Gravitational Reference Sensor Technology Advancements

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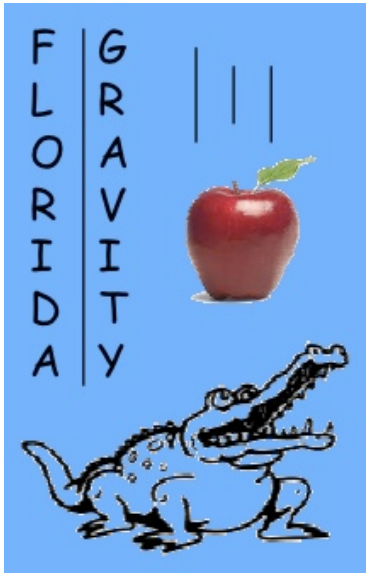

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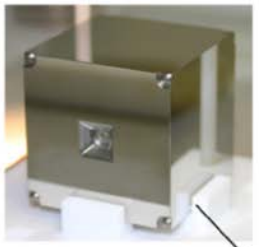
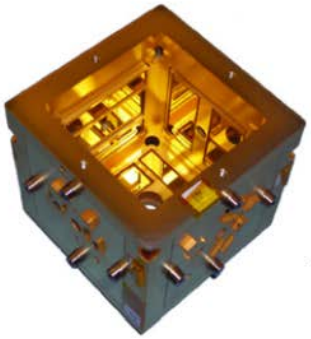
LISA Gravitational Reference Sensor

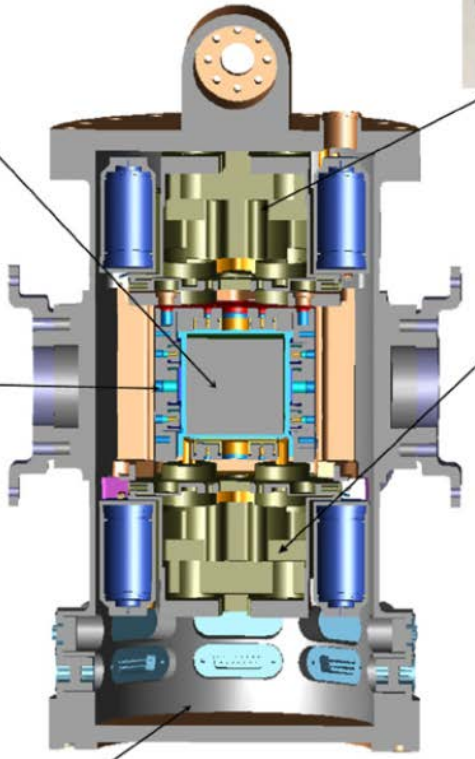


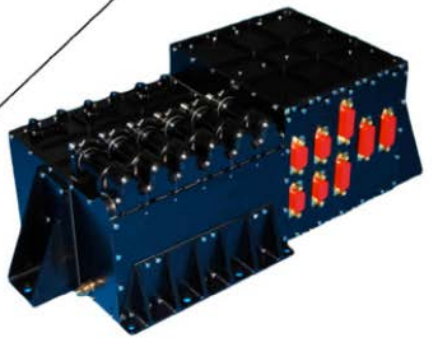
Test Mass (FM)

Caging Mechanism (EQM)



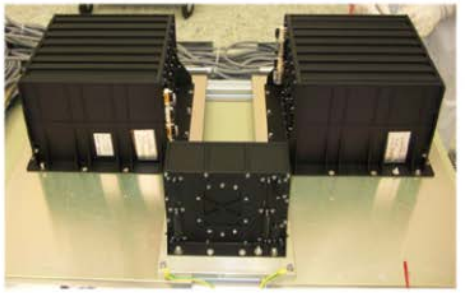
Electrode Housing (FM)





UV Light Unit (FM)

Vacuum Chamber (FM)

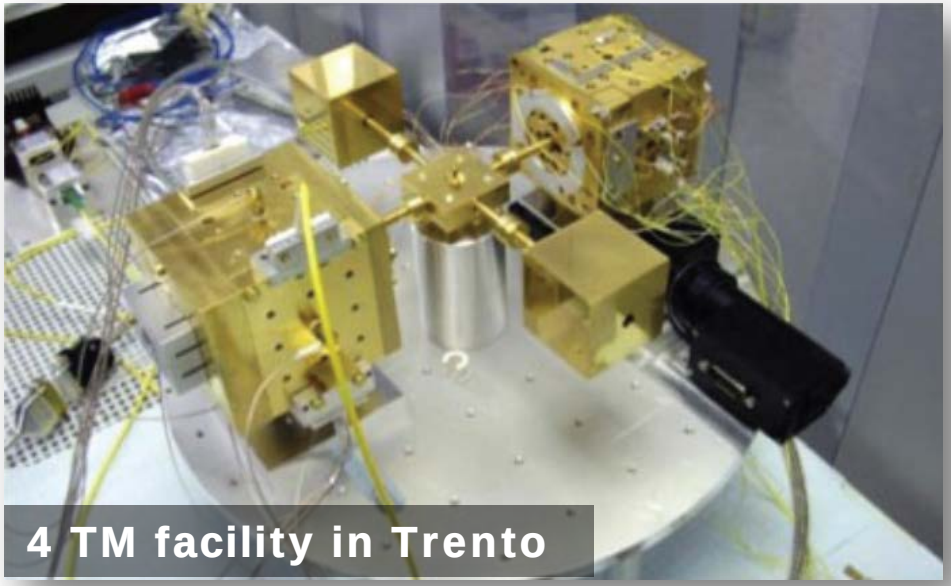


Front End Electronics (FM)

