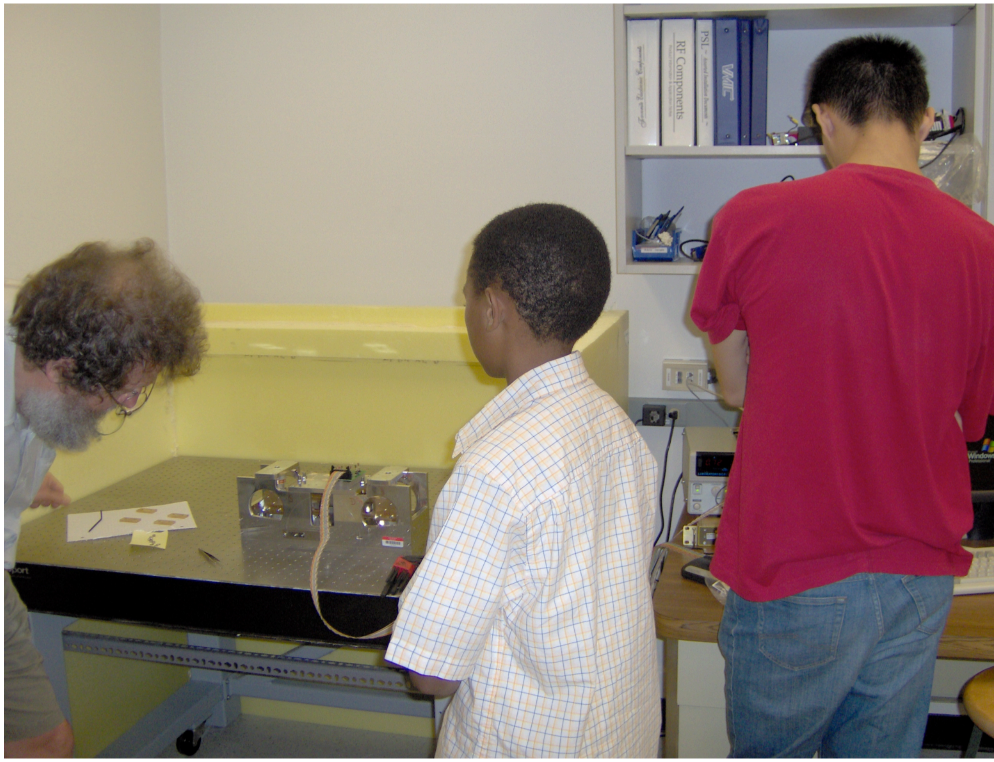
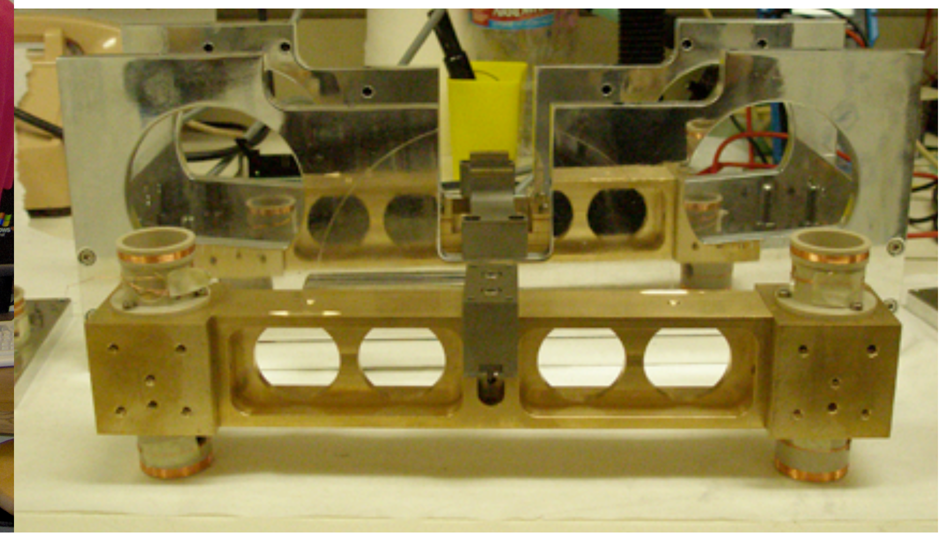
Tiltmeter Studies





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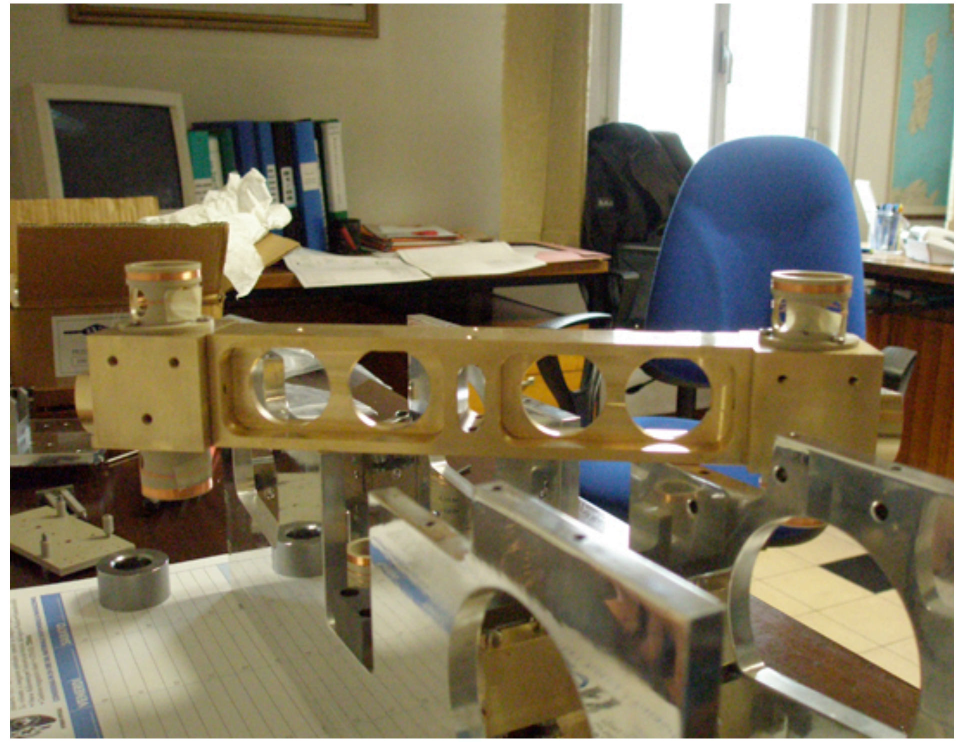
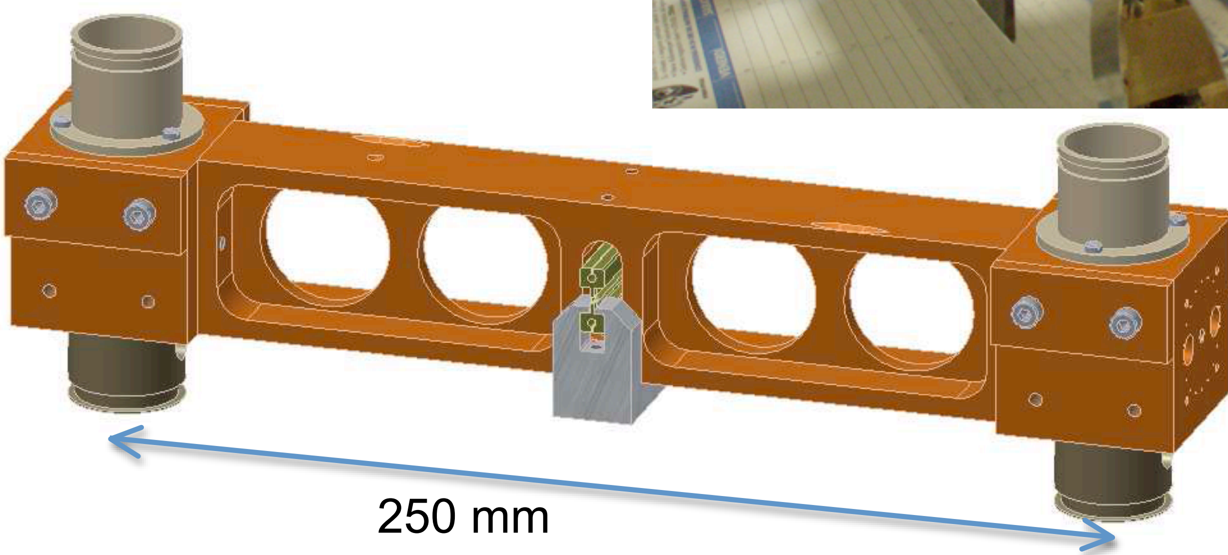
SCCUR, CSU Dominguez Hills, November 21nd 2009 LIGO-G1000710-v2

Why a Balance Tiltmeter?

