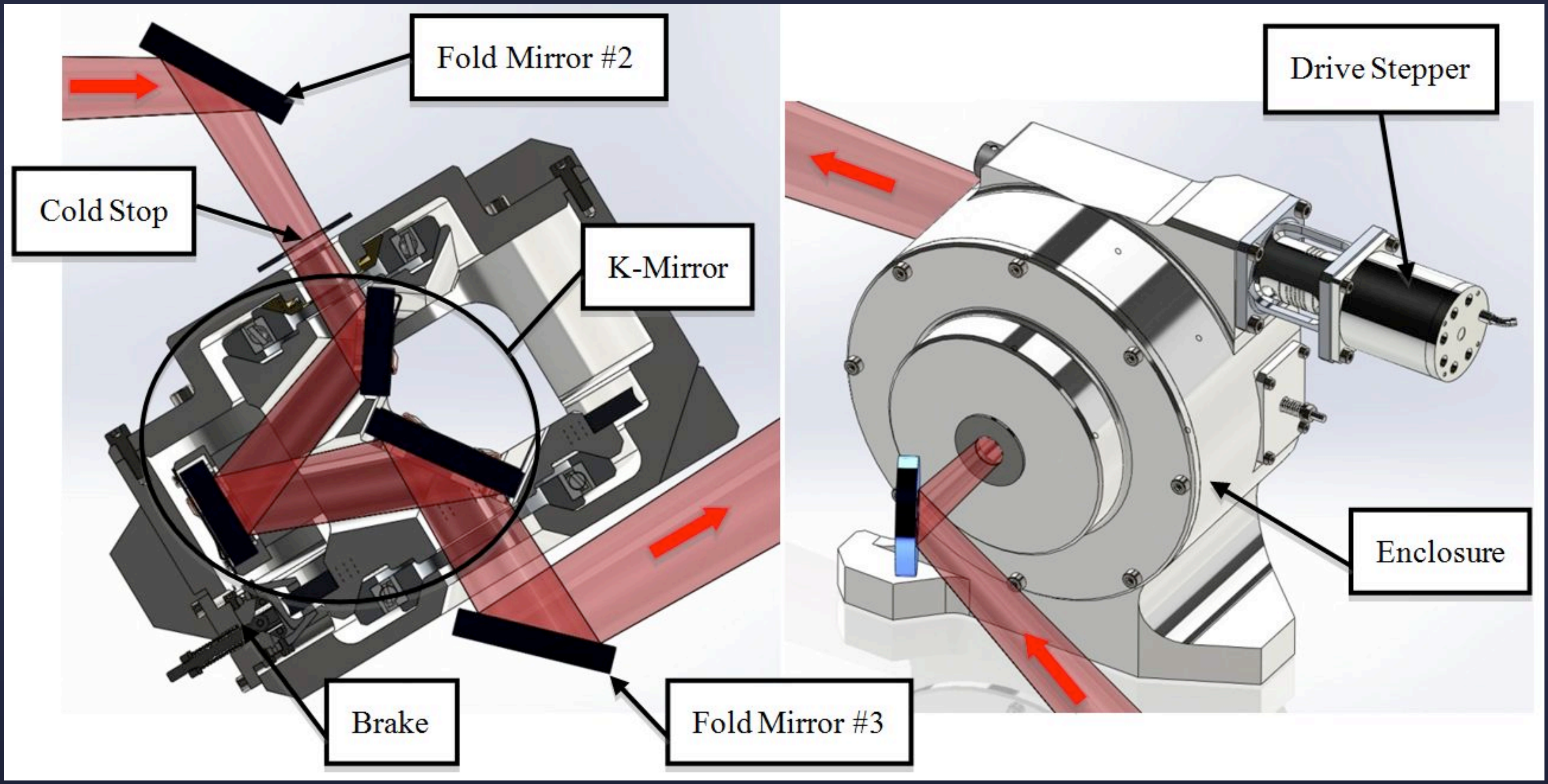


- Designed by G. Muller
- <u>First Concept</u>



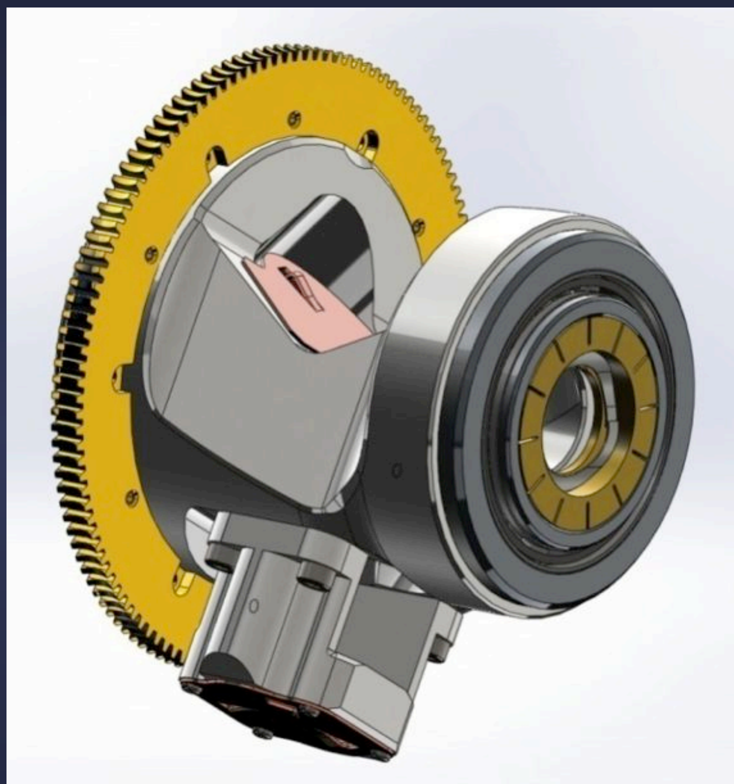
CAPM: Image Rotator

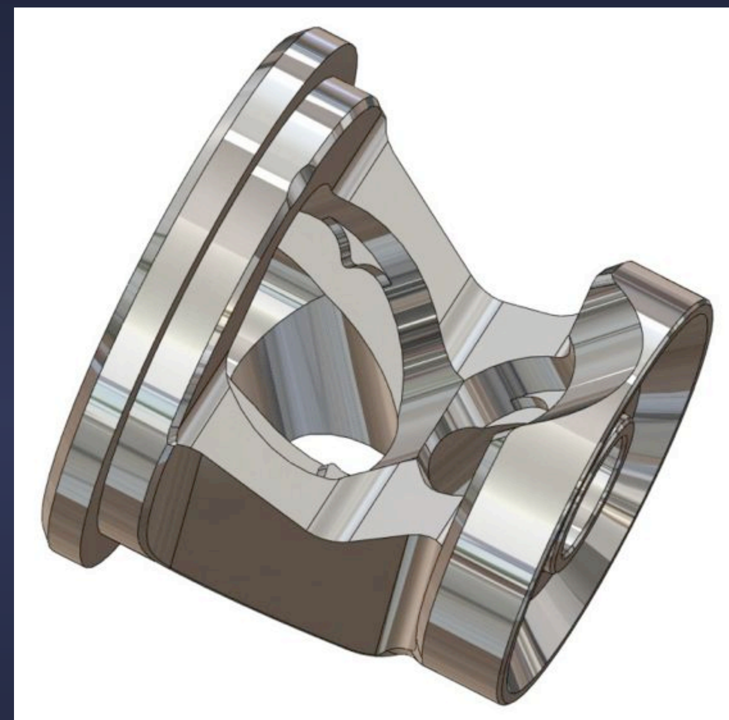
New Concept: 2 Folds and Cold Stop separated to facilitate Alignment