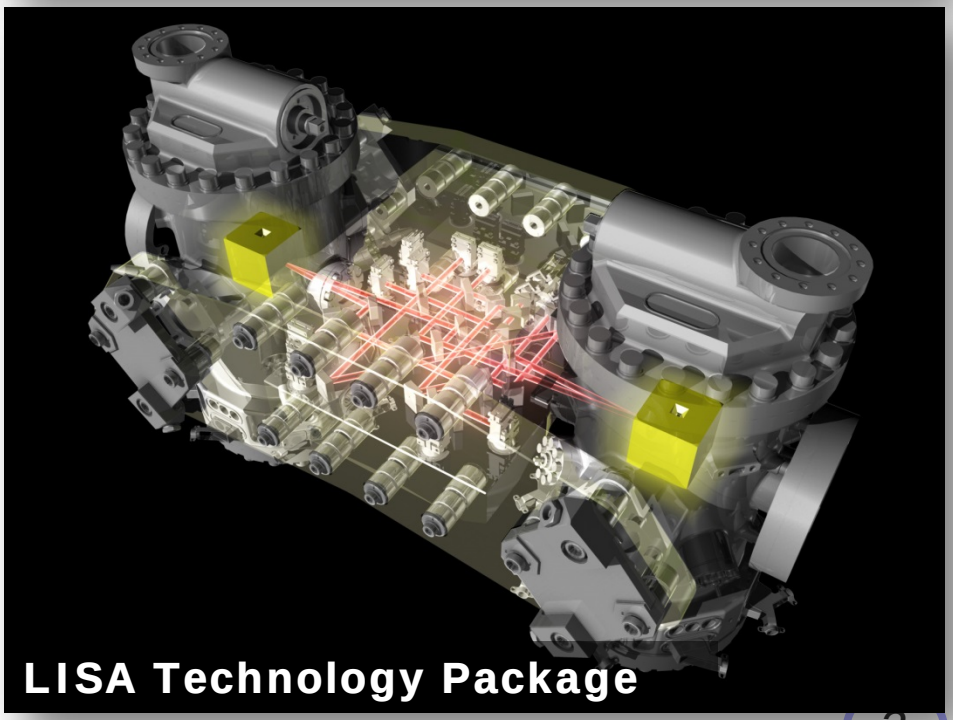
*F. Antonucci et al (2011)

GRS Testing

- Torsion pendula
  - Provides one (or more) DOF decoupled from local gravity
  - U. Trento leading the development of the GRS, with two torsion pendula


4 TM facility in Trento

- LISA Pathfinder
  - ESA LISA Technology Package will test the GRS in space
  - Launch: July 2015