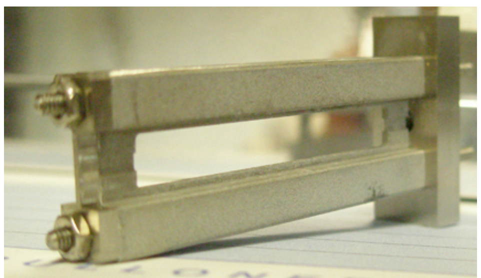
- Compact, portable
- UHV compatible
- Can work inside the Virgo and LIGO vacuum chambers

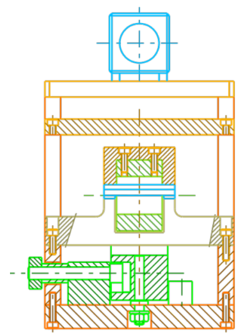


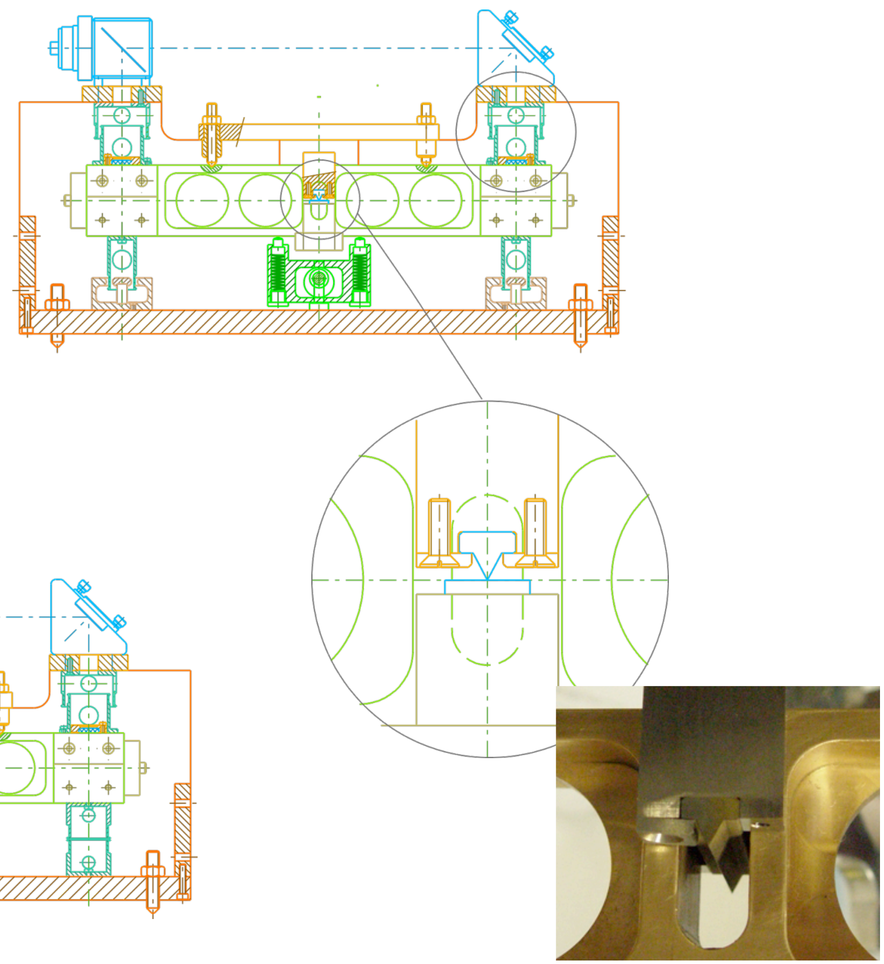


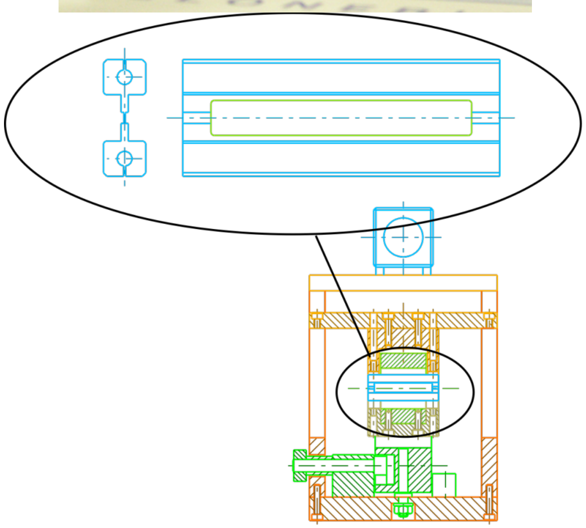
Flexure or knife-edge hinge?

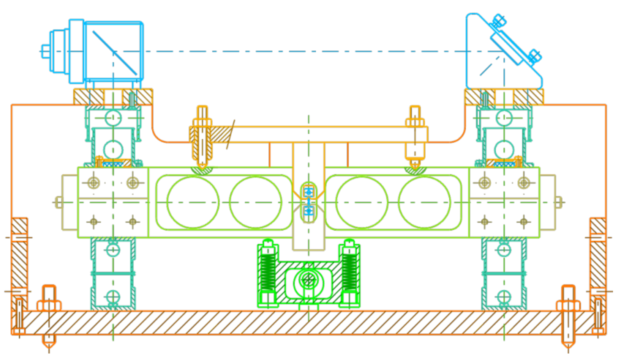
- Mechanics designed to compare the two options