CAPM: Image Rotator

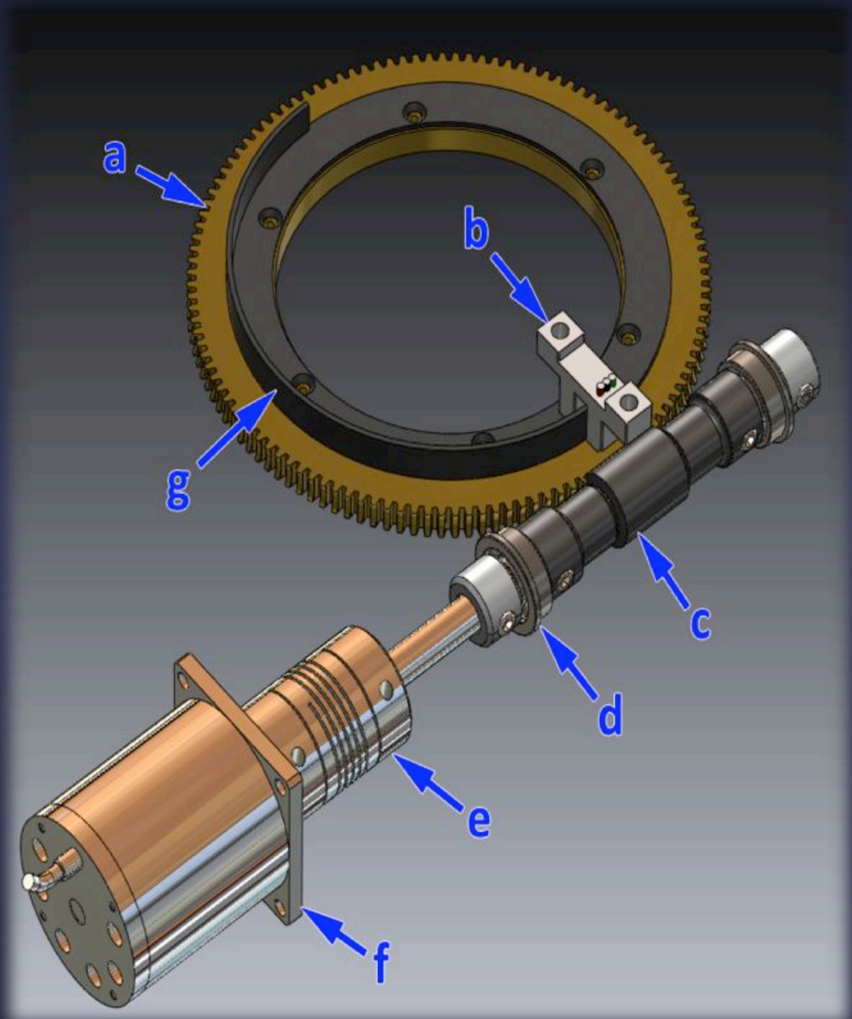
K-Mirror Assembly and K-Mirror Hub:





Note: The middle mirror of the K-mirror assembly is separated from the main hub because it would be very difficult to fabricate as one part.

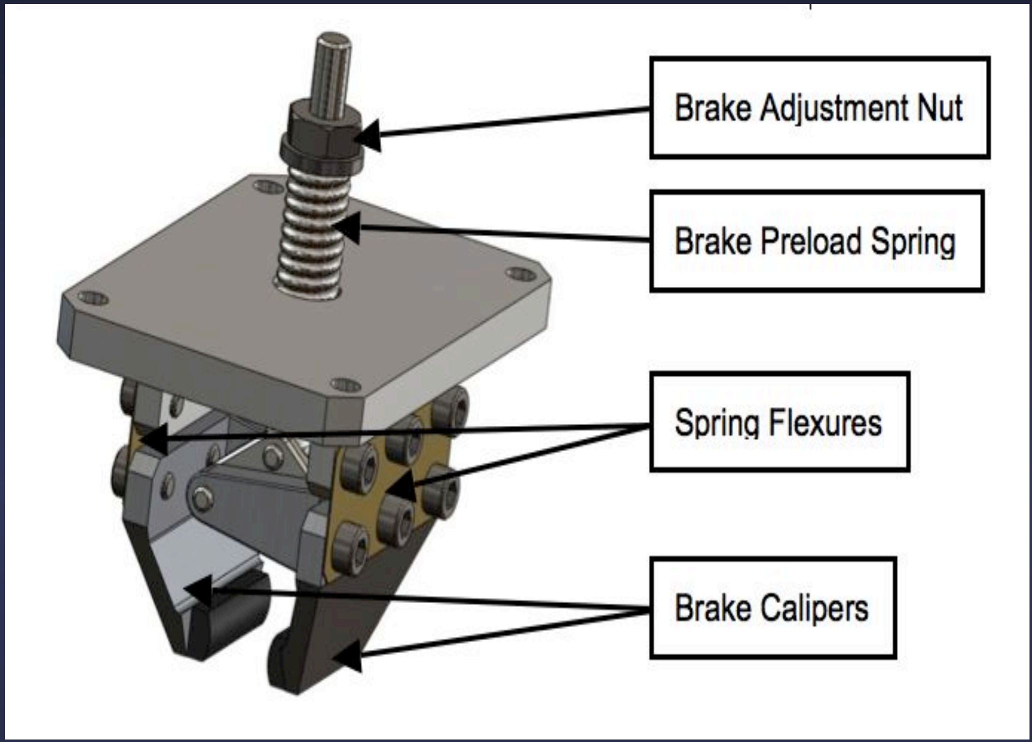
CAPM: Image Rotator Drive



a) 120 tooth brass worm gear
b) Hall effect sensor
c) Vespel worm
d) Drive shaft bearing
e) Flex coupling
f) Stepper motor

