ECX SRF Cavity Tuner Design:
Outline for ECX Final Design Review

- Design Basis:
  - Cavity Parameters and Calculations
  - RF Tuning Performance Criteria
- Tuner Overview
  - Design Concept, Components and Schematic
  - Coarse Tuner Drive and Kinematics
  - Analyses for Tuner Optimization
  - Fine Tune Actuator Overview
  - FTA Selection
- Conclusion
  - Views of Tuner Assembly on Cryomodule
  - Related Mechanical Design Considerations

DESIGN BASIS:
Important Cavity Parameters & Calculations

- RF Cavity design 703.75 MHz
- Calculated Tuning Range 475 kHz *
- Calculated Tuning Coefficient 100 Hz/μm ± 10
- Maximum Cavity Displacement 4.75 mm
- Calculated Cavity Stiffness 6.84 kN/mm
- Maximum Load at cavity 32.5 kN

* based on b(proton)=27GeV, b(gold)=250GeV; courtesy Jorg Kewisch

DESIGN BASIS:
RF Tuning Performance Criteria

- Coarse Tuning:
  - Frequency Range: 475 kHz min.
  - Resolution: 1 kHz max. (10 μm at cavity)
  - Speed: 1 sec/kHz **
  - Duty: intermittent (8 times per day)

- Fine Tuning:
  - Frequency Range: 2000 Hz min.
  - Resolution: 25 Hz max. (250.0 nm at cavity)
  - Speed: <10 μsec/Hz ***
  - Duty: continuous

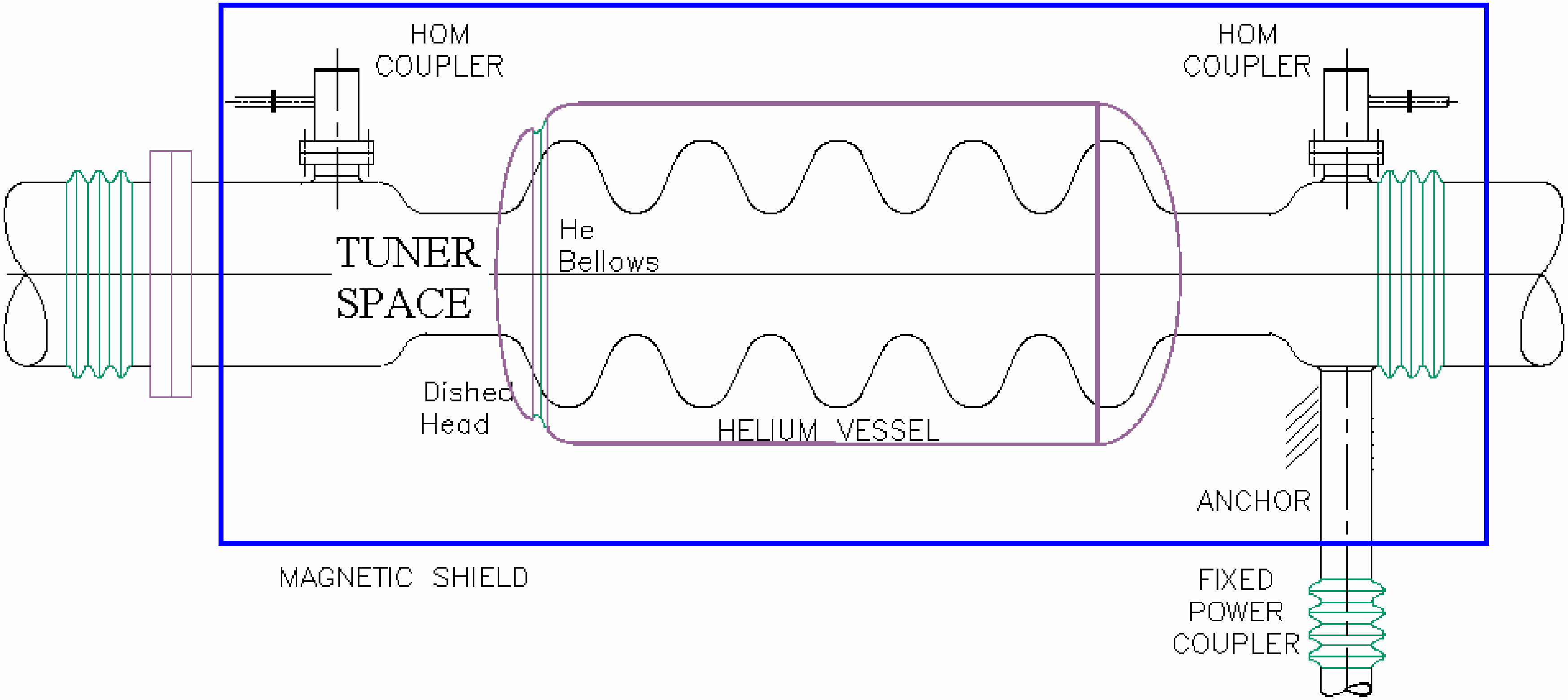
** expected based on reduction ratio & motor selection, limited by torque requirement