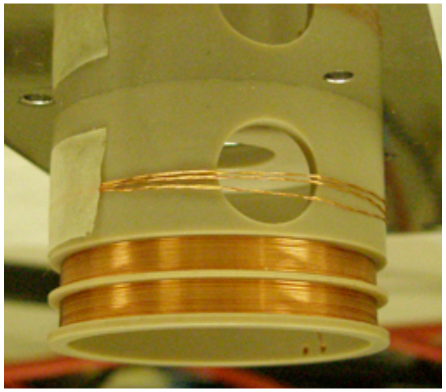


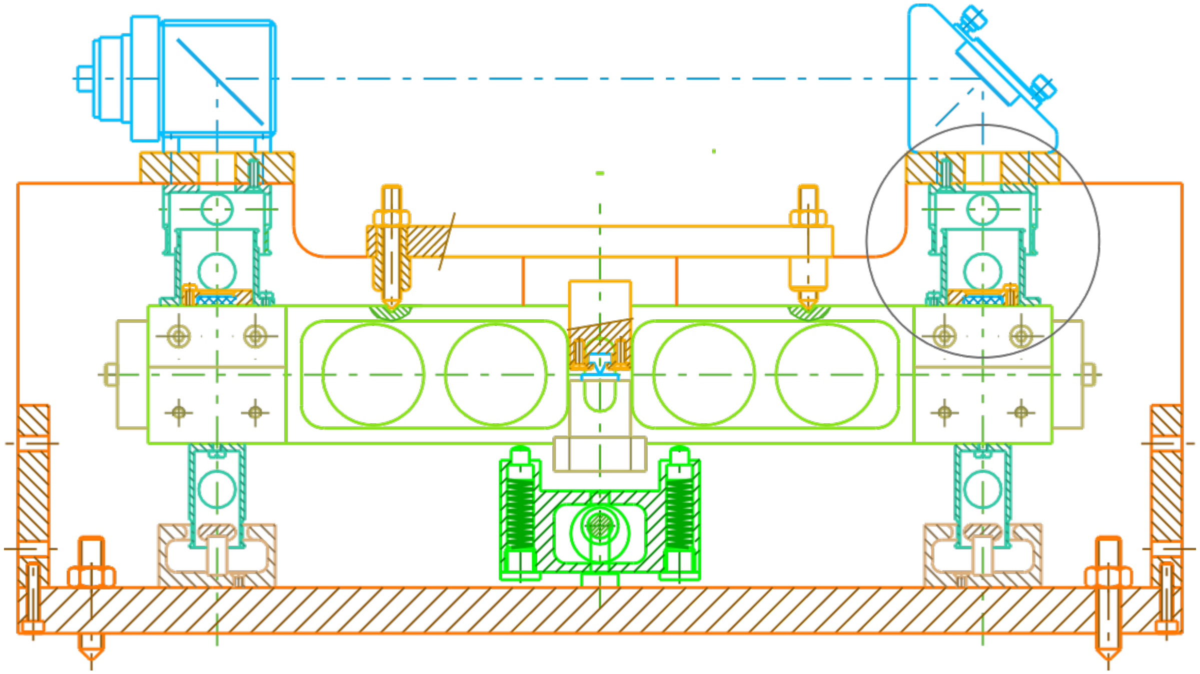


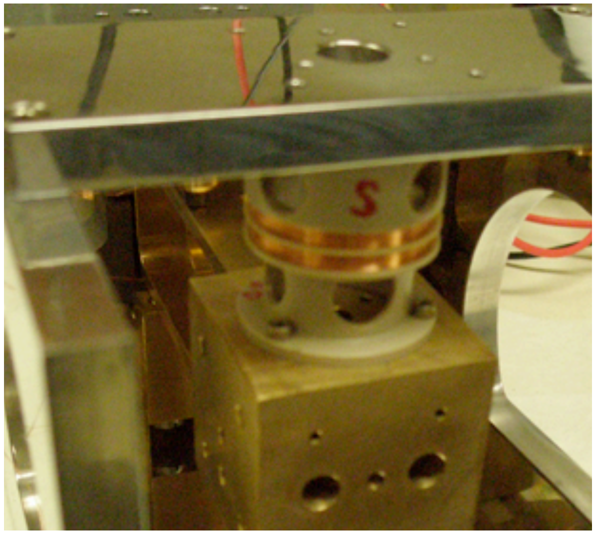


Other features

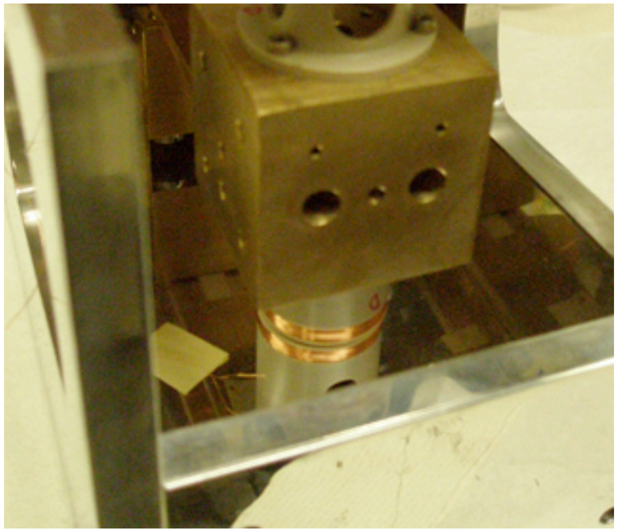
- Differential readout
- LVDT readout (easy)
- Michelson readout (higher precision)



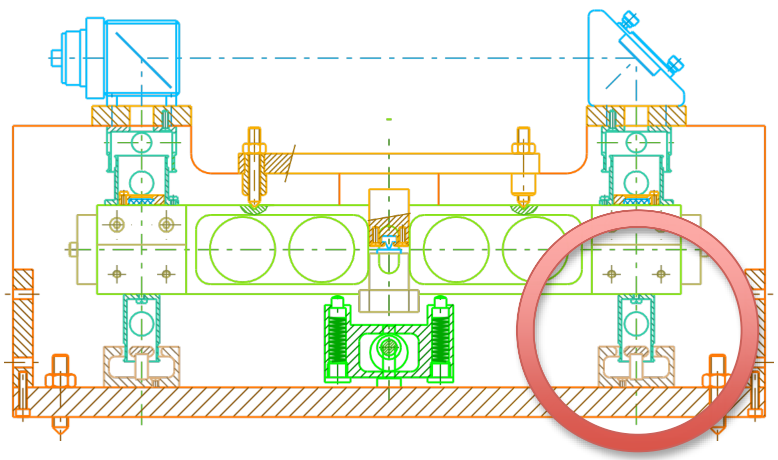


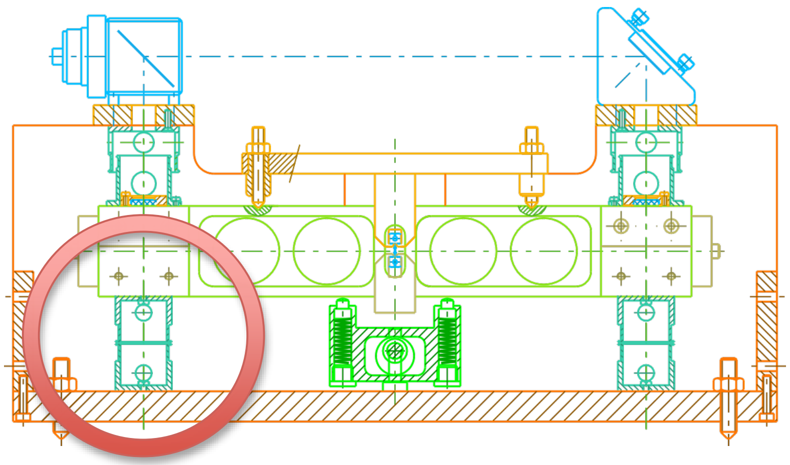


Other features



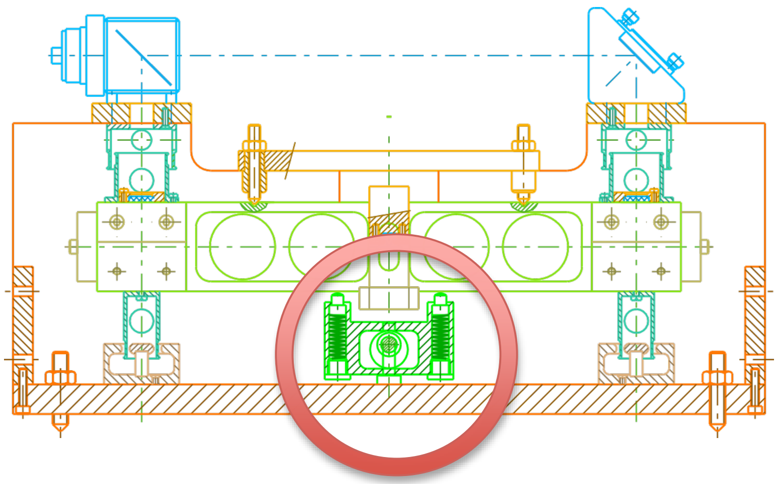
- Differential actuation
- Voice coil actuation
- RF actuation (insensitive to magnetic fields, power lines and solar wind perturbations)