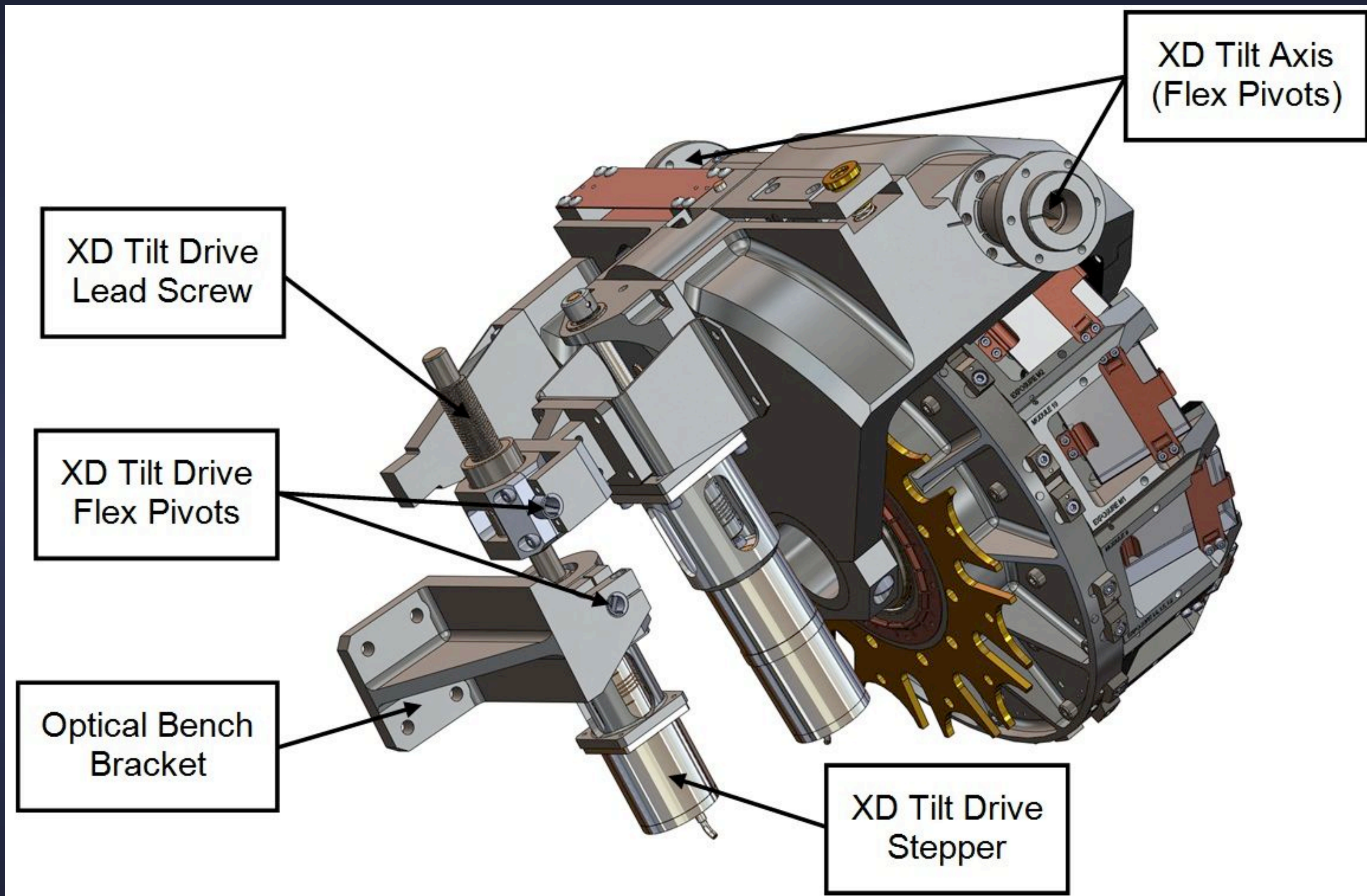
- Home position determined by state change of Hall-effect sensor (i.e. sense to not sense, but not vice versa)
- Count steps from home to determine position (Requires initialization procedure at startup)

CAPM: Image Rotator Anti-Backlash Feature



- The brake straddles the worm gear similar to a bicycle brake and provides a clamping force via a compression spring.
- The braking force is adjustable by adjusting the compression spring preload

CAPM: Cross-Disperser Tilt Mechanism



CAPM: Cross-Disperser Tilt Control

- Choice of a type of position sensor:

1. Hall Effect Sensor (F.W. Bell FH-301-040) : ☐

Pros	Cons
- Price - Already implemented in SpeX - Passive Sensing. Can be used simultaneously with Detector Readout.	- Unknown Accuracy ⇨ Too much effort needed to quantify at the level of accuracy required. - Range is limited. "Physical range reduction trick" (*) isn't applicable. - No package or mount included. - Potential irregular magnetization

2. Eddy Current Sensor (Kaman DIT-5200L / 20N): ☑

VS

Pros	Cons
- Known accuracy. - Comes as a set: Sensors + Electronics. - Extremely Linear. - Range can be tuned using a "Physical range reduction trick". (*) - Easier to implement	- Price. - Needs Coax cables. - Active sensor: can perturb detector readout. - Needs 10/15 minutes to warm up and give reliable data after turning it on => RF switch needed.

(*) The "Physical Range Reduction Trick" Can only be used with an active sensor and a passive target (aluminum). See Next Slide.

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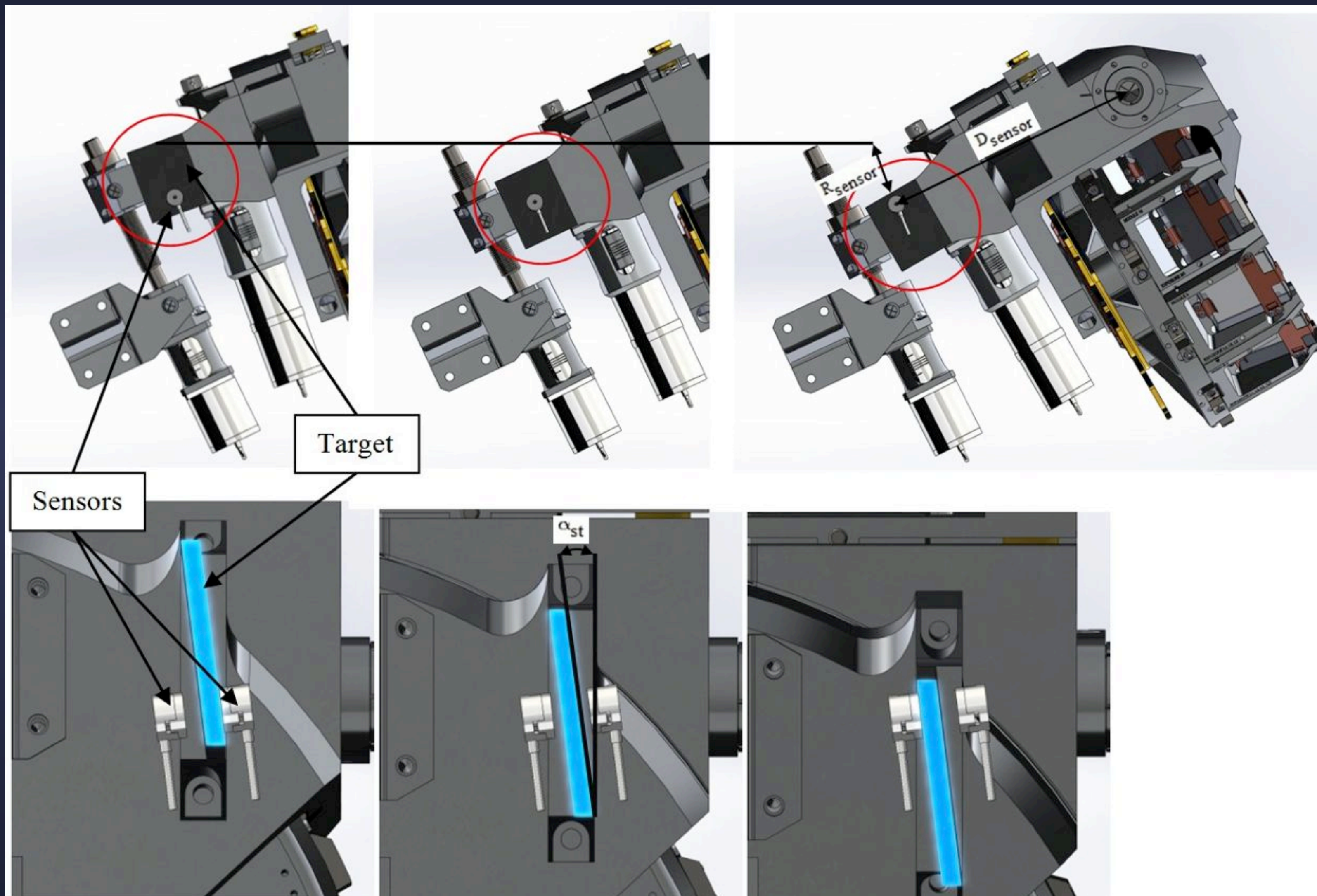
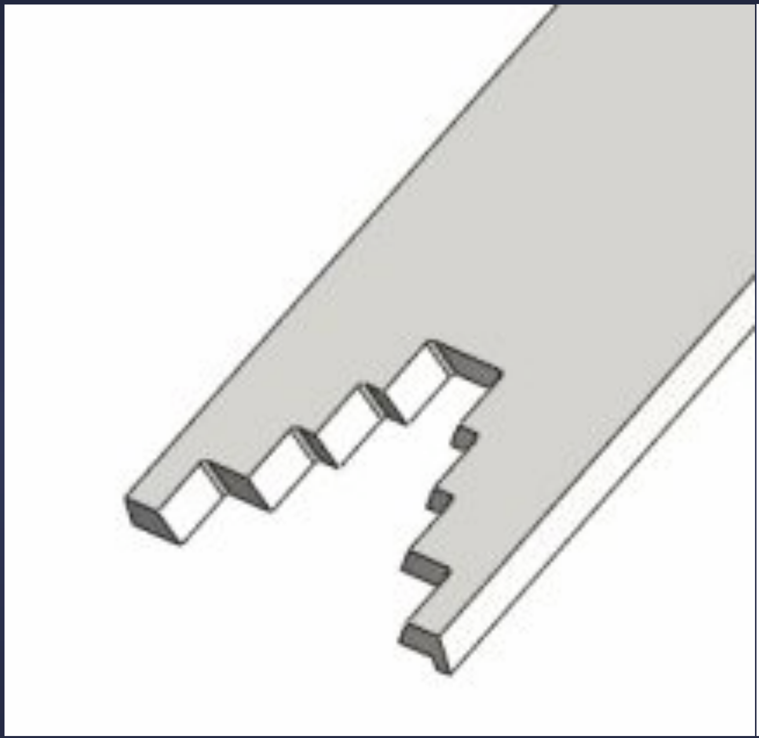
CAPM: Cross-Disperser Tilt Control