*** expected based on FTA selection, limited by FTA inductance

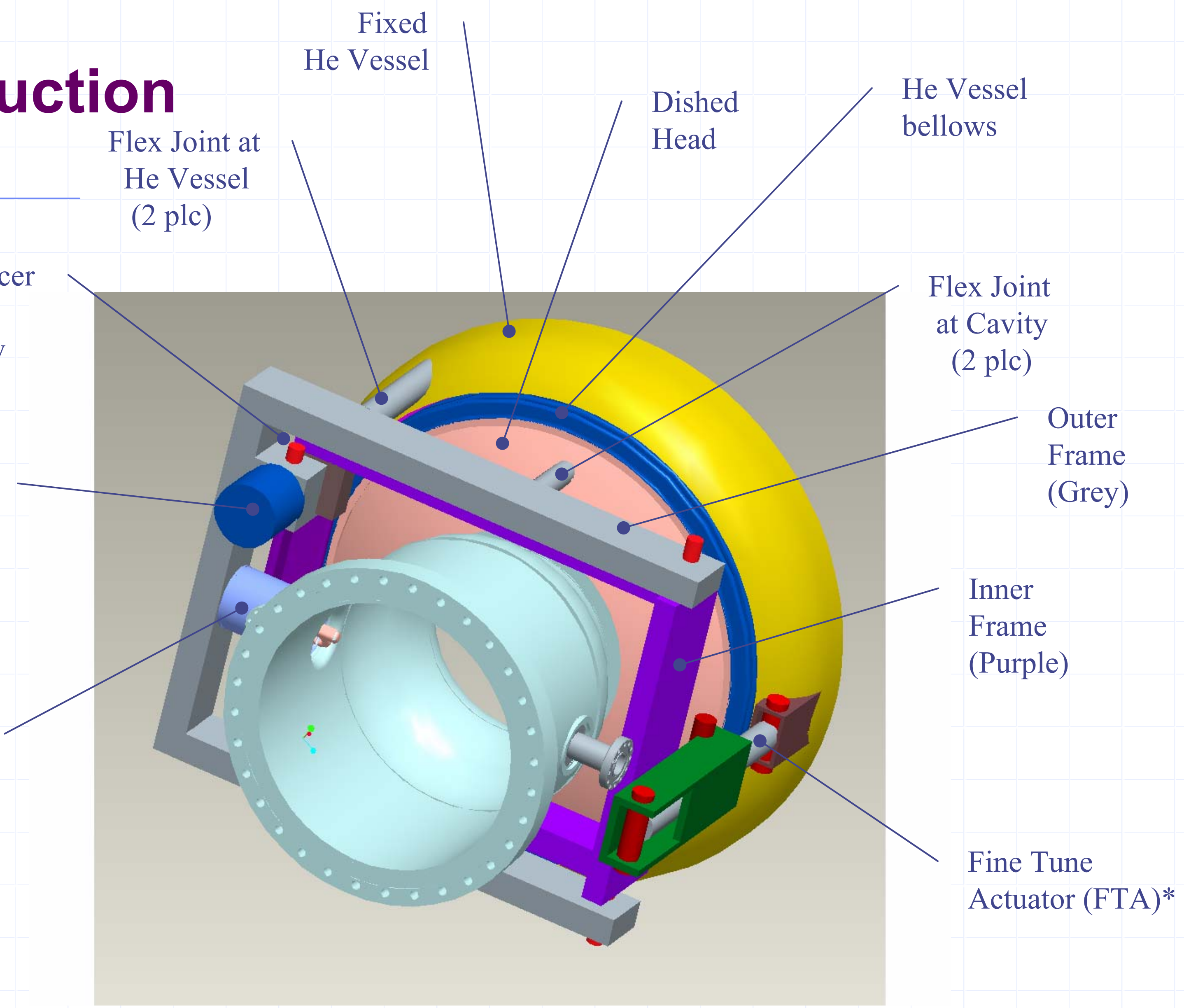
Tuner Mechanism Design Concept

- Adopted from SNS concept with further requirement:
  - 266% longer cavity displacement
  - 368% higher loads
- Tuner Envelope and Orientation:
  - aligned at angle of HOM at opposite end from power coupler
  - in vacuum space between helium vessel and magnetic shield
- Cavity Support Scheme:
  - power coupler end is fixed (all DOF constrained)
  - tuner end is guided (translational DOFs coupled to tuner)
- Tuner mechanism reacts compressive load in cavity:
  - pushes on dished head, pulls fixed helium vessel
  - loading provides inherent anti-backlash

Tuner Envelope within Cryomodule (schematic)