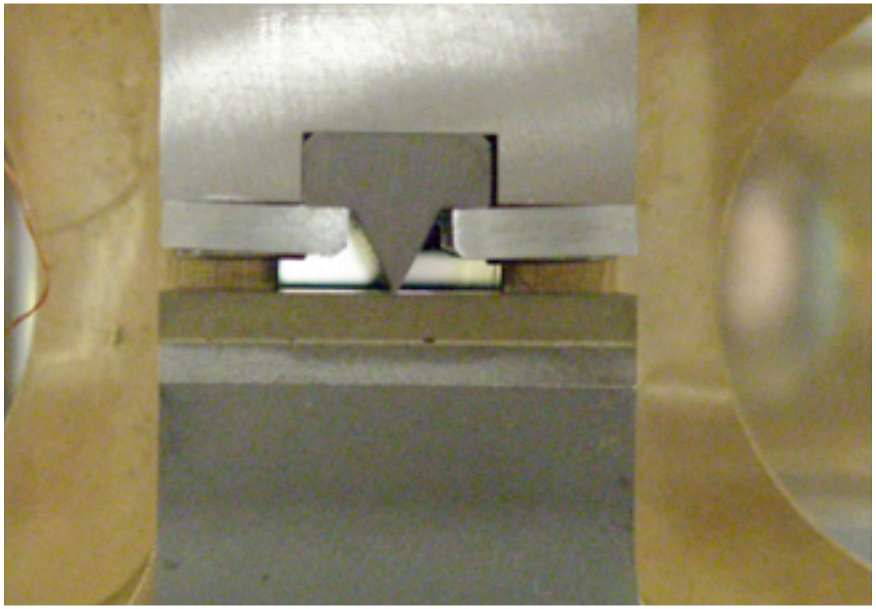


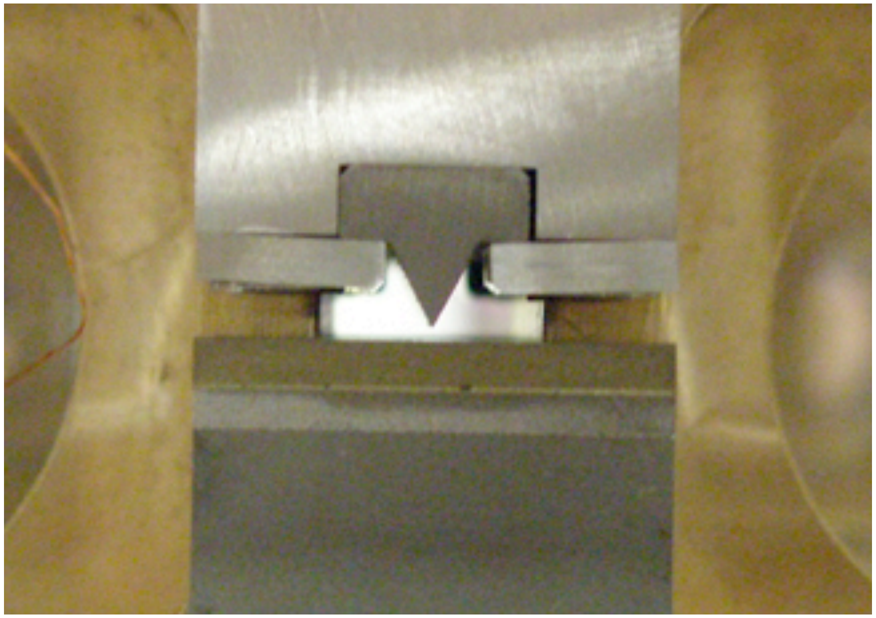


Other features

- Elevation mechanism
- Locks balance arm for transport

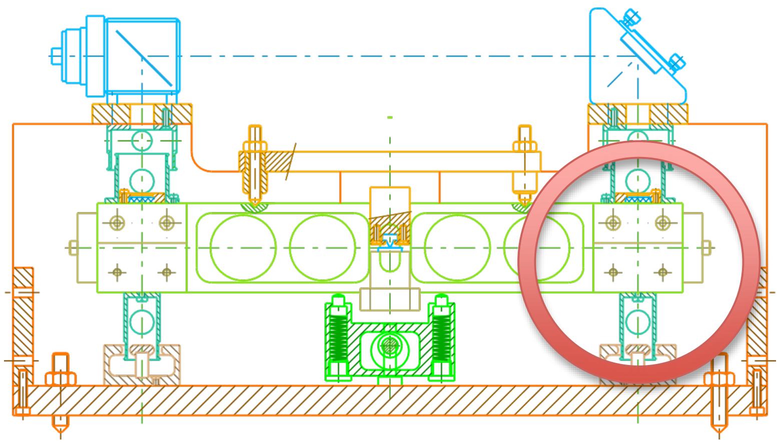


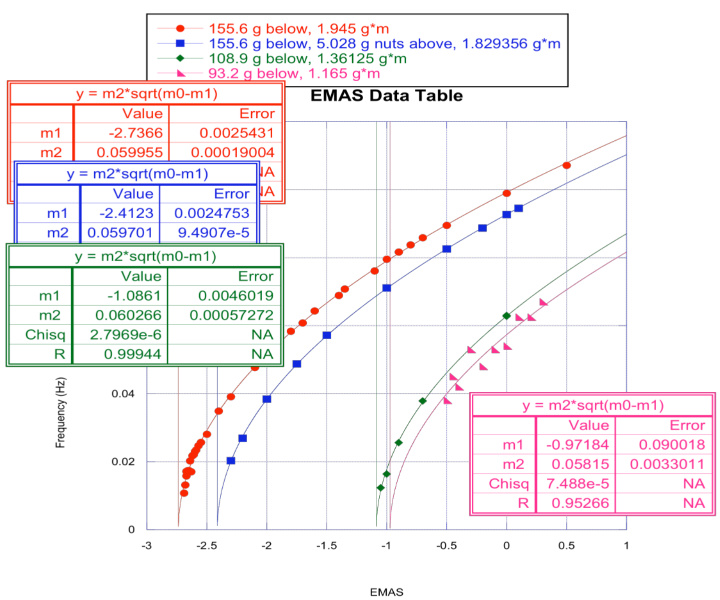


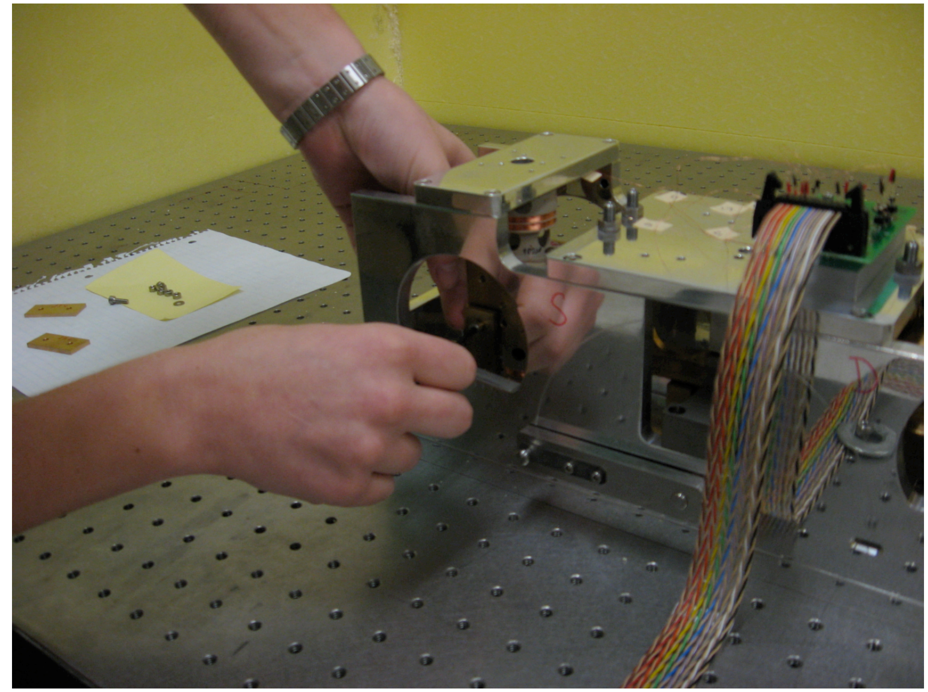


Other features

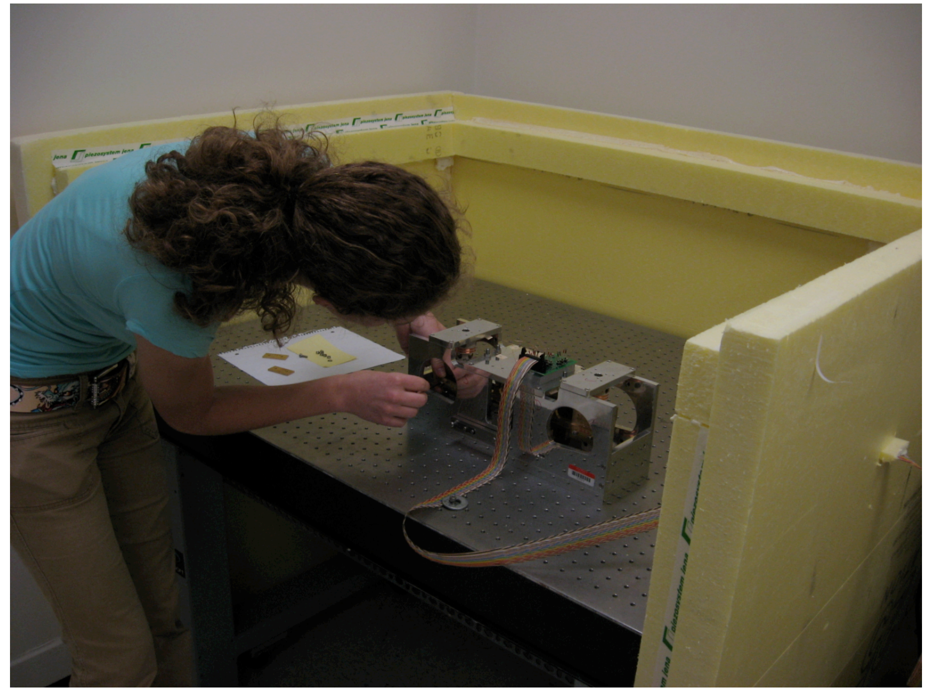
- Tuning masses to tune resonant frequency



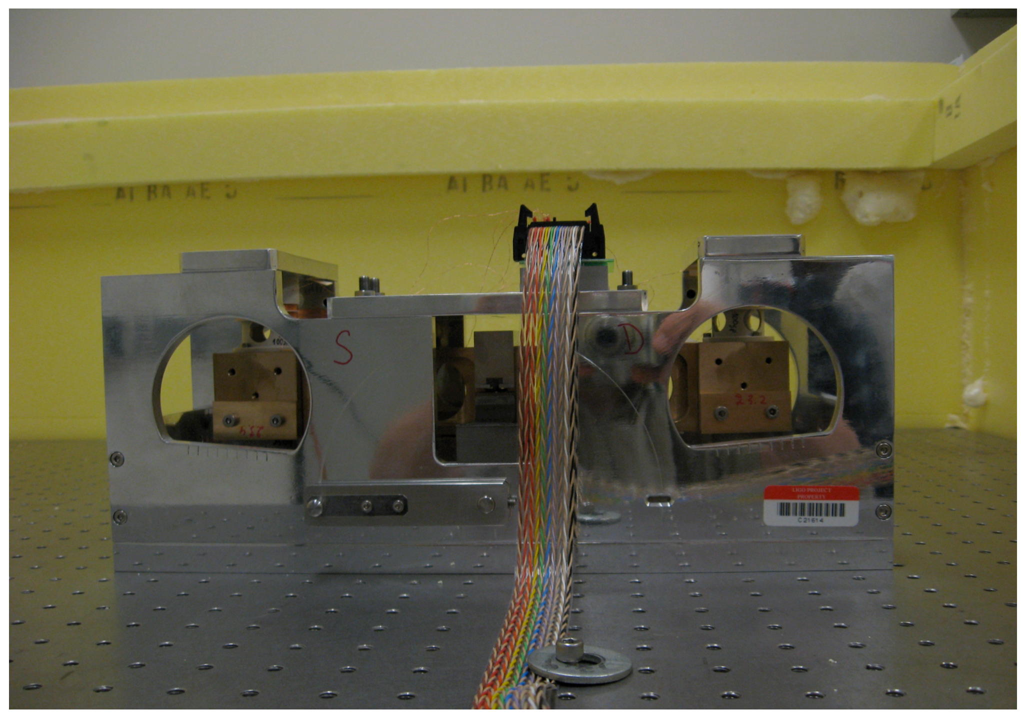




Other features

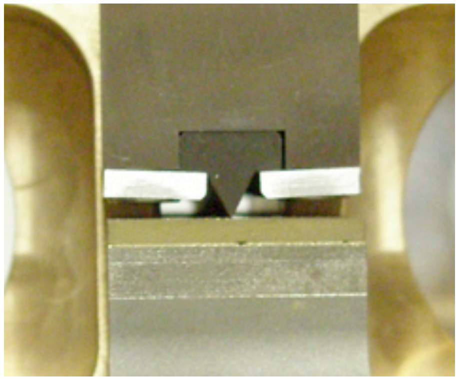


- Three-level, rigid, Matrioska wind/thermal shields to minimize ambient disturbances



R&D Strategy

- It was found that Self Organized Criticality controls dissipation and noise in metals at low frequency
- Expect larger noise when tuning at very low frequency
- Several flexure tiltmeters failed
- Over last few centuries people weighted gold and gems with knife edge scales
- Try knife-edge configuration first