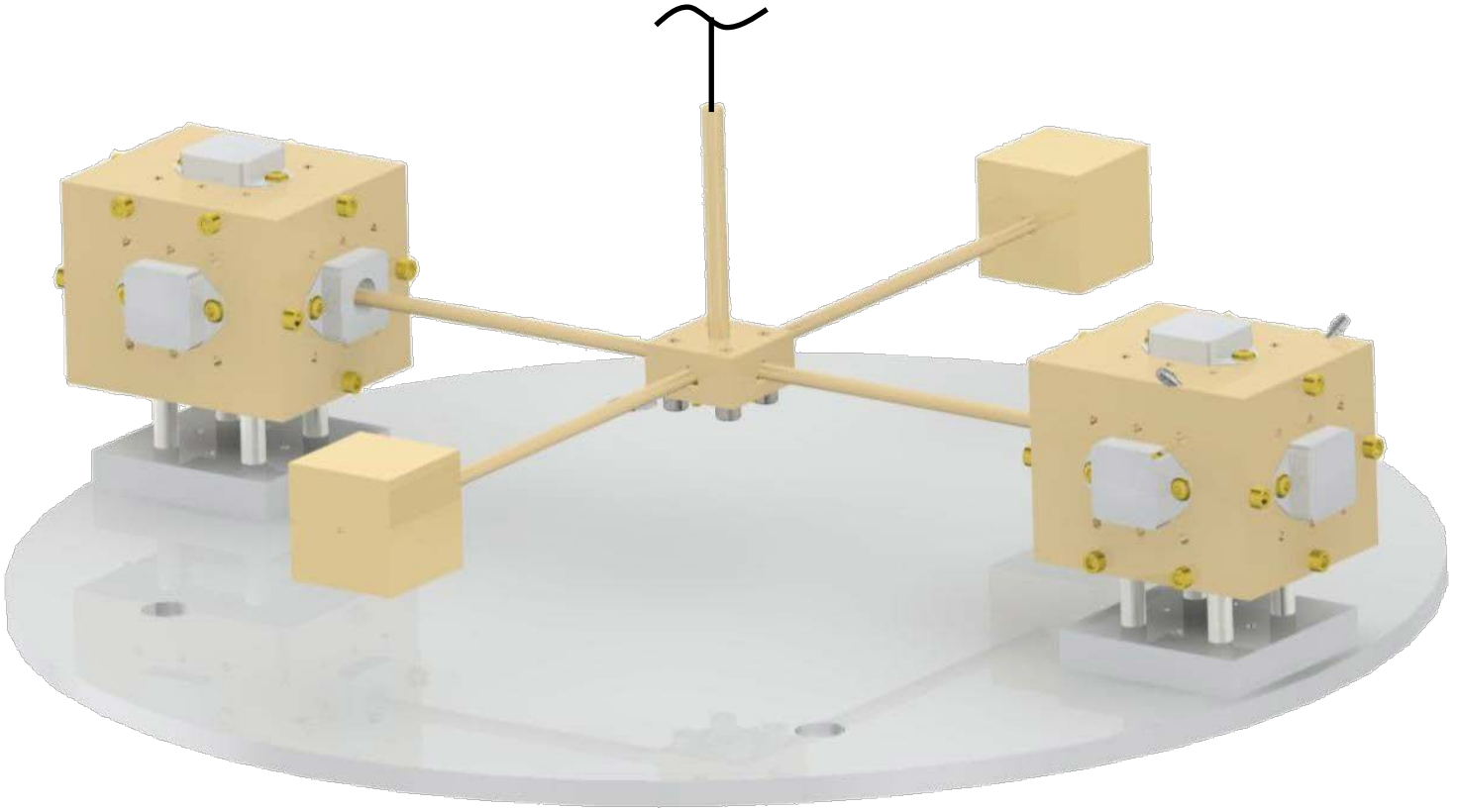

LISA Technology Package

Motivation for a New Pendulum

- Strategic:
  - No GRS testing facilities currently exist in U.S.
  - Develop U.S. scientific expertise in GRS technology
  - Drag-free is important for several future space missions
- Technical/scientific:
  - Focus on R&D (focus in Europe is on risk reduction for LTP):
    - Improve electronics: simpler, lighter, lower power consumption
    - Charge Management System: lower cost, better performance
    - 6 degree-of-freedom IFO readout
  - Independent confirmation of results from Europe
  - GW data analysis: GW signals likely need to be analyzed simultaneously with systematic effects