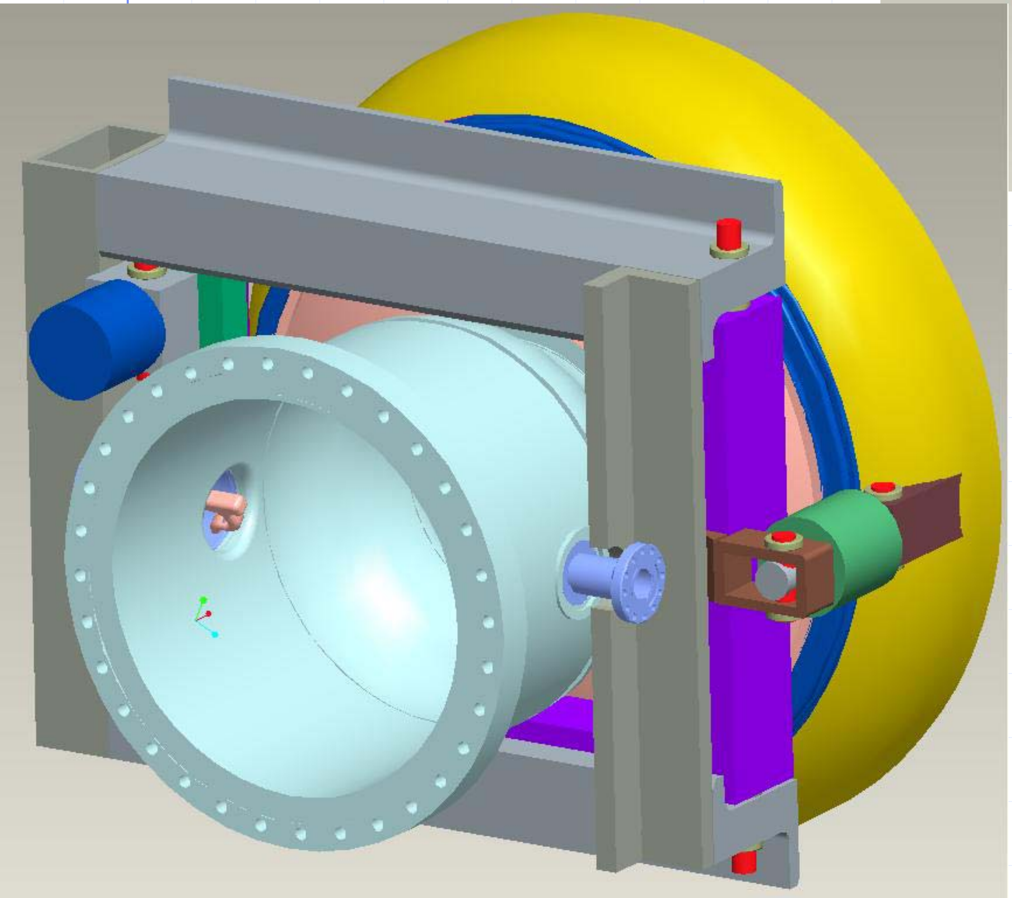
Tuner Construction

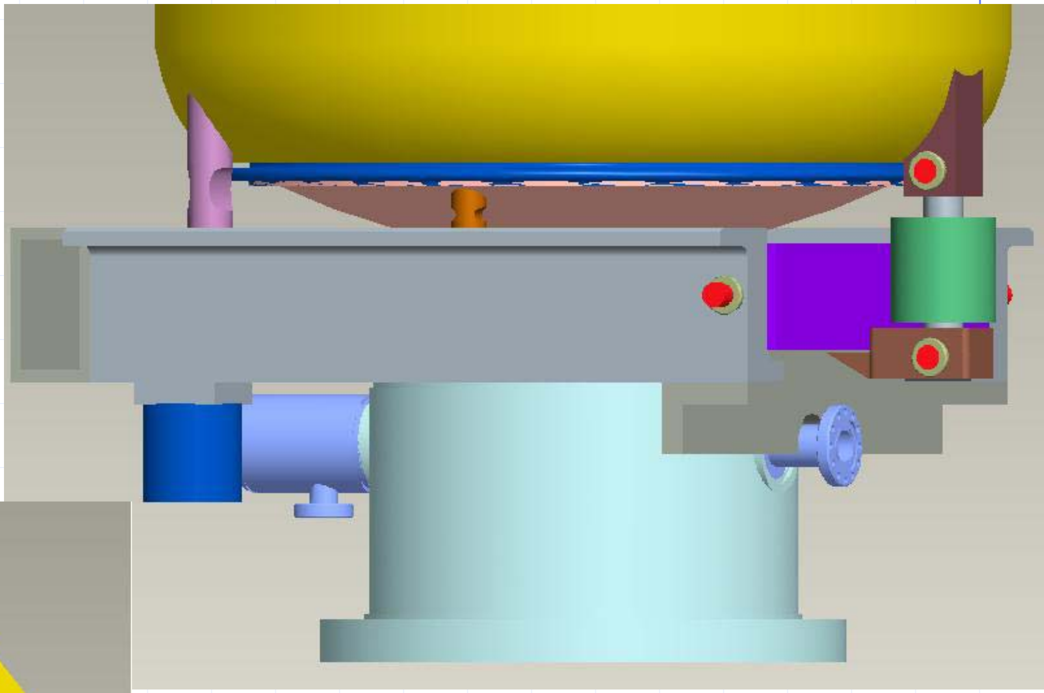


***Shows piezo P-025.200 by physikinstrumente for FTA. Certain hardware removed for clarity. See following images.**

Tuner Assembly

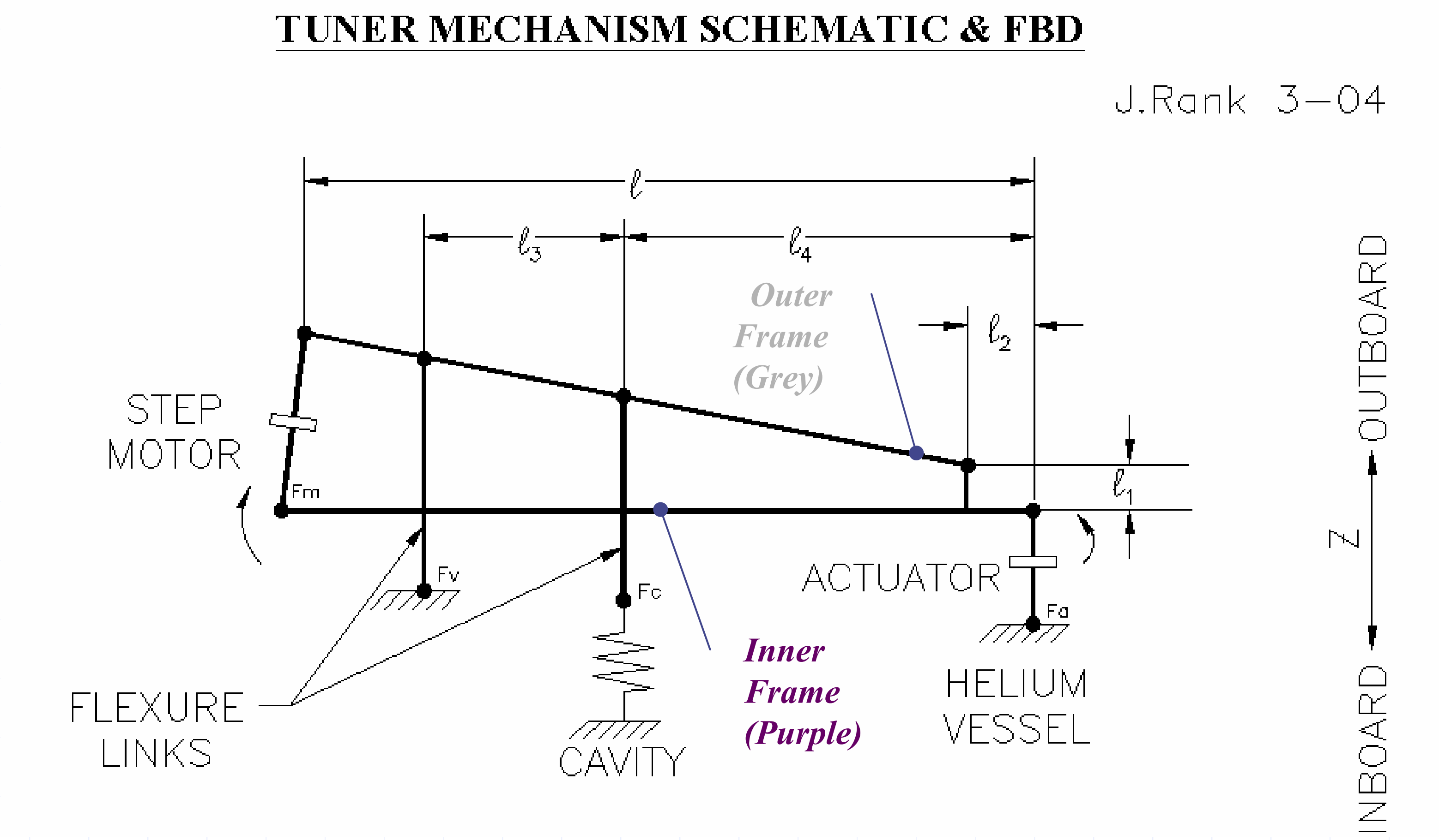
End View
(slightly rotated about Z)





Top View
(slightly rotated about Z)

Tuner Mechanism Schematic



Coarse Tune Mechanism Kinematic Simulation

See Analytix Linkage Program Animation

Coarse Tuner Drive Specifications

- Coarse tune reduction ratio (for 10 μm cavity resolution)