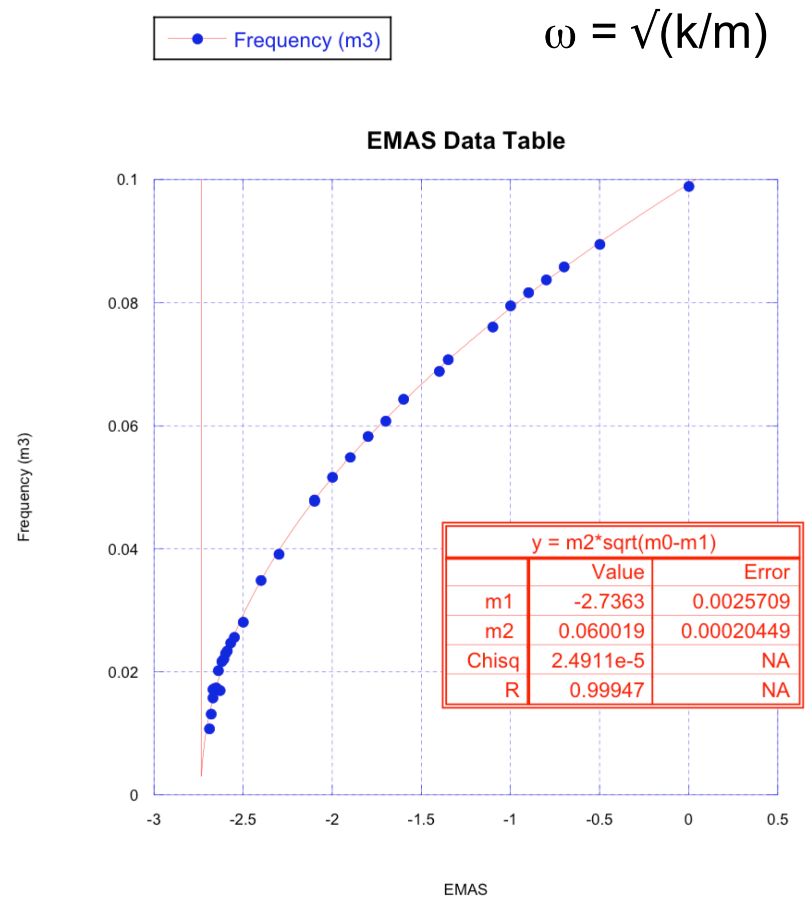


Balancing

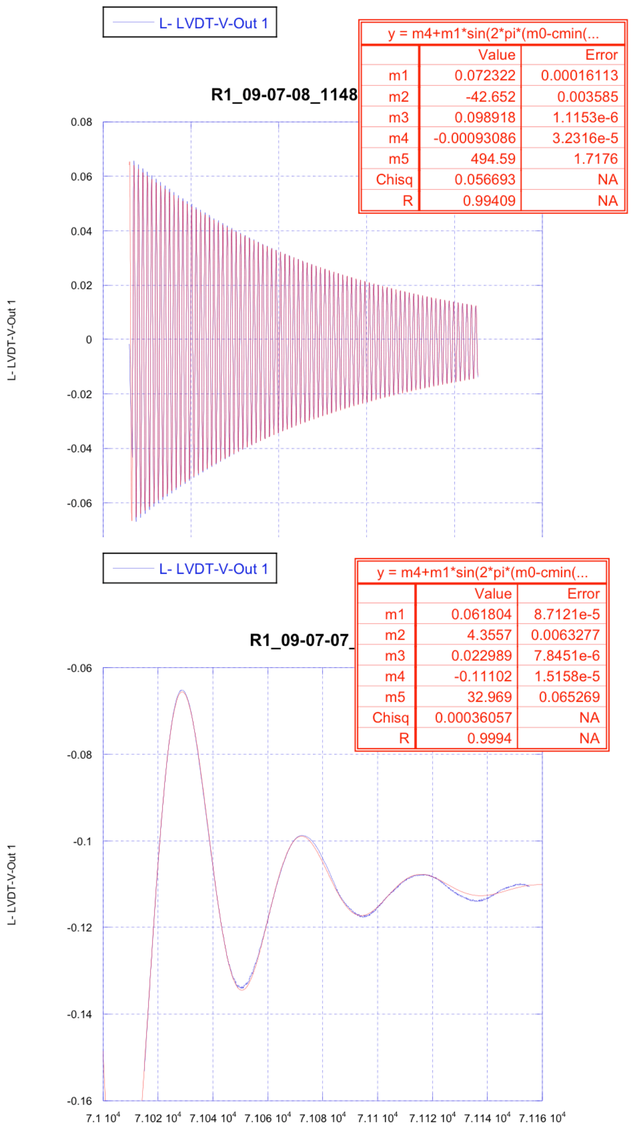
- Tiltmeter mechanically balanced to 27.8 microNm balancing torque
- More accurate balancing possible in system
- Applied 0.7125V balancing @ 39 μNm/V

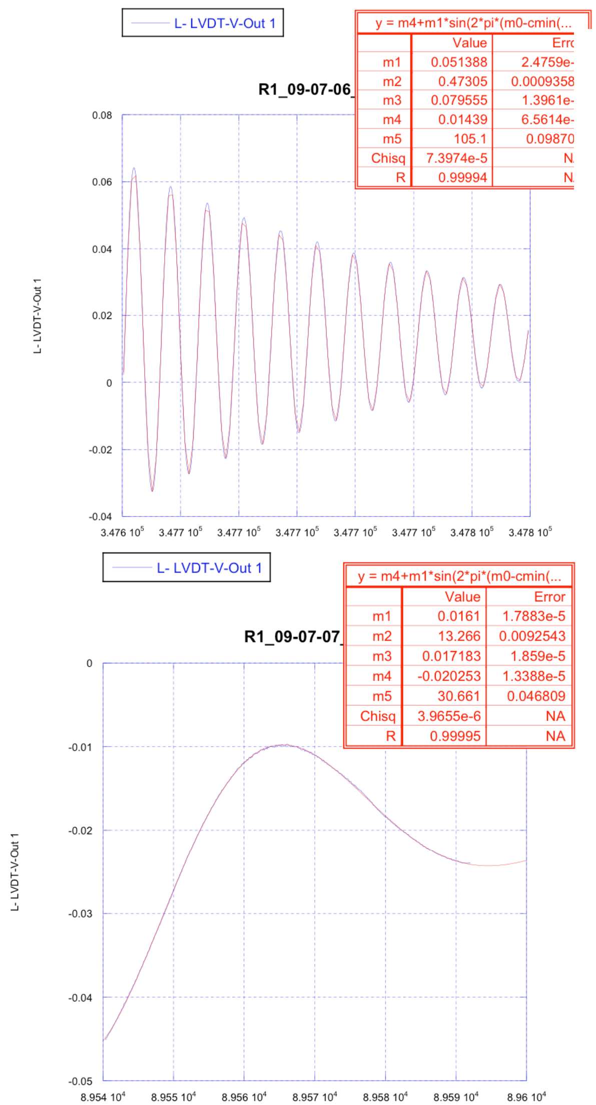
Initial Results

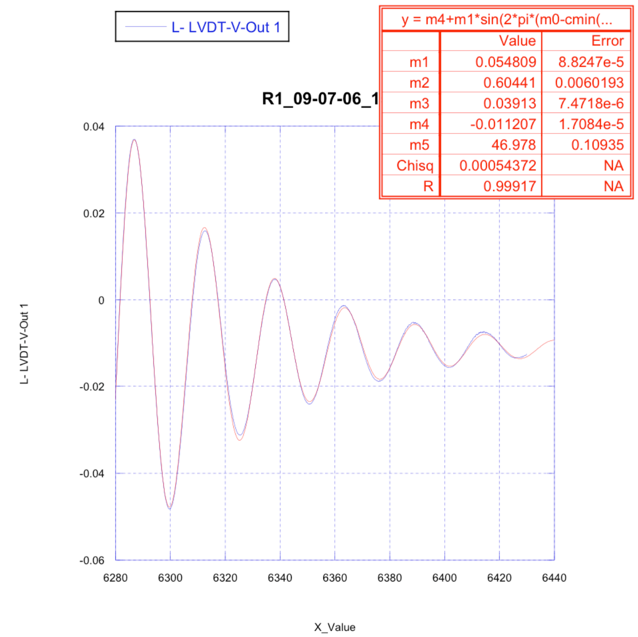
- Frequency tuning with Electro Magnetic Anti Spring (EMAS)
- Behavior as expected
- Easily reach 10 mHz
- Behaves smoothly!



Q-factor vs. Frequency (EMAS)