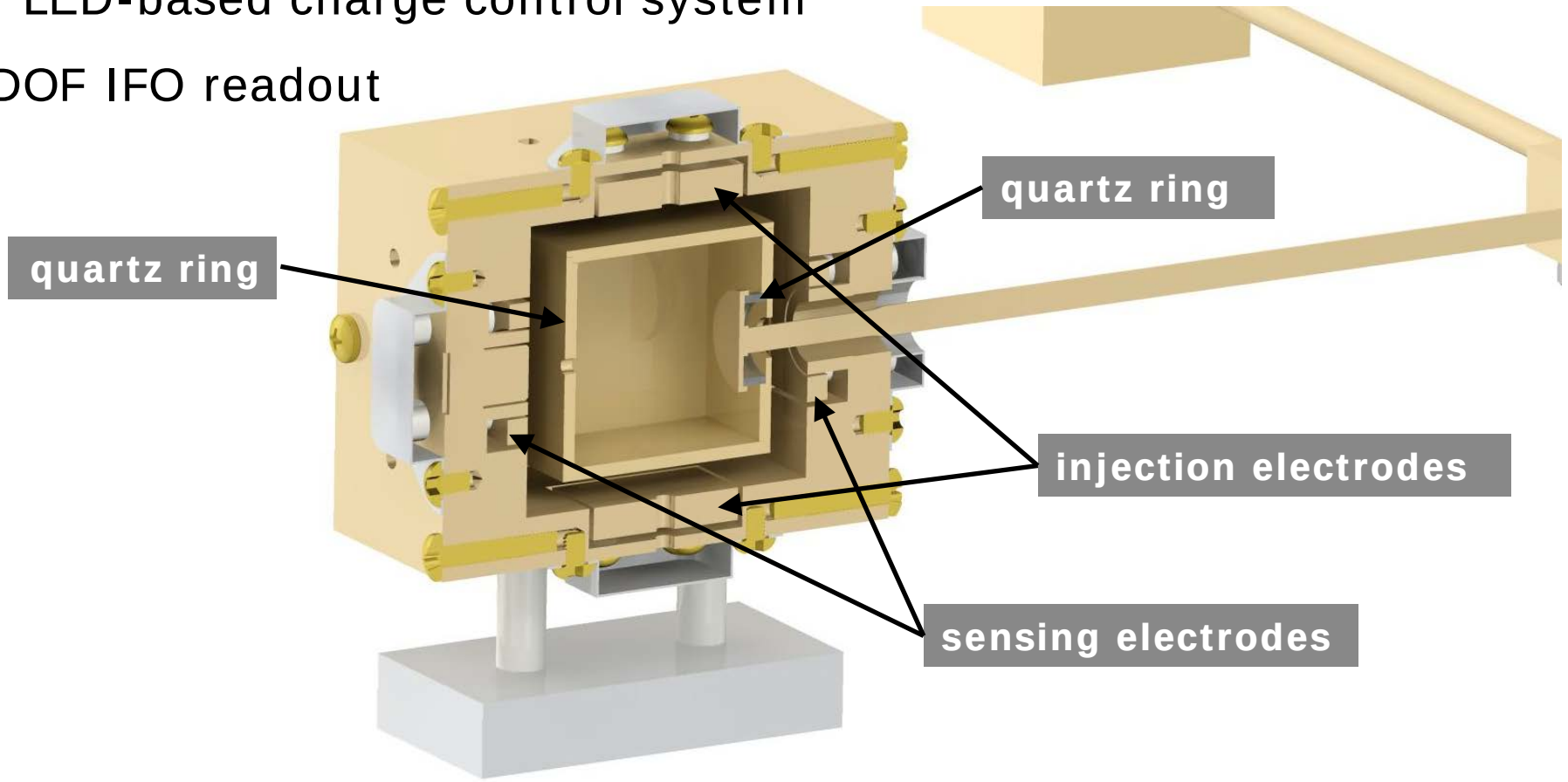
UF Torsion Pendulum Design

- Based on Trento design principles
  - Torsion fiber supports cross bar with 4 hollow test masses
  - Light weight al structure reduces required fiber diameter
  - Focus: Measurement of surface forces

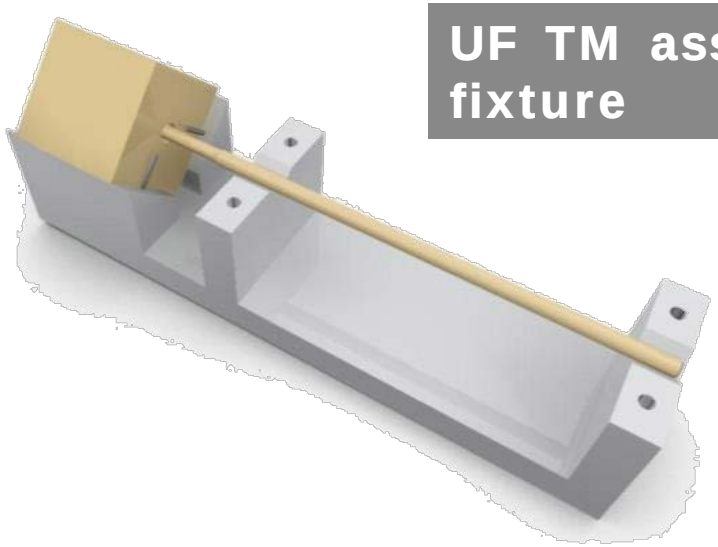


UF Torsion Pendulum Design

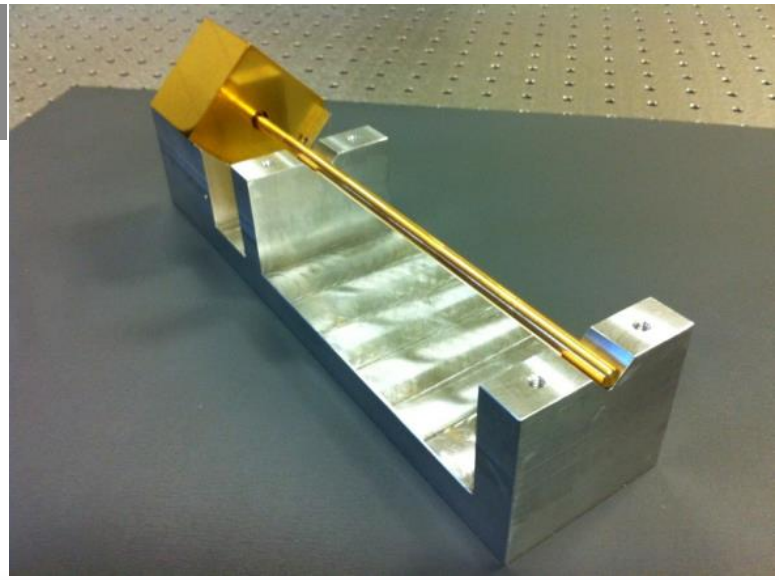
- Based on Trento design + modifications
  - Longer arm for more real-estate & separation of forces & torques
  - Underground facility for improved thermal, seismic isolation
  - UV LED-based charge control system
  - 6 DOF IFO readout