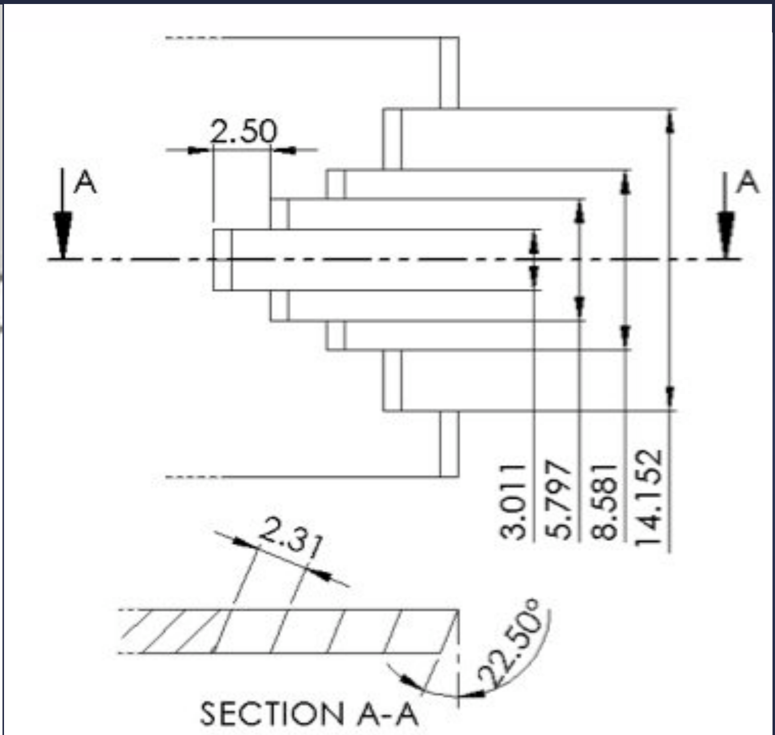


DISCRETE LINEAR POSITION MECHANISMS (DLPM)

DLPM: Dekker Mechanism

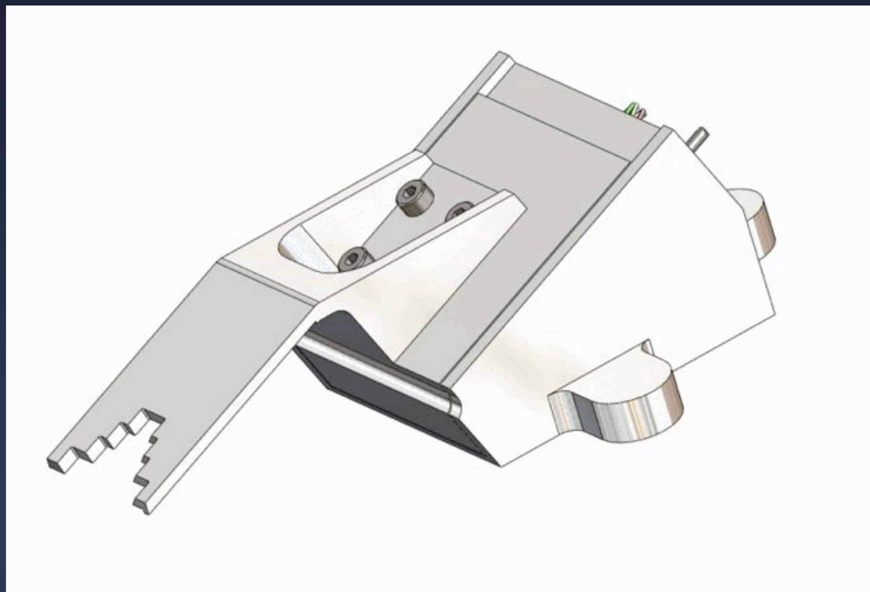
Mask Shape and Dimensions:





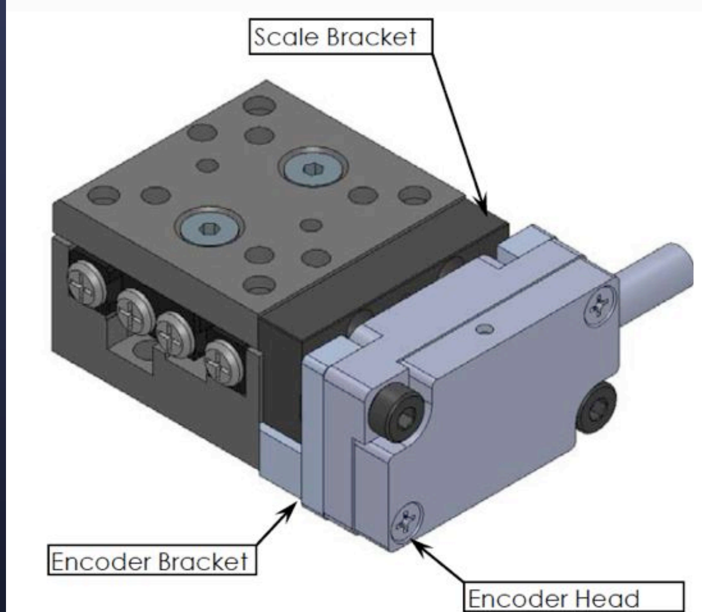
- 4 ≠ Slit Length
- Step width > widest slit to decrease accuracy requirement on X.
- 22.5deg inclination of the opening to be // to the beam.

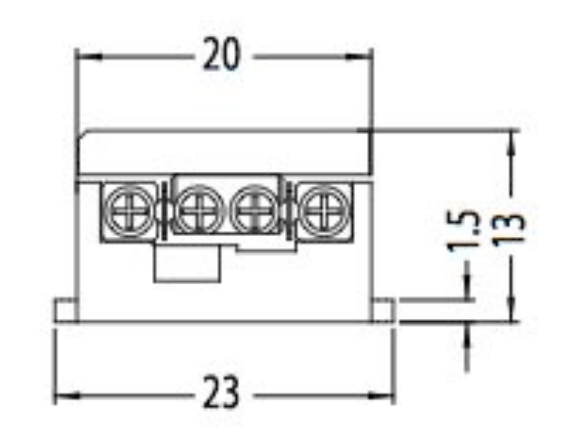
DLPM: Dekker Mechanism



First Concept:

- Off-the-Shelf Piezo-Stage with Encoder (Cryogenic rated)
- Miniature Design
- Light-tight enclosure of the piezo-stage.