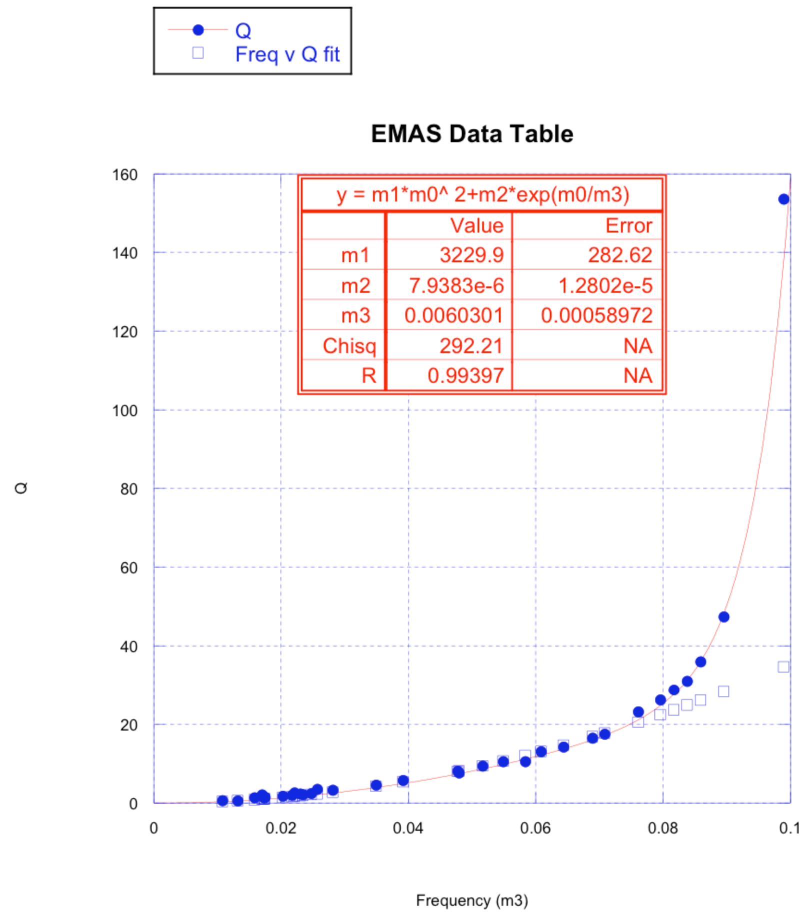




- Bumpiness connected with SOC avalanches seems absent

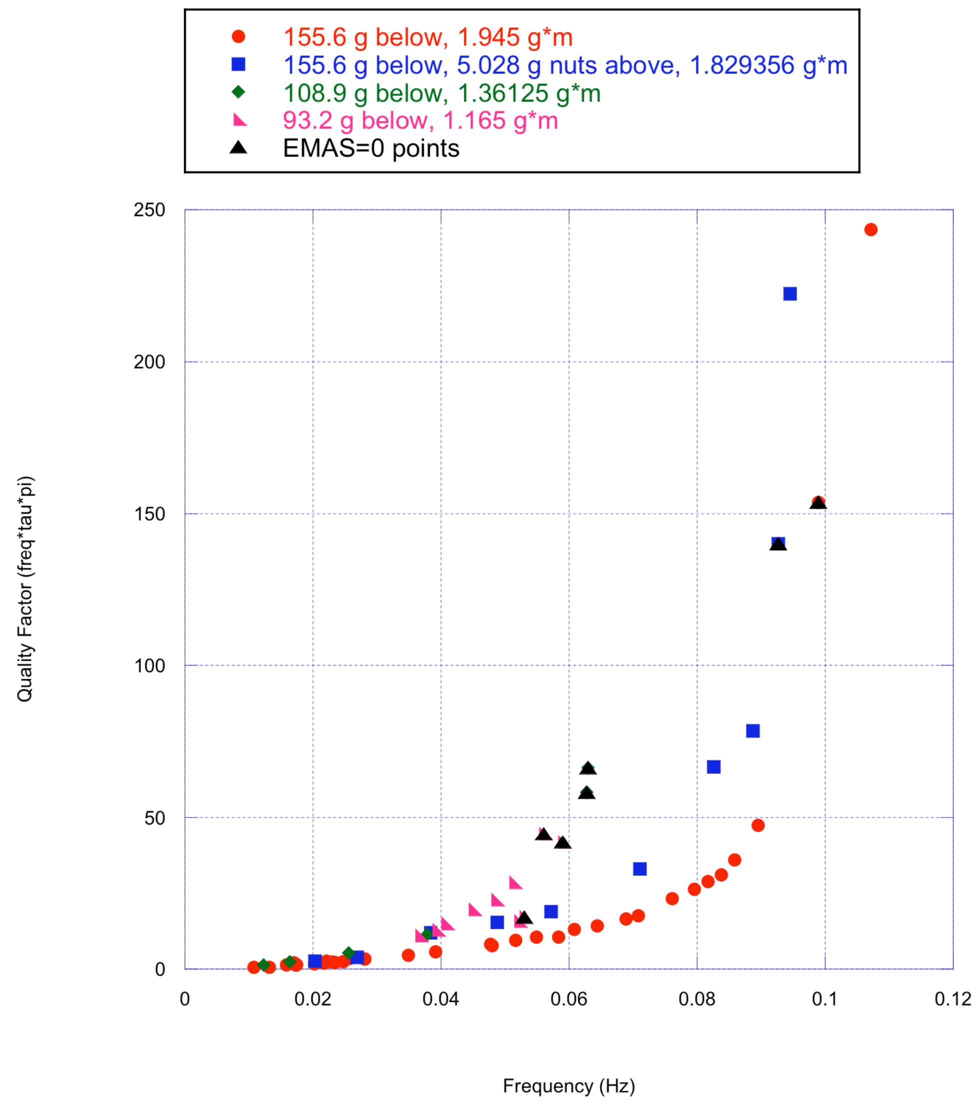
Q-factor vs. Frequency (EMAS)

- Apparently quite good
- Low frequency - quadratic
- High frequency - exponential
- Similar to flexures results



Q-factor vs. Frequency (EMAS)

- Cross check with Gravitational Anti Springs (more mass above pivot point)
- Fails to overlap above 30 mHz
- Need to repeat the scan changing only the mass distribution (no EMAS)
- Scatter perhaps due to amplitude dependence of losses
- Computer feedback delay falses Q-factor data
- More work needed