  - 2:1 lever advantage
  - ~1.18:1 bi-directional displacement reduction (non-linear)
  - 50:1 planetary reducer head
  - Lead Screw Pitch: 6 TPI
- Drive System Specs
  - 200 steps/rev gives net ~100 Hz/step
  - 3/4" dichronited power screw
  - 16.8 kN load applied at power nut
  - design for 1.0 kN-mm torque
- Stepper Motor
  - 60 mm frame Slo-Syn KM063 bipolar stepper
  - Radiation Resistance: > 10^8 rads
  - special cryo-rated; conduction cooled by heat sink braid (4K)

Analyses Performed for Tuner Optimization

- Analyses of Tuner Structure:
  - Kinematic: optimized linkage ratio; cavity & flexure lateral loads
  - Stress: first pass FEA optimized frame section to reduce strain
  - Stiffness: SS frame microphonics affect, FTA load characteristic
  - Stress: SS flex joint design within allowable bending + shear
  - Thermal strain: effect on SS flexure & pin joints and Ti mounts
- Design for Life:
  - Coarse Tuner Drive
    - (8 cycles/day)*(365 days/yr)*(20 yrs) = 6.0×10^4 cycles
  - Fine Tune Actuator
    - (60 cyc/sec)*(2.34×10^7 sec/yr)*(20 yrs) = 2.8×10^{10} cycles