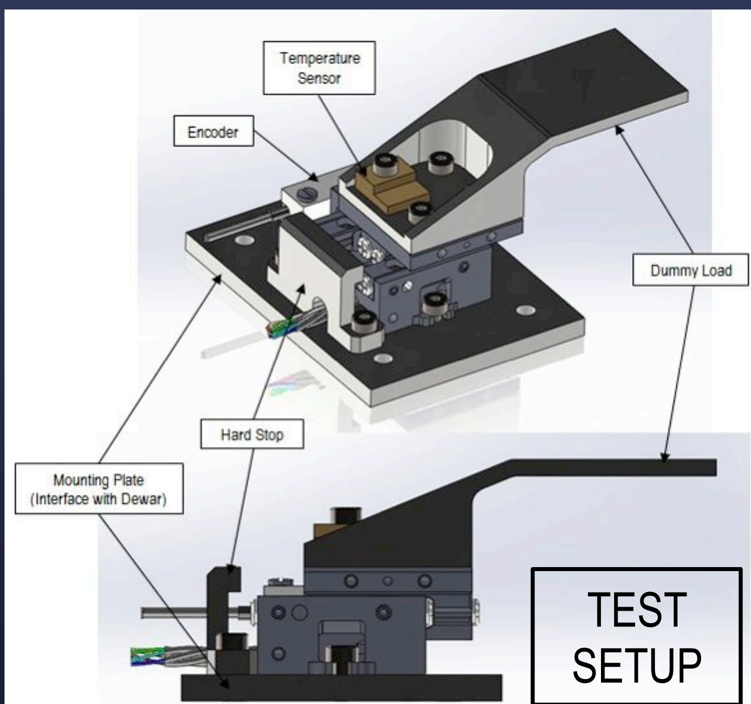


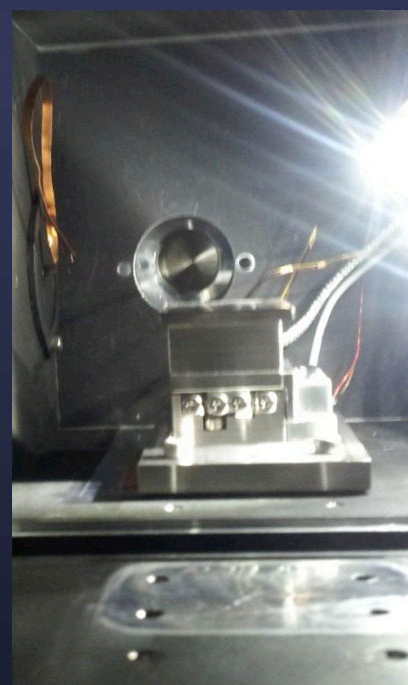


(dimensions in mm)

DLPM: Dekker Piezo-Stage Testing

- Refurbished an old instrument into a test dewar.
- Test plan includes cryo& vacuum test, position hold test, re-initialization test, hard-stop test and Lifecycles.
- First and second tests unsuccessful. No movement at 77K. Still troubleshooting with Vendor.





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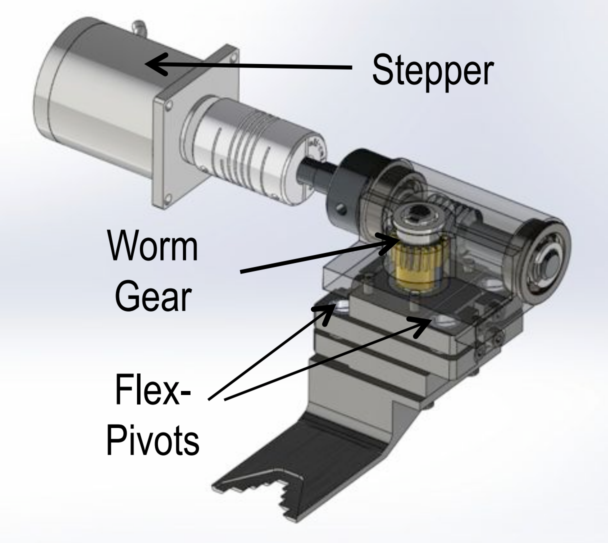
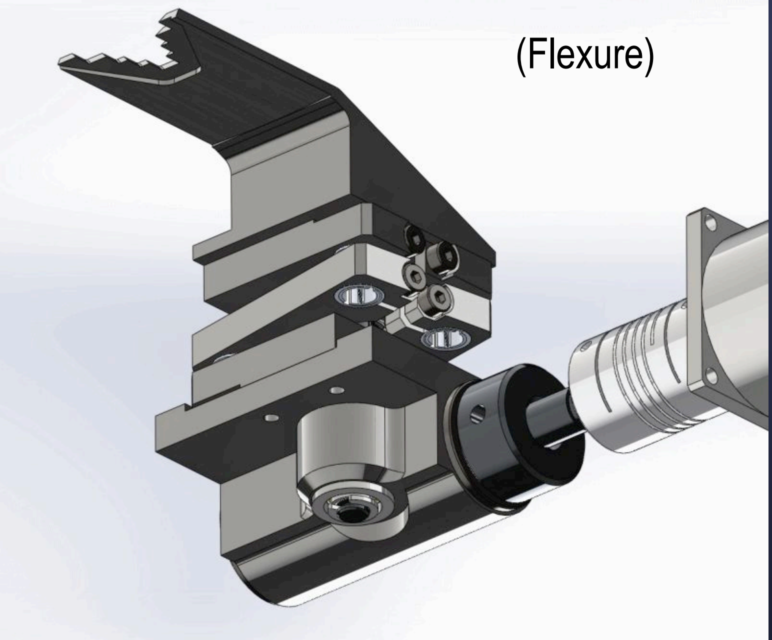
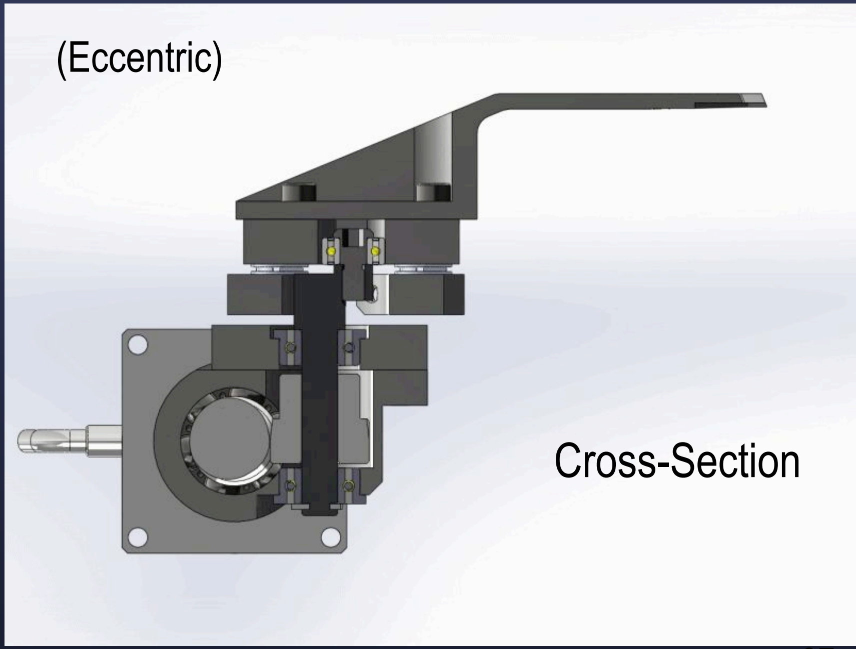
DLPM: Dekker Piezo-Stage Alternative Concept