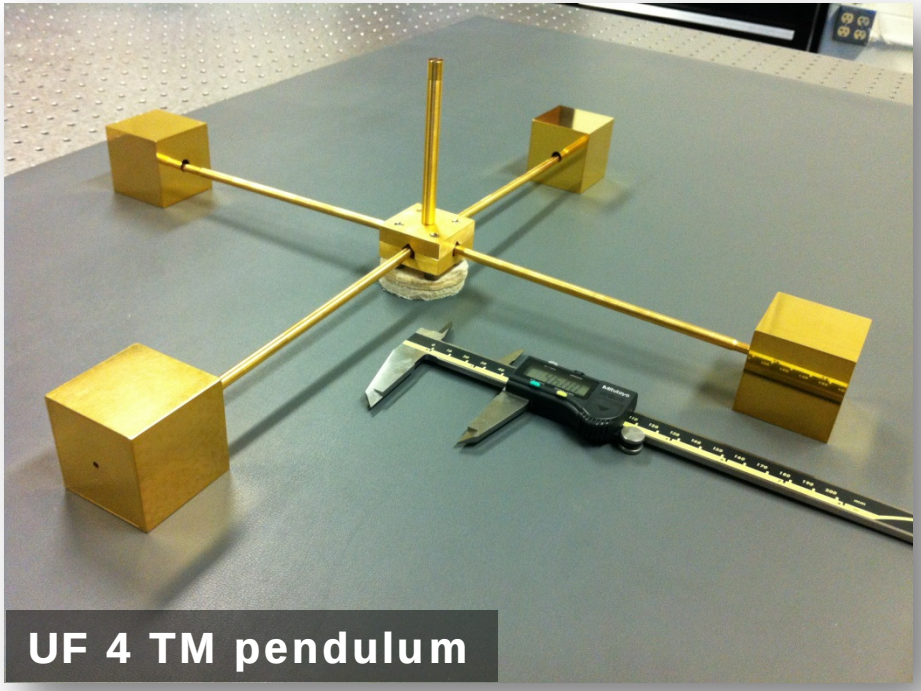


UF Torsion Pendulum Fabrication

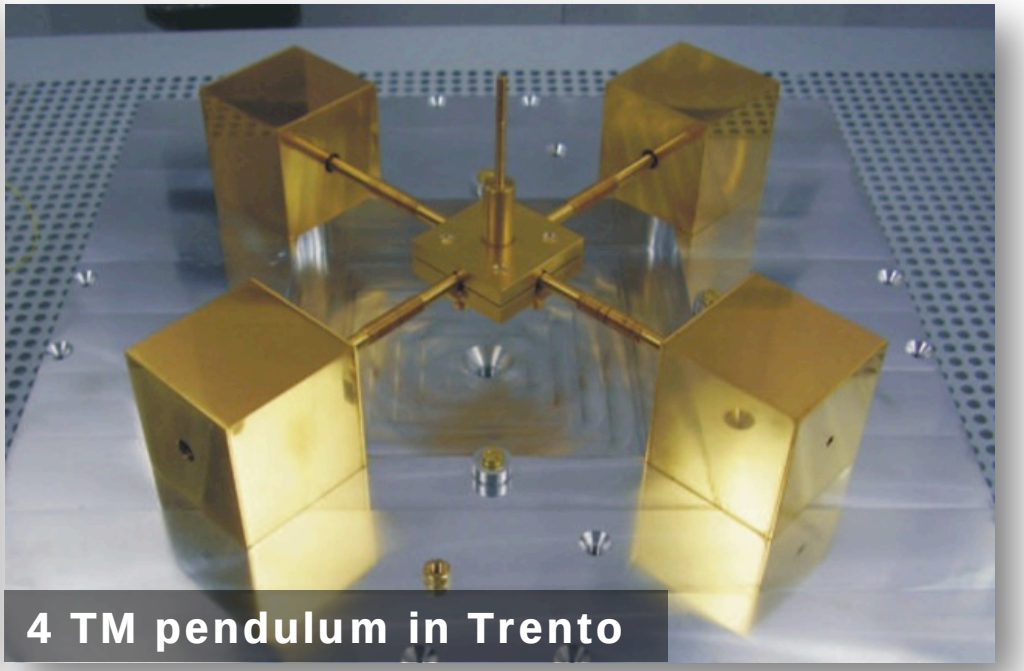


UF TM assembly fixture





UF 4 TM pendulum



4 TM pendulum in Trento

Zoo of Test Mass Surface Force Noise

Stiffness:
Sensing bias
TM charge
DC voltages
Any force gradient…

Thermal effects:
Radiometer effect
Radiation pressure
Differential out-gassing