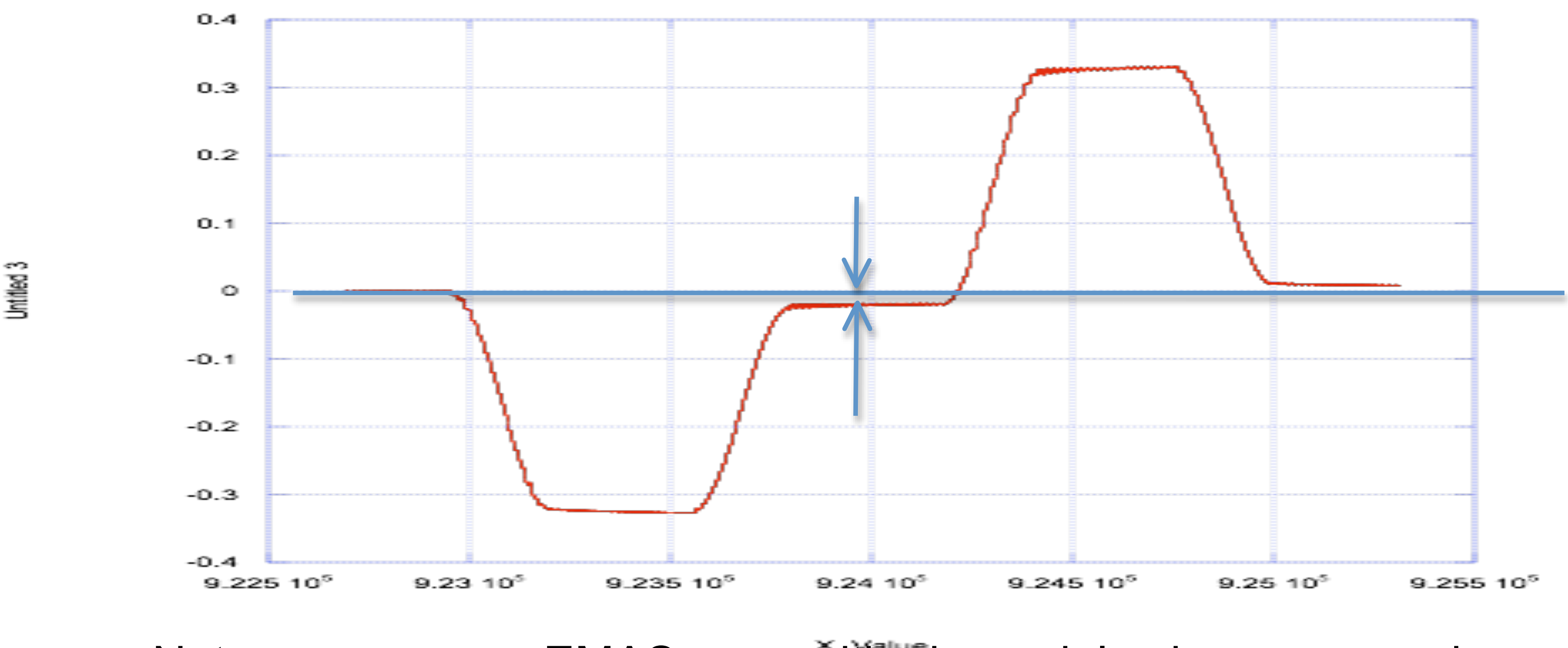


Hysteresis Testing

- Key parameter ! !
- In metal springs hysteresis was harbinger of SOC noise

Hysteresis Testing

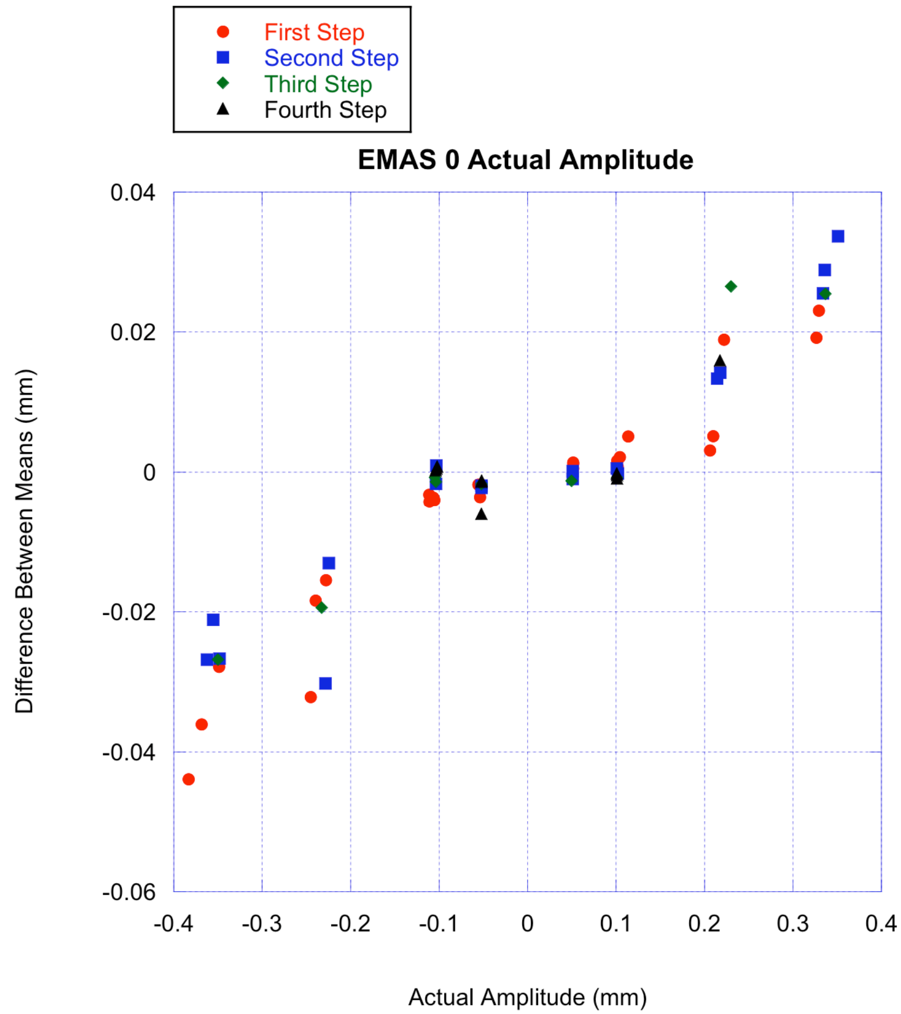
- Slow application and removal of force
- Compare starting and returning position



- Note: we can use EMAS even with phase delay because we do not measure Q-factors

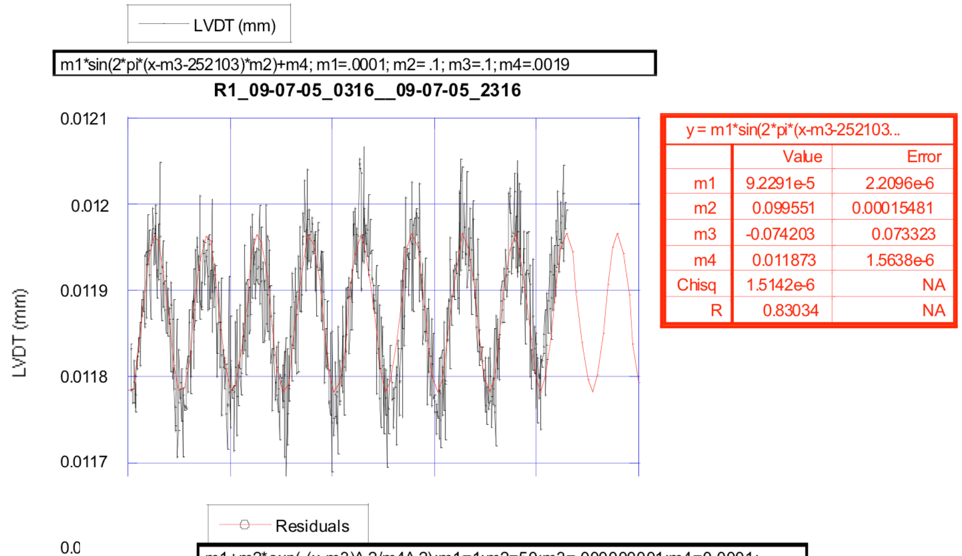
Hysteresis Testing

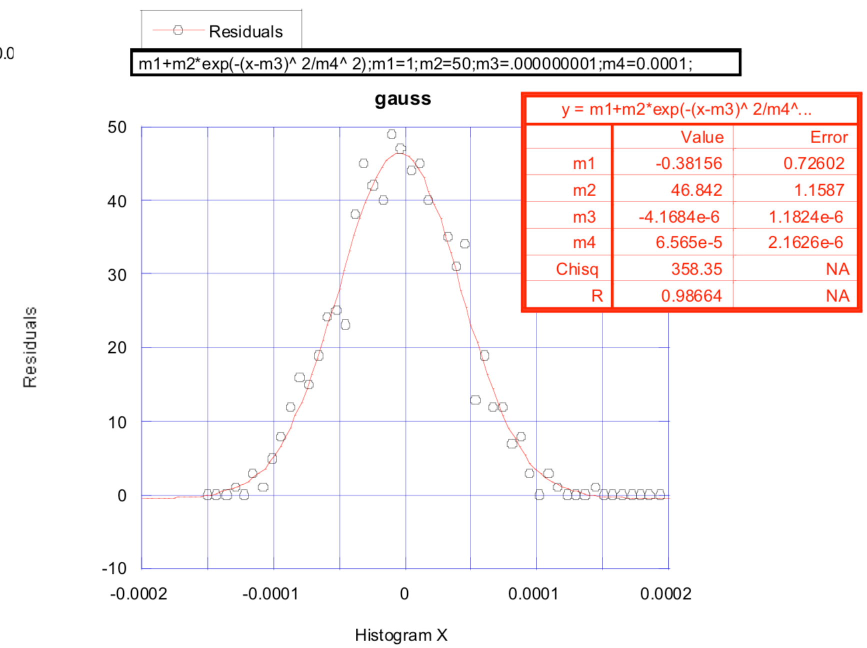
- Hysteresis reduced or may be vanishing for small displacements amplitude



Noise Studies

- Fitting over short stretch to eliminate ambient re-excitation at resonant frequency (air conditioning + seismic excitation)
- Can suppress some noise by averaging over one period
- Residual give 65 nm upper limit of noise
- Digitization dominated
- Can improve





Conclusions

- Tiltmeter with knife-edge hinge worked well
- Seems not to show Self Organized Criticality (SOC) low frequency noise
- Used low grade knife. Space for improvements using TiN, Diamond, DLC coatings
- Will test flexures to study SOC
- Future work: more quality factor vs. frequency testing, use Michelson interferometer position sensors

Acknowledgements

- My mentor, Riccardo DeSalvo
- Abhik Bhawal and Morgan Asadoor
- LIGO
- California Institute of Technology