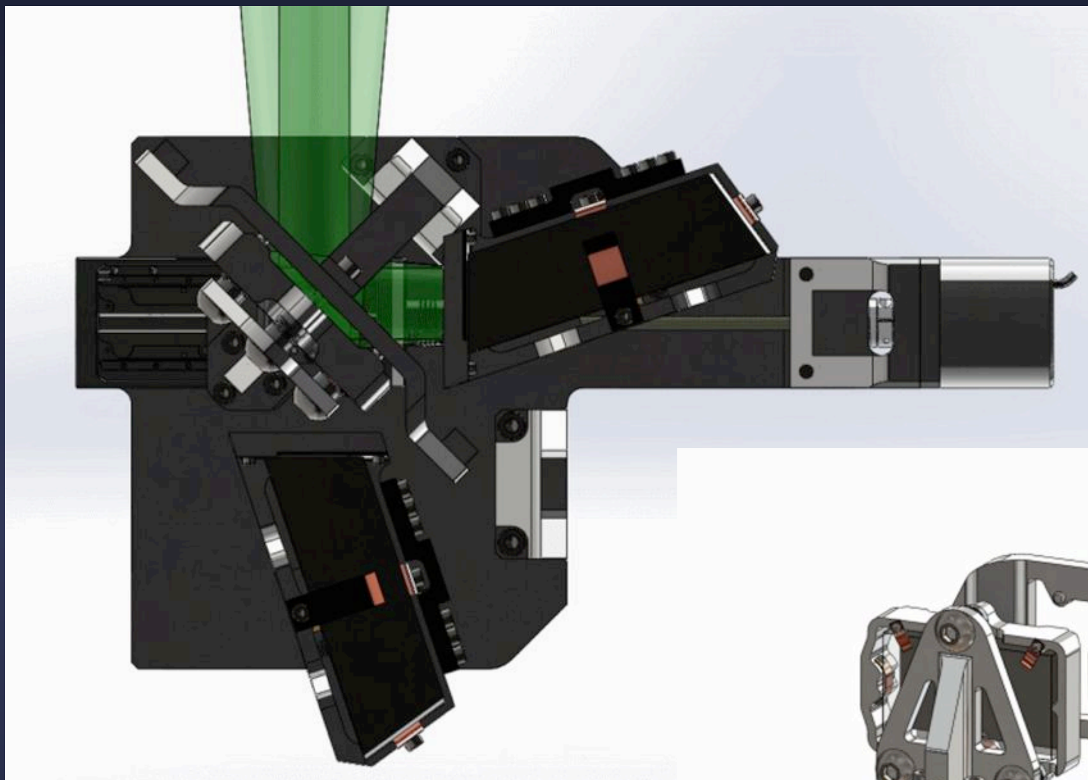
- Flexure Stage designed using Flex-Pivots.
- Powered using a Stepper + Worm Gear + Eccentric Cam.