Electrostatics:
TM random charging
Stray DC voltages
Electronics back-action

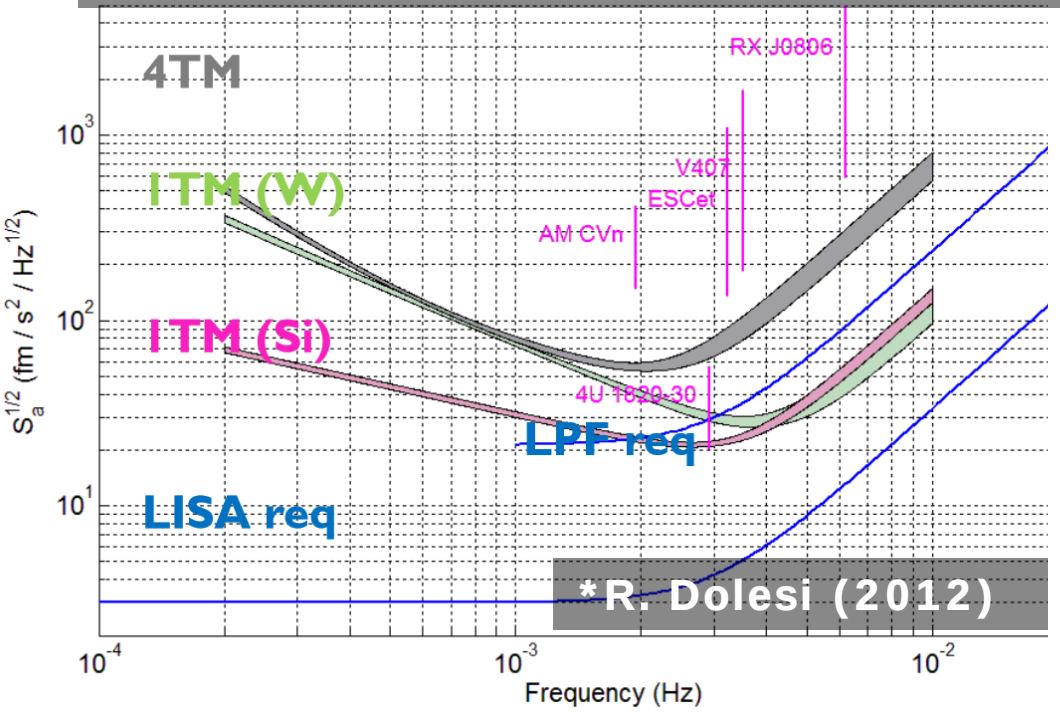
Residual gas damping

Unknown effects

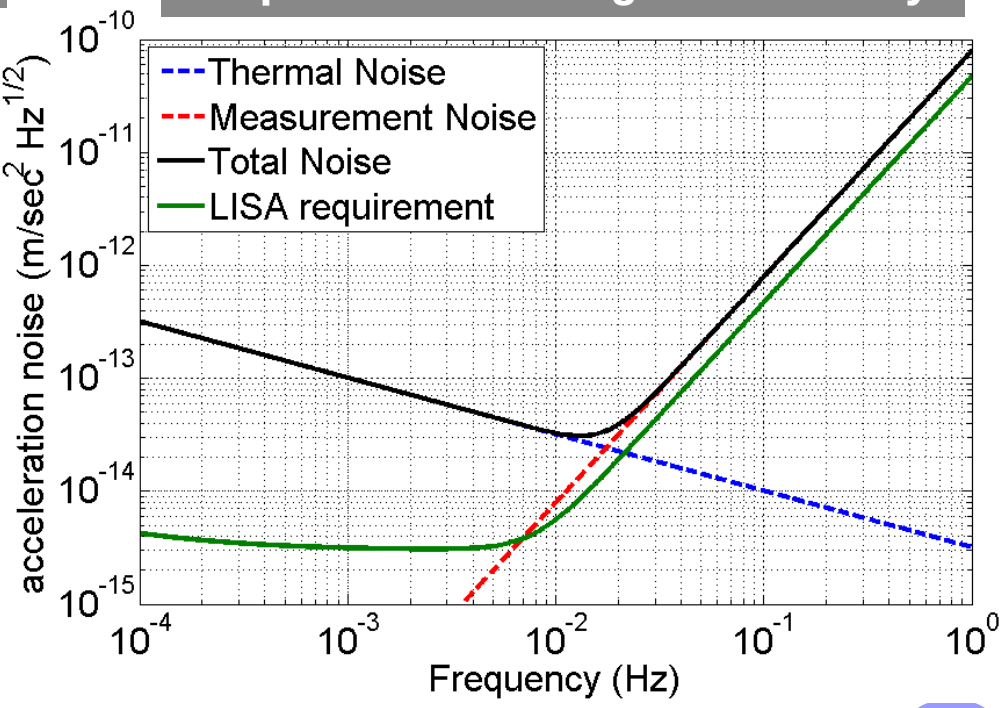
Predicted Noise Limit

- Thermal torque noise: W fiber, ~1 m length, 50 μm diam
- Arm length: 22 cm
- Pendulum mass: ~0.5 kg
- ϕ measurement: Differential interferometer ~ 10 prad $Hz^{-1/2}$