Fine Tune Actuator (FTA) Specifications

- Design for Tuning Range: ~ 2000 Hz
  - Required Stroke at Cavity: 20 μm
  - Minimum Stroke of FTA (at 2K): 41 μm
  - Rate: 7.69E+04 μm/sec
- FTA load characteristics
  - 16 KN internal compressive preload to react FTA tensile load
  - 16 KN max load for relaxed cavity; no load for compressed cavity
- Desired controller spec
  - 0-5 VDC on shielded coax cable
  - near linearly proportional output
- Fallback Design: actuator interchangeability
  - short history of custom, higher-preload magnetostrictives (MSTA)
  - largest commercially available piezo (PZT) is required

FTA calc

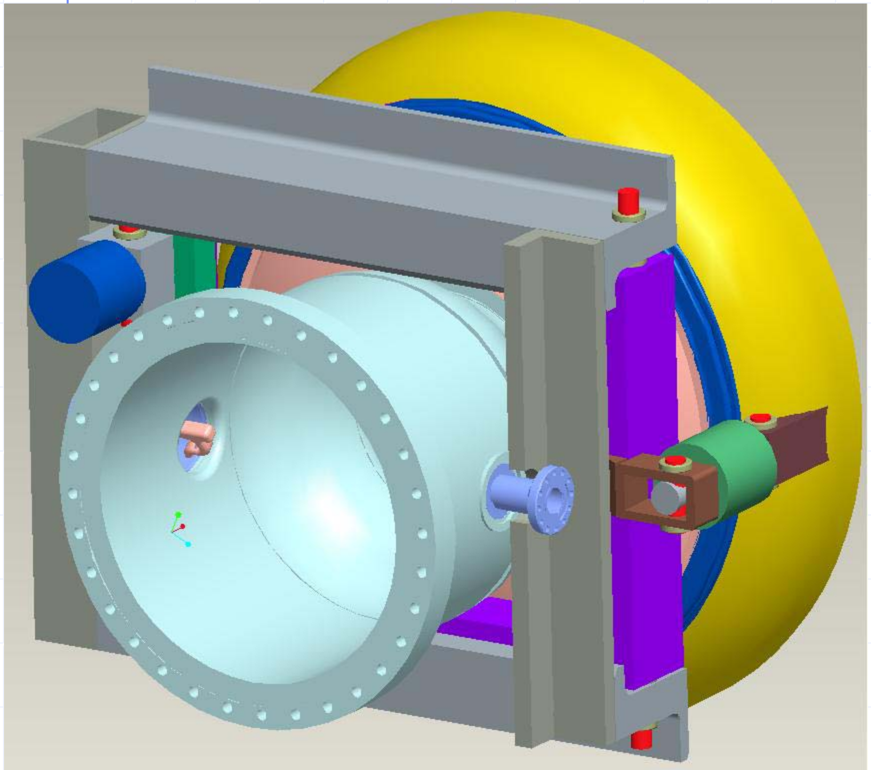
(PZT-025.200 by PI)

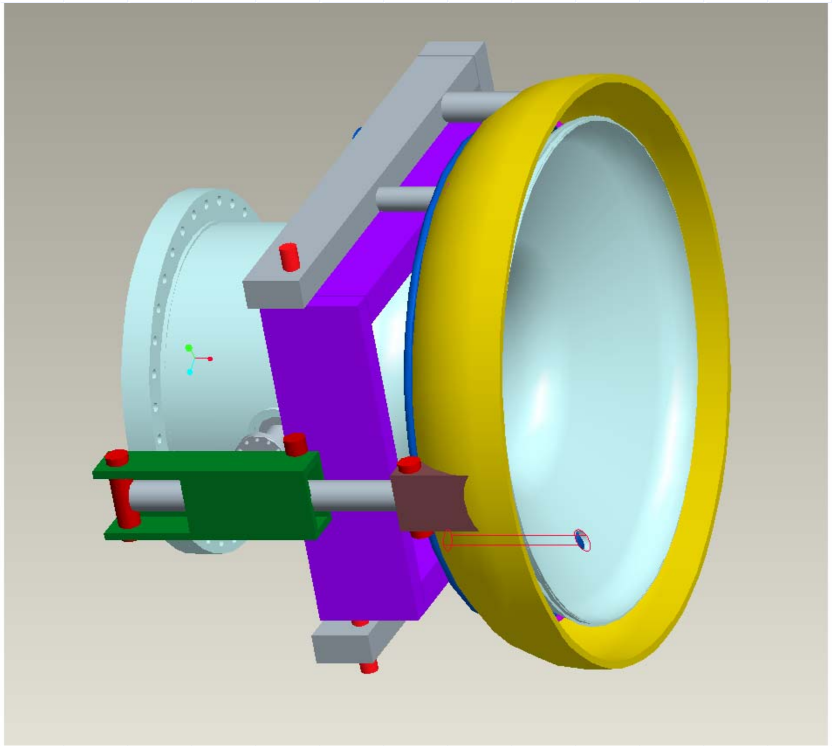
FTA-fine tune actuator calc				jr-3-04
		metric	english	
Cavity Specifications				
Stiffness [N/μm]	Kc	6.84	39011.92	lb/in
Tuning coefficient-cavity [Hz/μm]	df/dL	100.00		
Coarse tuning range-cavity [Hz]	dfc	4.75E+05	475 kHz	
Coarse tune displacement-cavity [μm]	dLcext	4750.00	187.01	mils
Fine tuning range-cavity [Hz]	df	1995.00	2.0 kHz	
Fine tune displacement-cavity [μm]	dLfext	19.95	0.79	mils
Fully extended load-cavity [N]	Fcext	32475.75	7300.84	lb
Add'l load for fine tuning	Ffext	136.40	30.66	lb
FTA Specifications (warm)				
Max. allowable compressive load-PZT [N]	Fcallow	16000	3596.94	lb
Stiffness-PZT [N/μm]	Kt	54	308124.00	lb/in
Nominal zero load displacement-PZT [μm]	dLo	300	11.81	mils
Available push (blocking) force-PZT [N]	Fpcalc	473.79	106.51	lb
Available FTA displacement-PZT [μm]	dLtcalc	291.23	11.47	mils
Tuner Mechanism Parameters				
Cavity lever length to vessel flex link [cm]	L3			
FTA lever length to vessel flex link [cm]	L3+L4			
FTA load multiplier/mechanical advantage	R	2.05		
Eff. system stiffness reacted by FTA [N/μm]	Ks	1.63		
FTA Calculated Minimum Requirement				
Req'd push force-PZT	Fpmin	66.54	14.96	lb
Req'd stroke at cryo temp-PZT	dLtcold	40.90	1.61	mils
Req'd stroke at room temp-PZT	dLtwarm	286.28	11.27	mils
Compressive load on FTA at course tune	Fcmin	15841.83	3561.38	lb

Fine Tune Actuator (FTA) Selection Criteria

- Cryogenic operation
  - stroke of magnetostrictive element increases at cryo temps
  - piezo stroke reduced 5-10x; length must be compensated
- Load characteristics:
  - Robustness: element is brittle; design out tension & shear
  - designed within "blocking" force limits
  - Force vs. displacement curve: sensitive to system stiffness
  - dynamic response limited by FTA inductance (only!)
- Environmental effects:
  - Heat load: signal frequency & waveform dependent
  - Stray field influence & sensitivity: passive shield required

Tuner Installed on Helium Vessel & Cavity





Conclusion

- ECX tuner design serves as prototype for ERL
- Custom magnetostrictive actuator to be tested/proven
- High displacement & load capacity has been tackled
- Tuner/Stiffener concept developed for noisy environments

The End

Thank you for your time, expertise and support!

Related Mechanical Design Considerations

- additional load (steady) due to He external pressure
- shielded feedthrough design: stepper motor, FTA
- frame assembly: over HOM & bell; clear shield & struts
- access for service
- greaseless, cryogenic bearings
- coarse tuner reacted load: *self-locking* ?
- cavity fatigue – cold working
- lateral (radial) load on cavity end
- cavity installed with preload?, or designed oversize!!
- cavity ‘free-end’ support affects; microphonics limit
- allowable mechanical backlash: 0.25 μm max (0.01 mil)
- repeatability: control system drift, hysterisis, material creep
- titanium (grade 12) mounts to He vessel
- acme class 4G thread power screw