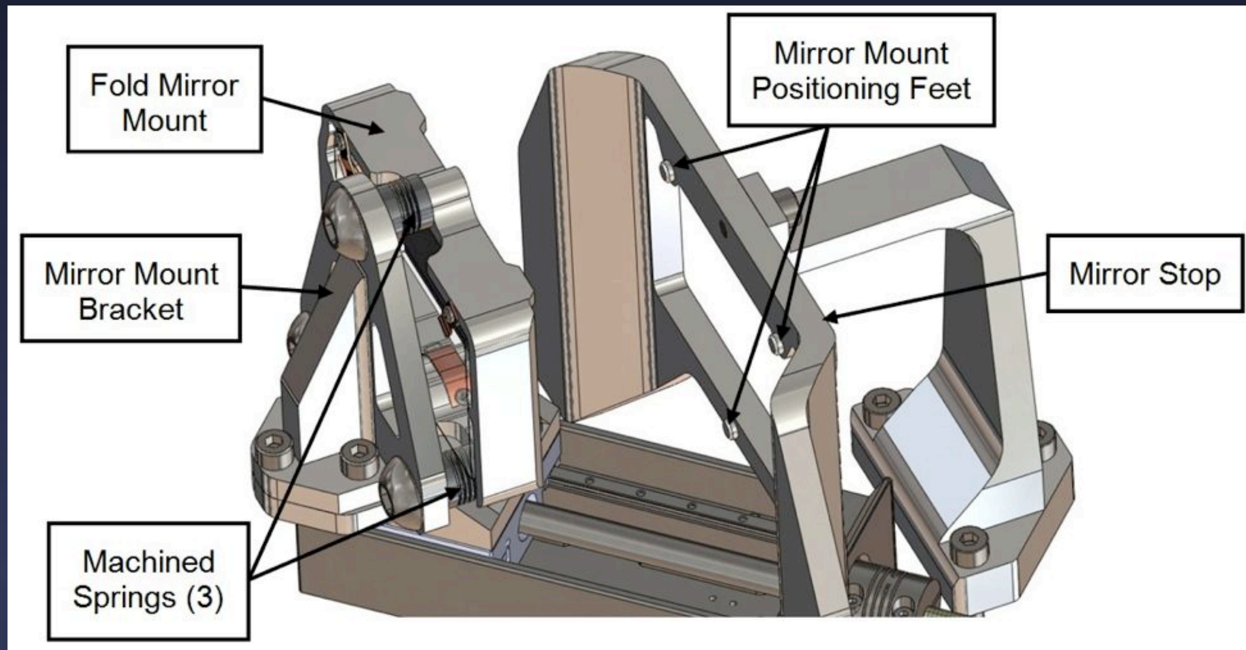


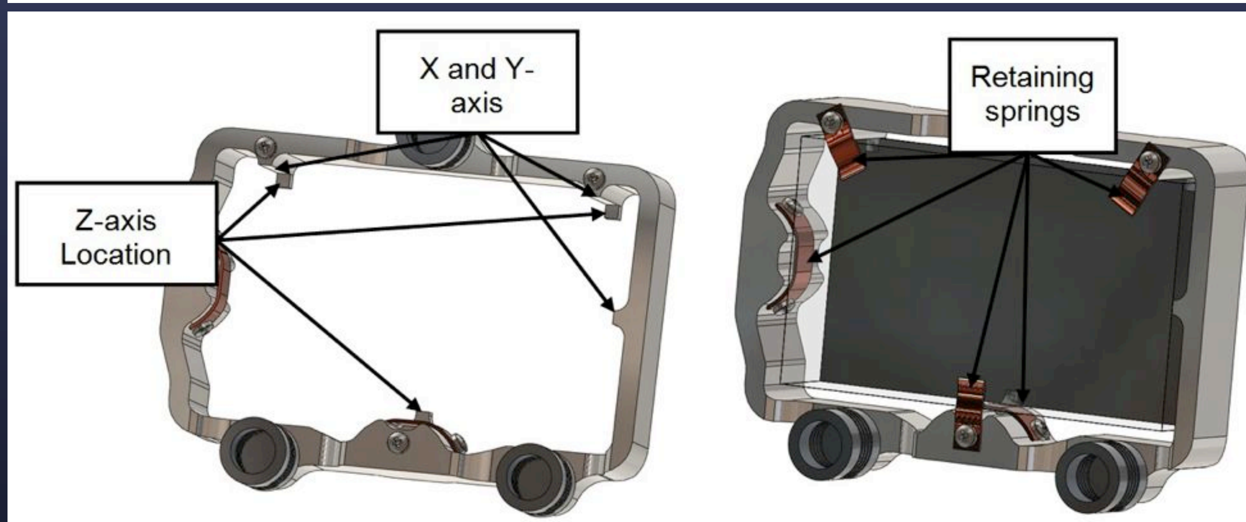
DLPM: Immersion Grating Mechanism



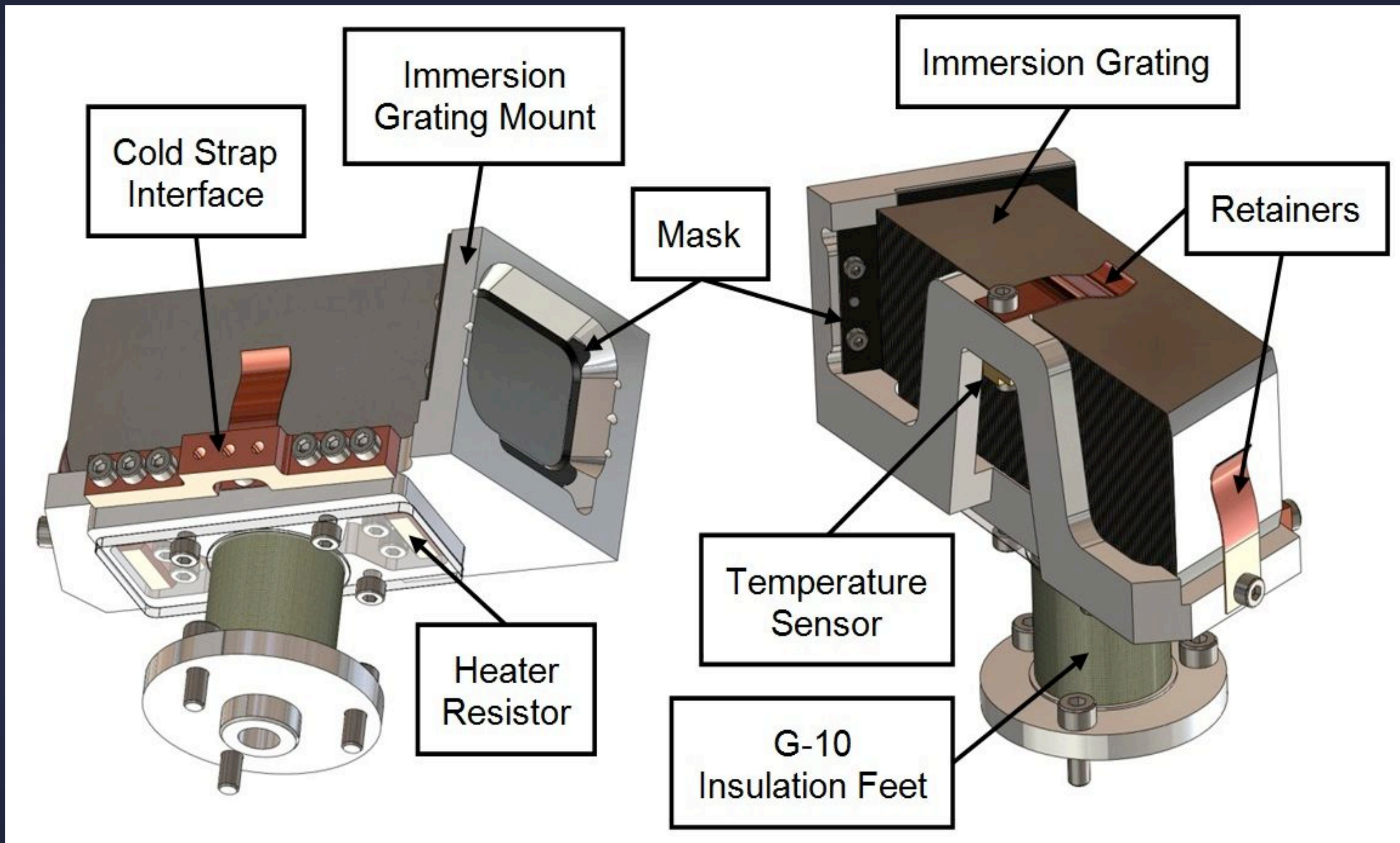
- Light-tight motor mount
- Mounting Sub-plate
- Preloaded Mirror Mount
- 45deg stage due to available Space