Measured Trento pendulum sensitivity

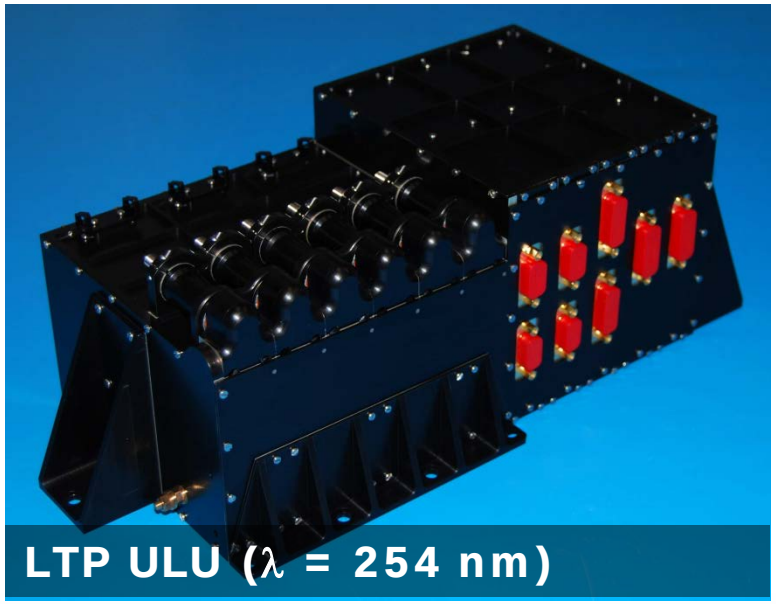


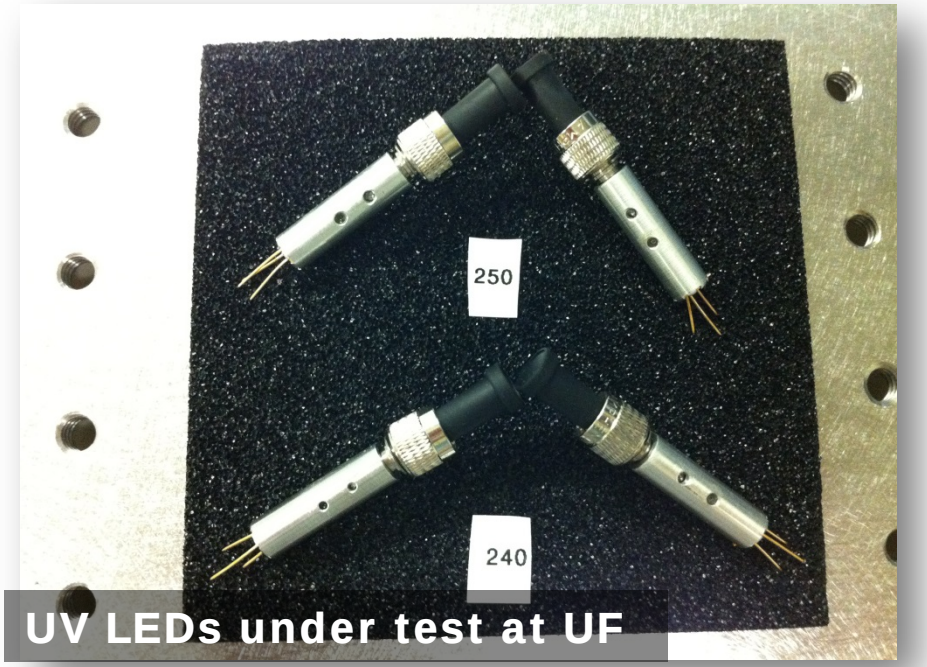
UF pendulum design sensitivity



Charge Control

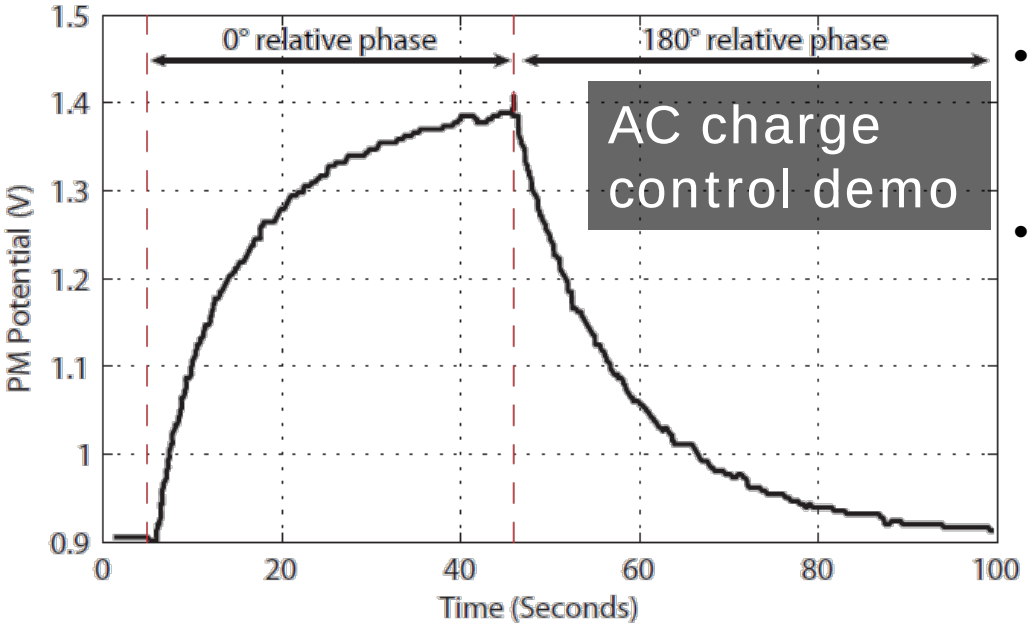
- TM charges due to release after launch & cosmic rays (50 e/s)
- Charge increases electrostatic stiffness & interacts with E fields
- TM Charge control via UV photoemission demoed by GP-B
- New (~2005) fast-switchable UV LEDs can replace Hg lamps
  - 240 nm UVLED $\rightarrow \lambda = 243 \pm 10$ nm (below Au work function ~243 nm)
  - Enables ac charge control
  - ~10x reduction in SWaP


LTP ULU (λ = 254 nm)

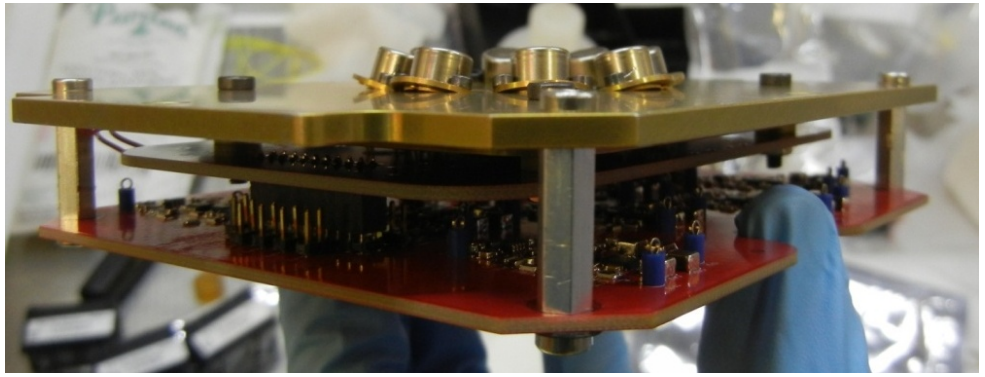


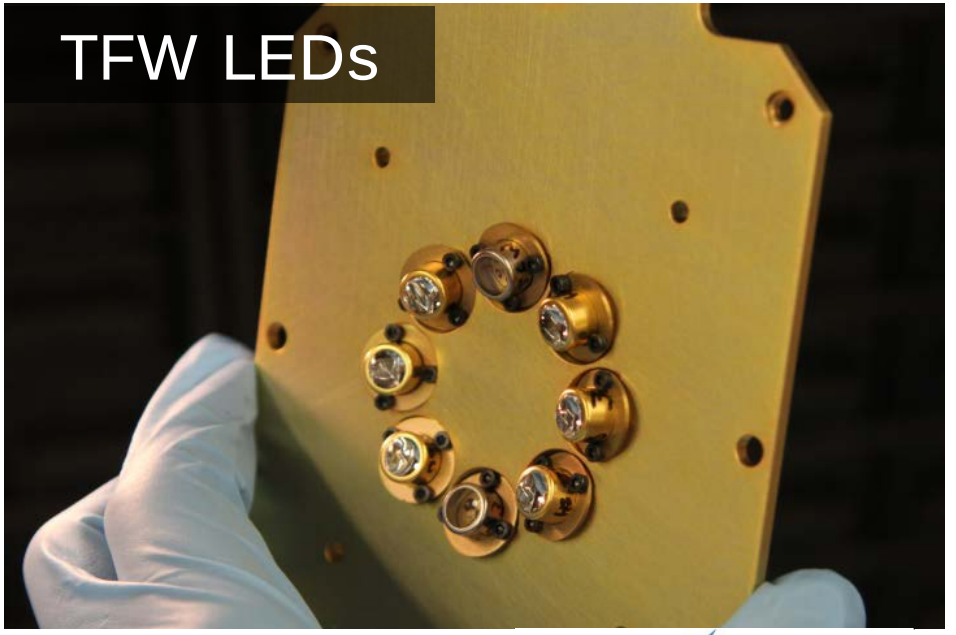
UV LEDs under test at UF

UV LED Small Satellite Mission



- Flight model payload successfully completed qualification test at ARC
- Launch: Oct 2013
  - Saudi Sat on Russian Rockot





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Conclusion

- Development of a torsion pendulum in the U.S. has both strategic and technical/scientific importance
- Design and construction of such a facility has begun at UF

05/13	06/13	08/13	09/13	03/14
• Pendulum Assembly	• Sensing Electronics	• Position Stages • Actuating Electronics • UV Charge Control	• STC fab • Vacuum Chamber • Pendulum Suspension	• Functional Test

- UV LED Small Satellite mission (launch in Oct. 2013) will demonstrate active charge control in space