DLPM: Immersion Grating Mechanism



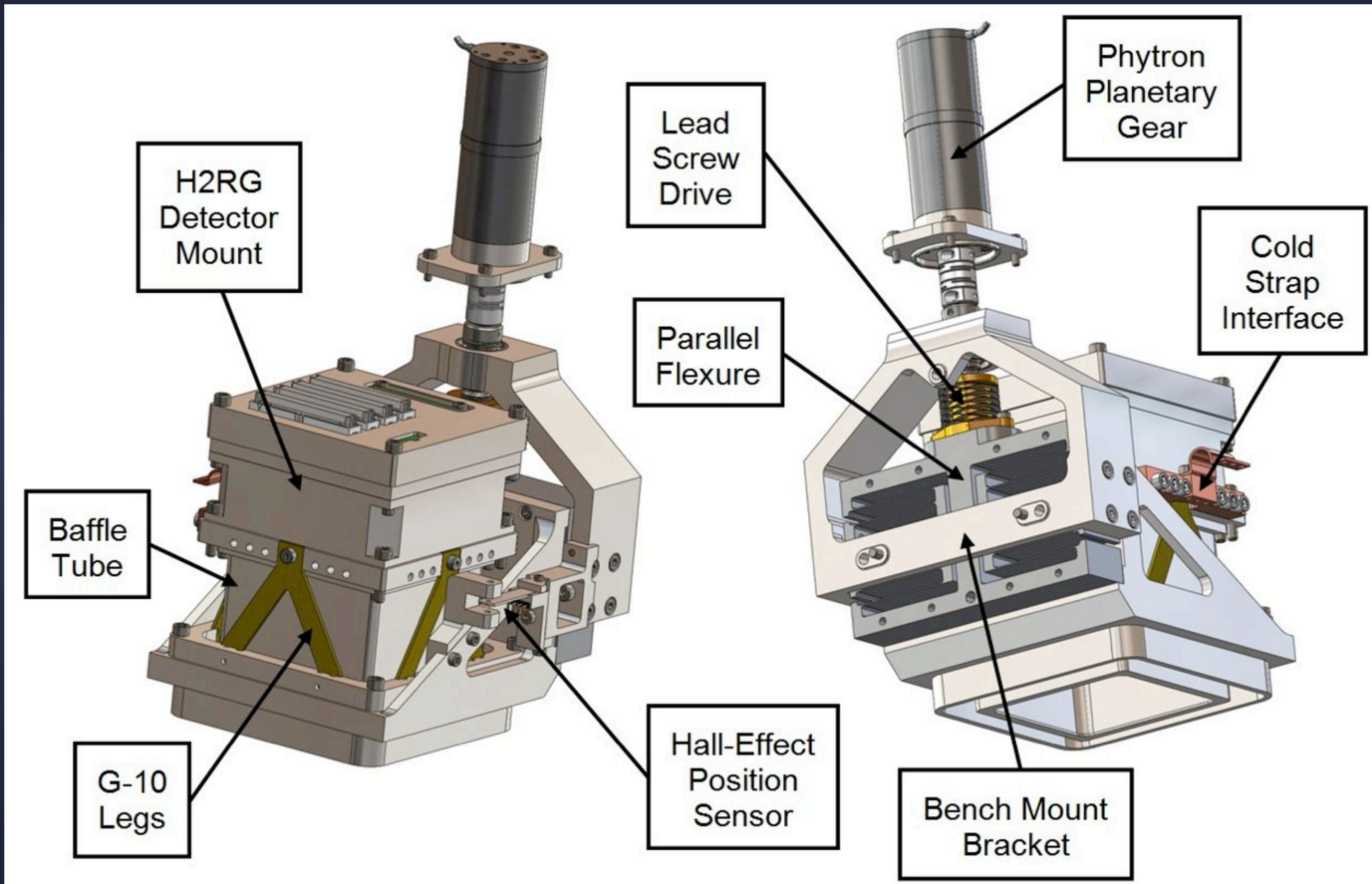


DLPM: Immersion Grating Mechanism

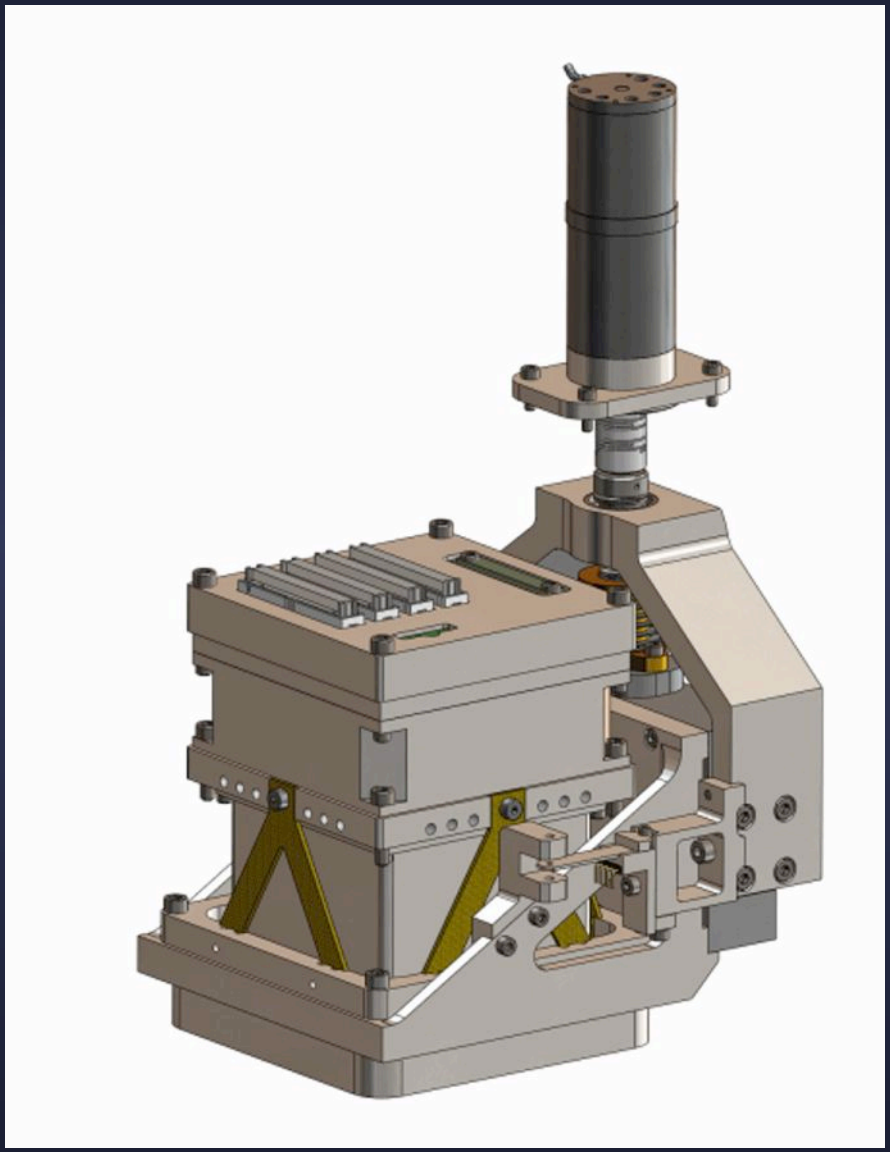


CONTINUOUS LINEAR POSITION MECHANISMS (CLPM)

CLPM: Detector Mount and Stage

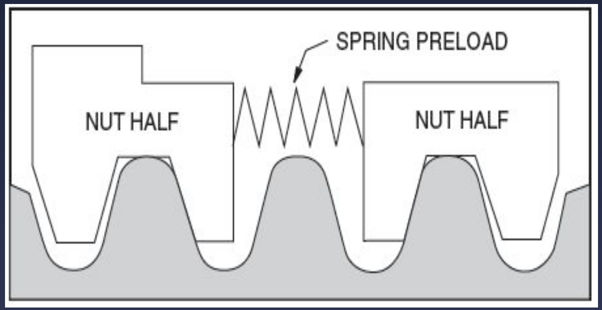


CLPM: Detector Mount and Stage



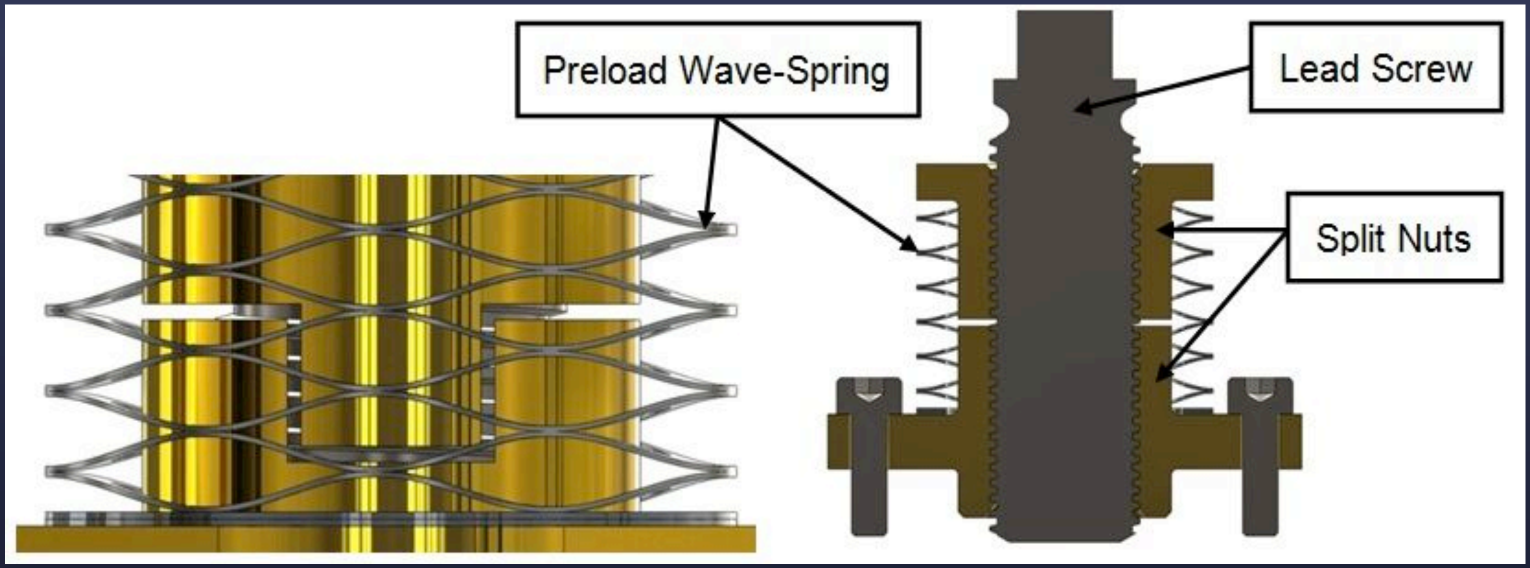
- Focus Stage Design based on SpeX Flexure-Stage but with simplified gearing (off-the-shelf planetary) and improved anti-backlash system.
- “Configuration Board” for ARC controller cabling

CLPM: Detector Focus Stage



Anti-backlash System:

- Split-Nut preloaded with wave-spring
- Nuts shaped to stop relative rotation
- Preload > Flexure Axial Force + Moving Load



CLPM: Detector Mount and Stage

H2RG Mount with New Configuration Board: