Gravitational reference sensor technology development for LISA

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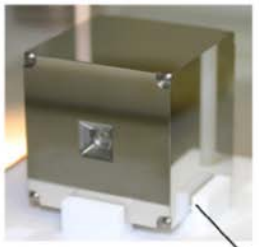
LISA Activity in U.S. since 2011 Breakup

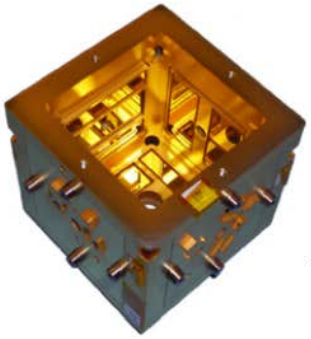
- ST7/LISA Pathfinder (JPL/GSFC)
  - Micronewton thrusters, drag-free control, data analysis
- NASA planning for Jr partnership with ESA on L3 (LISA)
- NASA commissioned L3 Study Team – D. Shoemaker, Chair
  - Phase 1 - FY16-17: Analyze the options for NASA participation in L3 & work with the eLISA consortium on proposals to ESA
  - Phase 2 - FY17-18: Prepare report for 2020 decadal survey on NASA's participation in L3 as a minority partner
  - Interim report on possible NASA technology contributions for L3 to be made public soon (~week)
  - L3ST website: http://pcos.gsfc.nasa.gov/studies/L3/
- NASA GWSIG, N. Cornish & J. Conklin, co-chairs
  http://pcos.gsfc.nasa.gov/sags/gwsag/gwsag-maillist.php

LISA Gravitational Reference Sensor

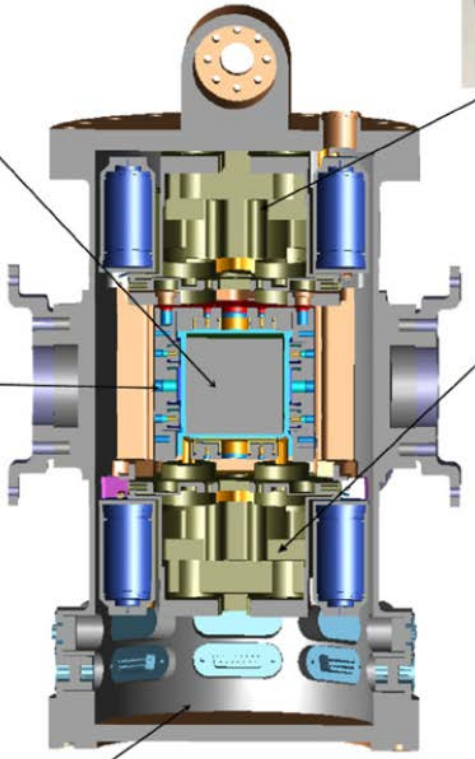


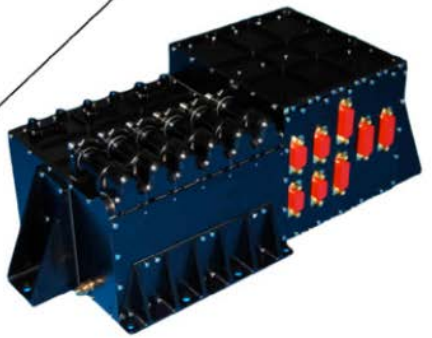
Test Mass (FM)

Caging Mechanism (EQM)



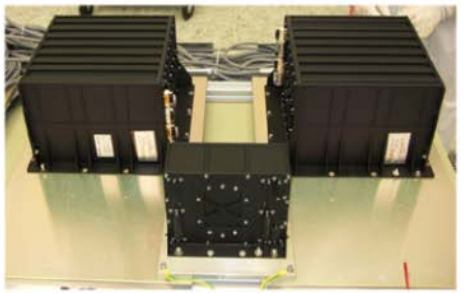
Electrode Housing (FM)





UV Light Unit (FM)

Vacuum Chamber (FM)

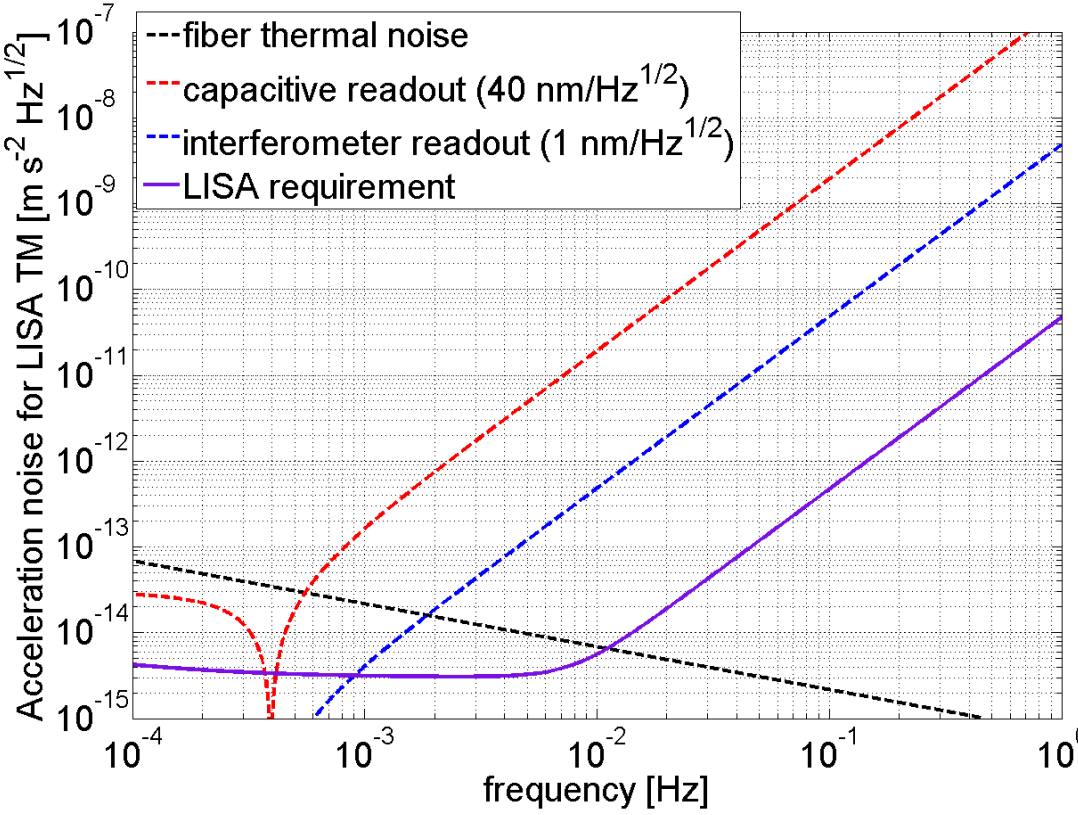


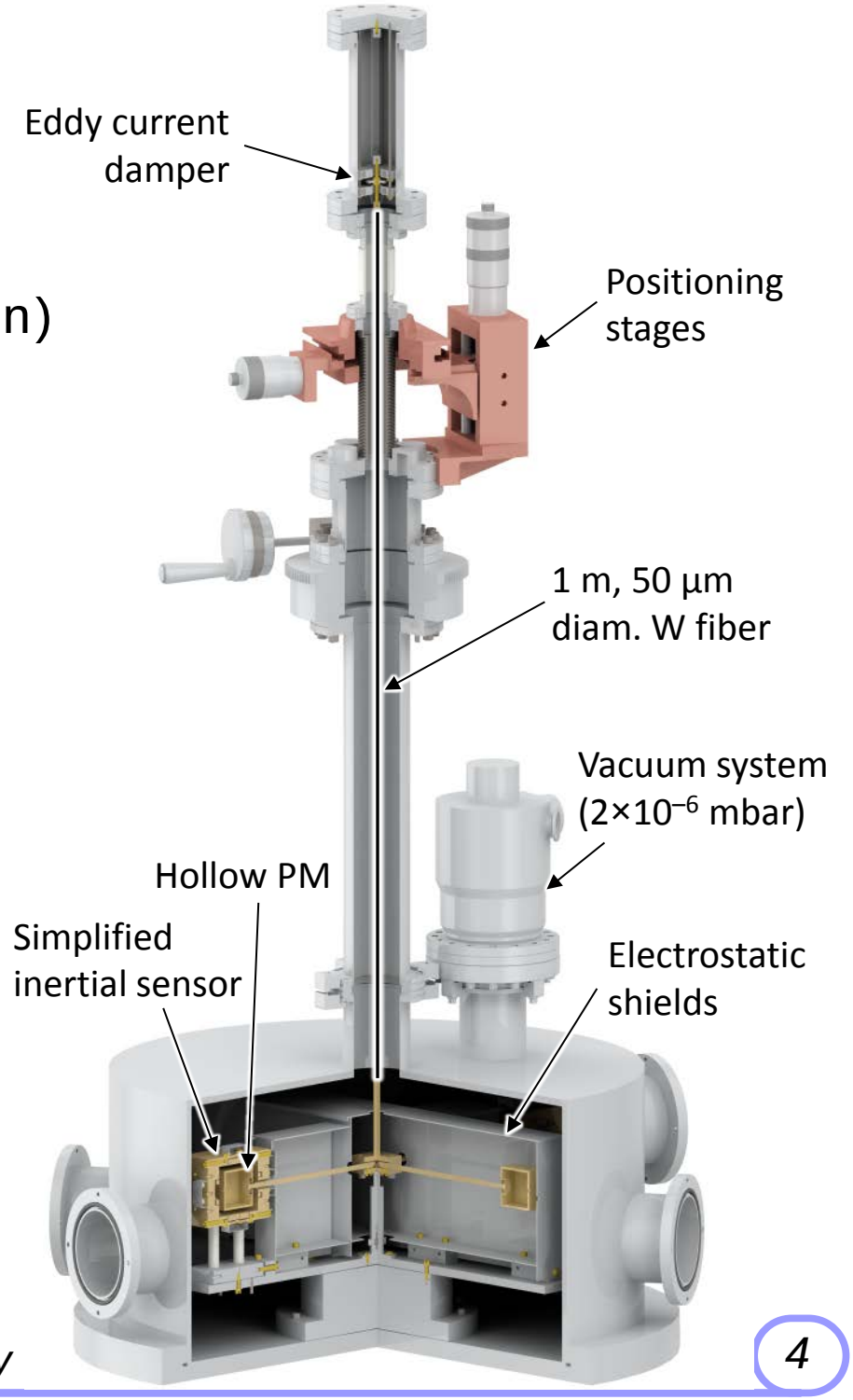
Front End Electronics (FM)

*F. Antonucci et al (2011)

UF Torsion Pendulum

- Follows 4TM Trento pendulum
  - Fiber supports cross bar with 4 hollow TMs (rotation → translation)
  - Light weight (0.46 kg) Al structure reduces needed fiber diameter
  - Measures surface forces





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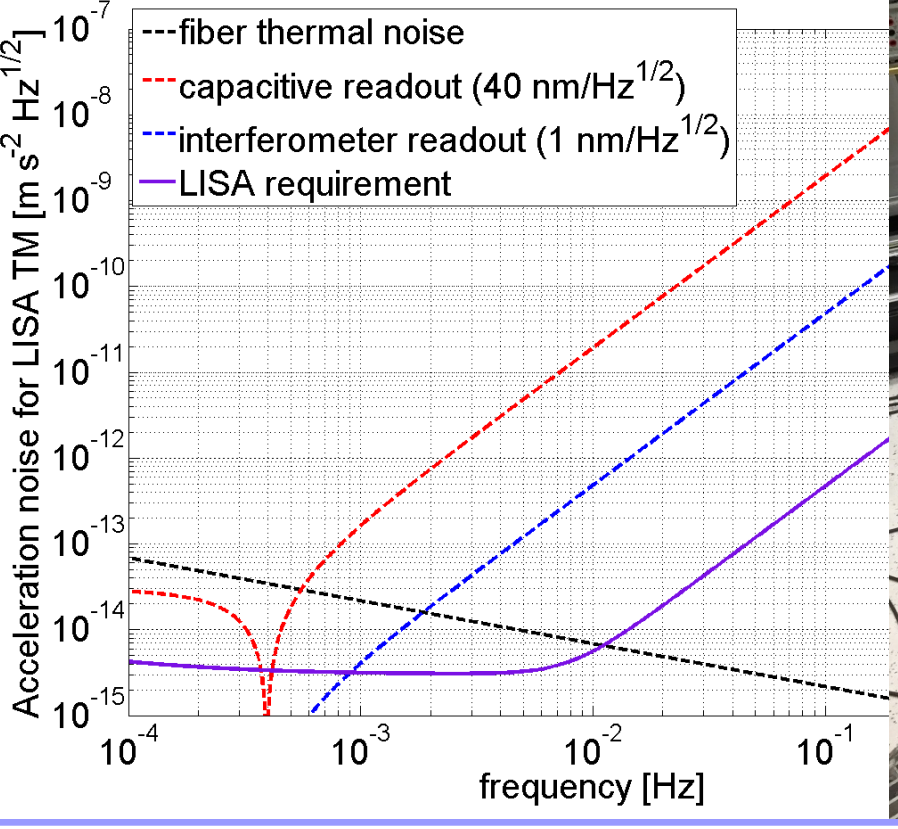

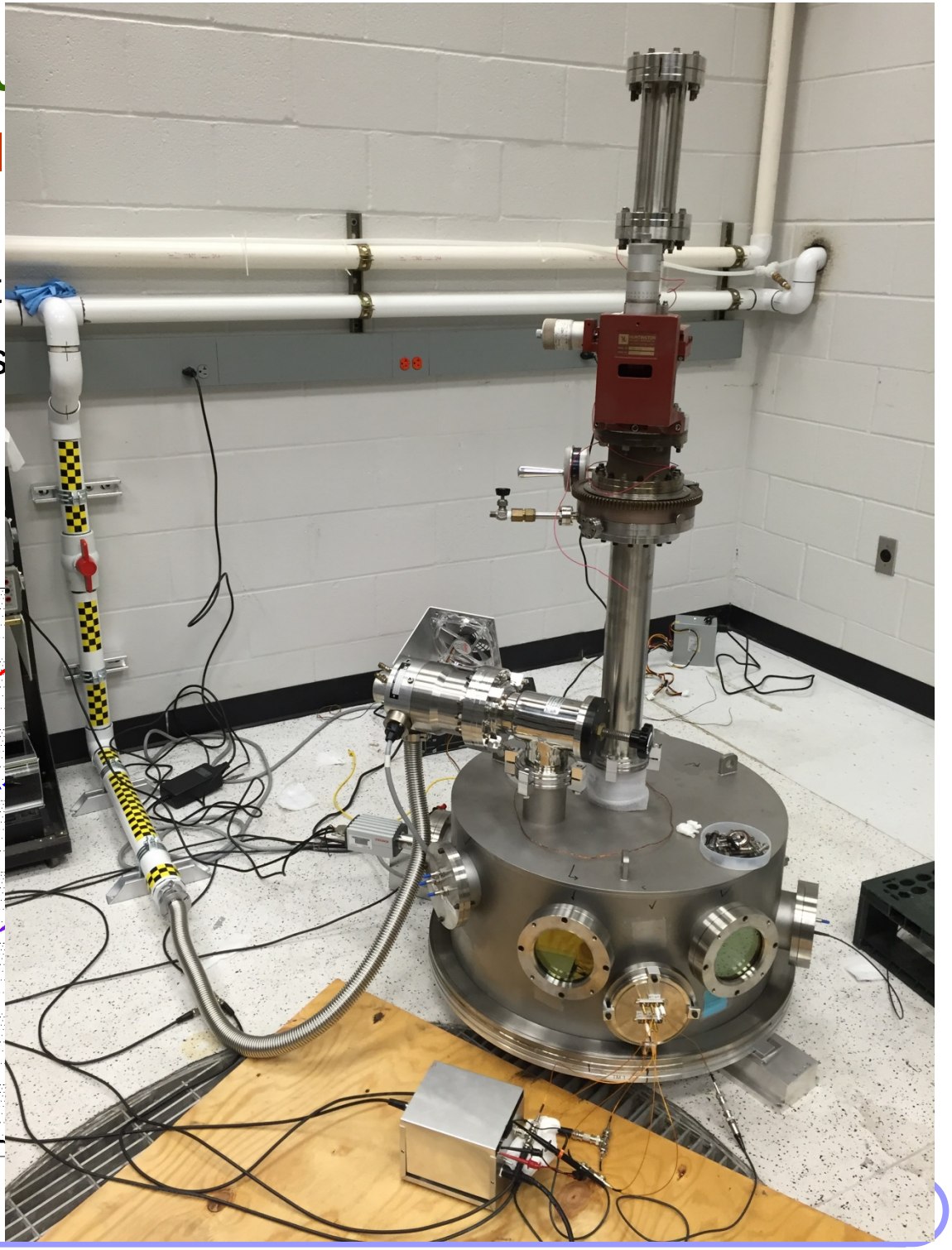

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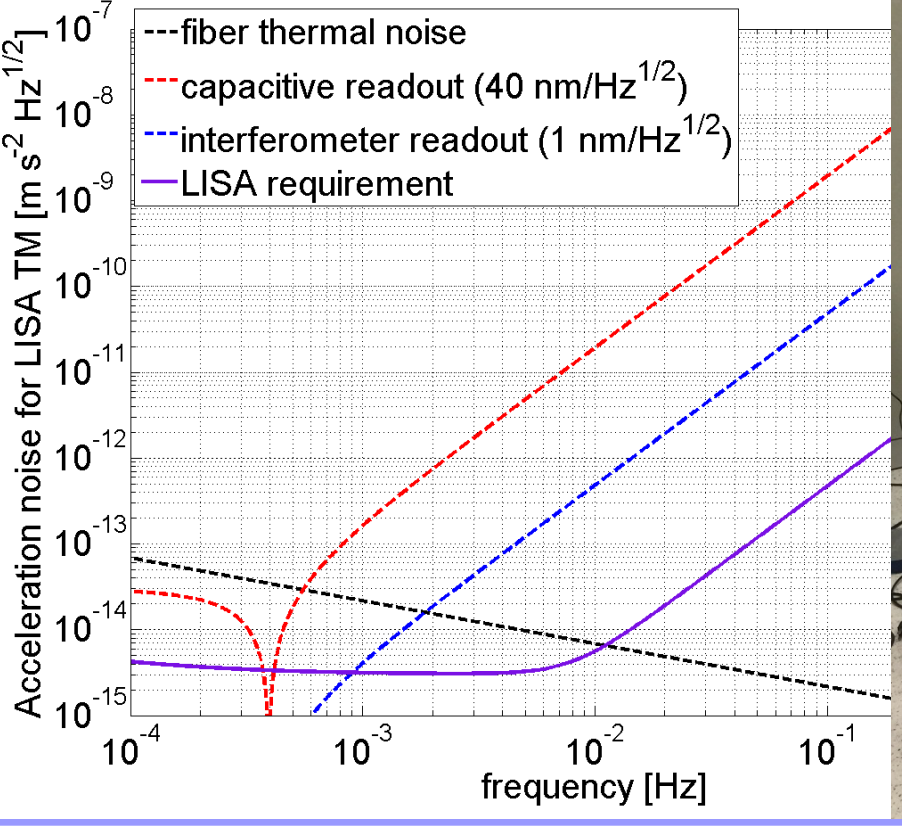
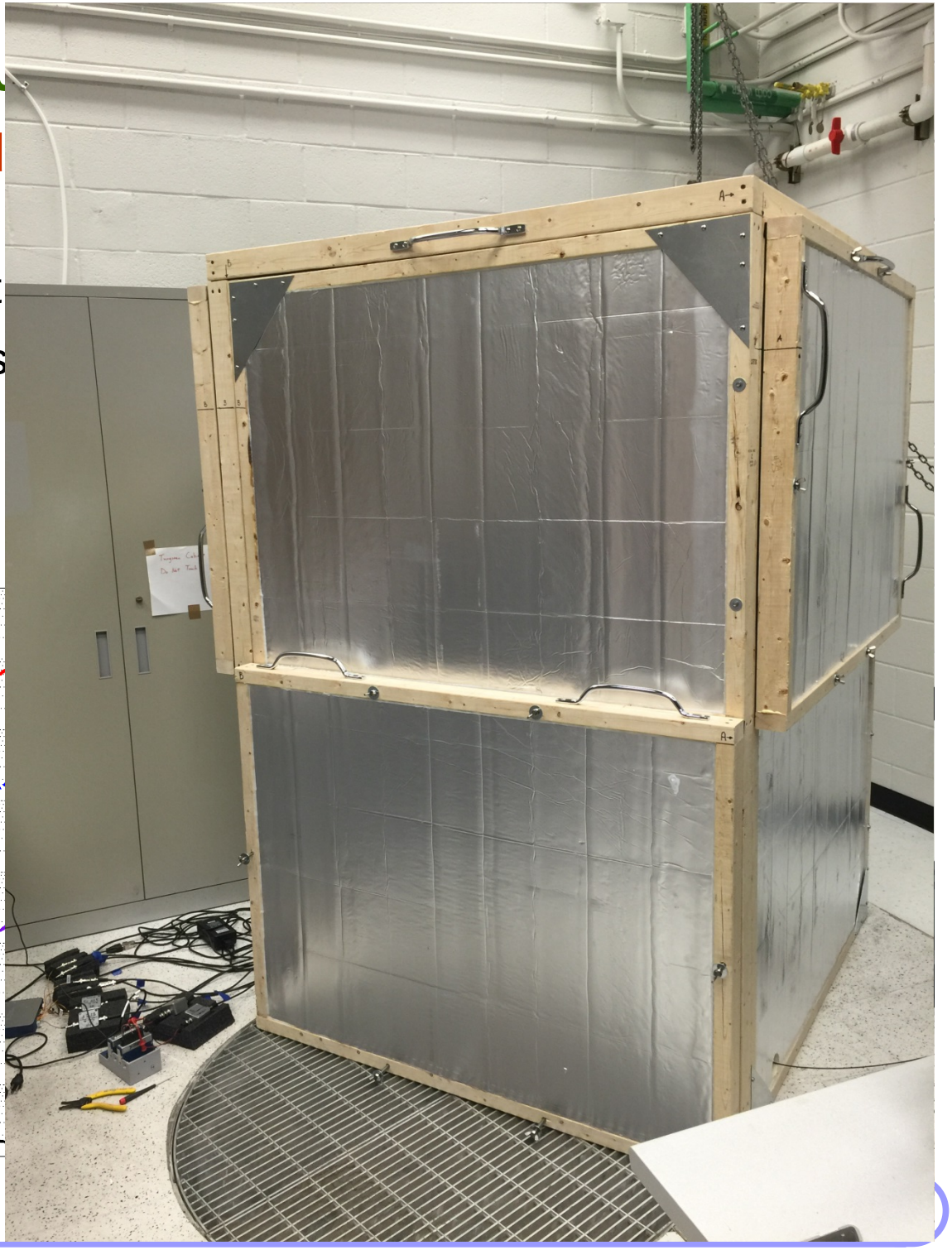
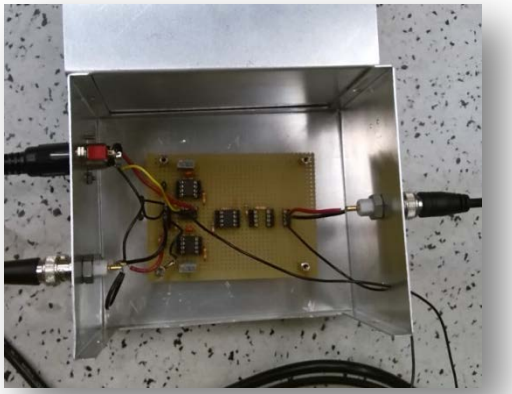
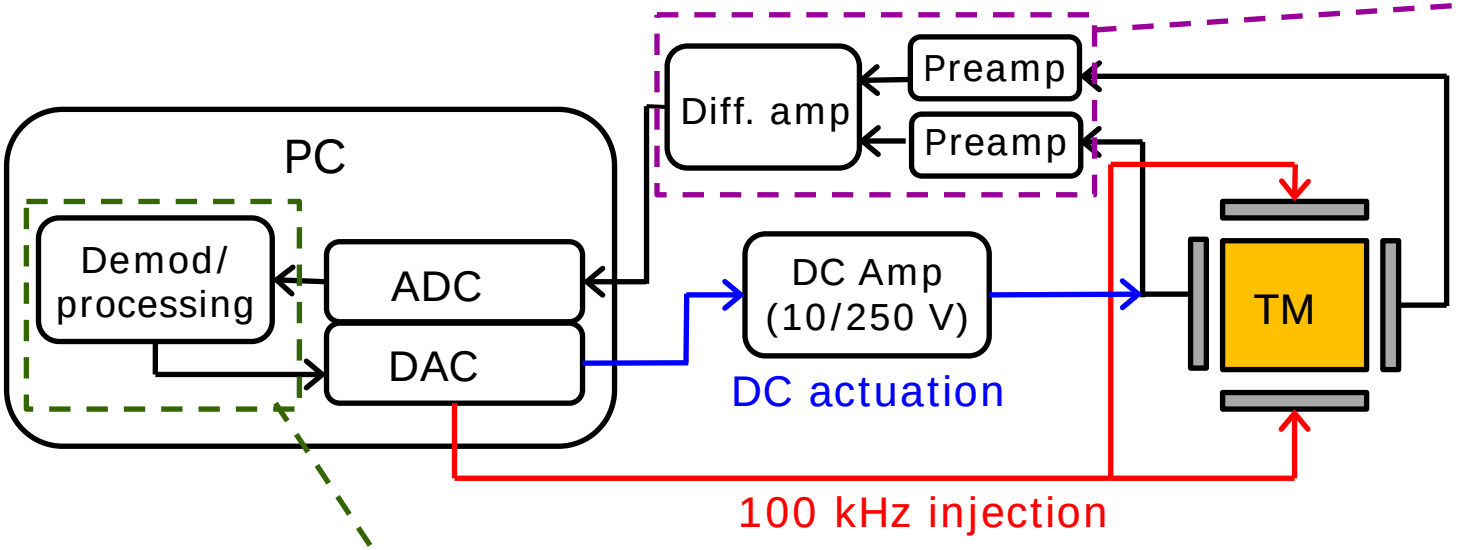


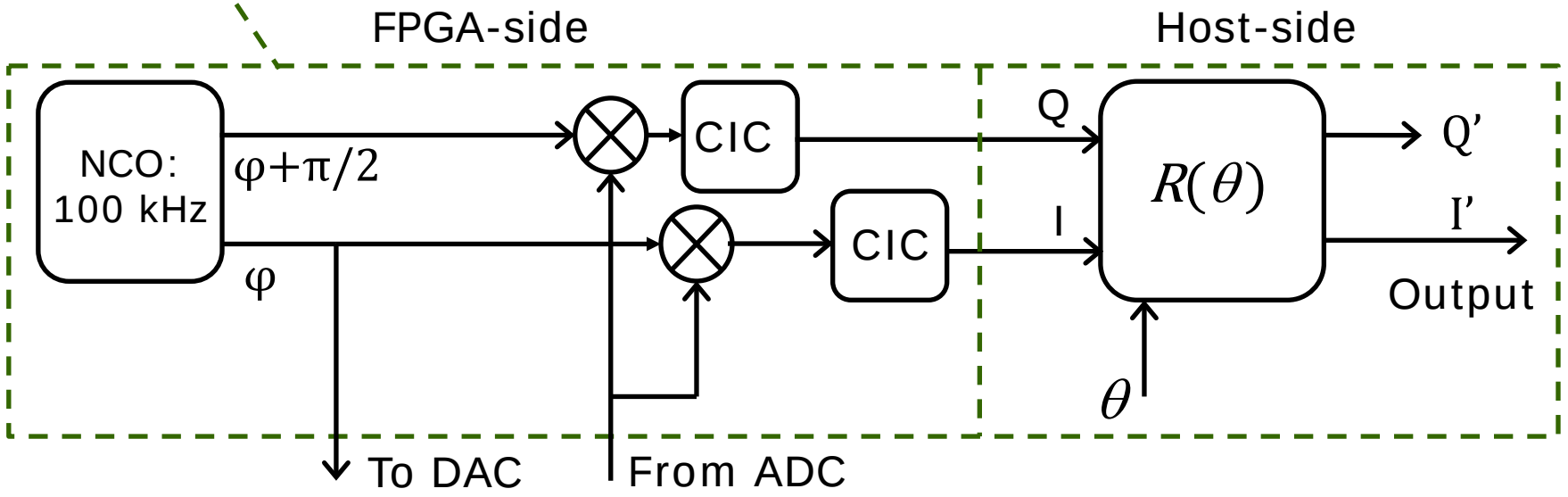


AC Capacitive Readout & DC Actuation

- Typical Sensitivity: 40 nm/Hz$^{1/2}$





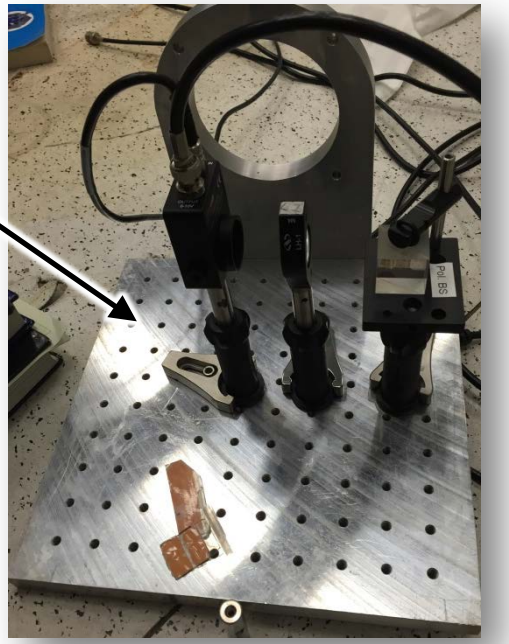


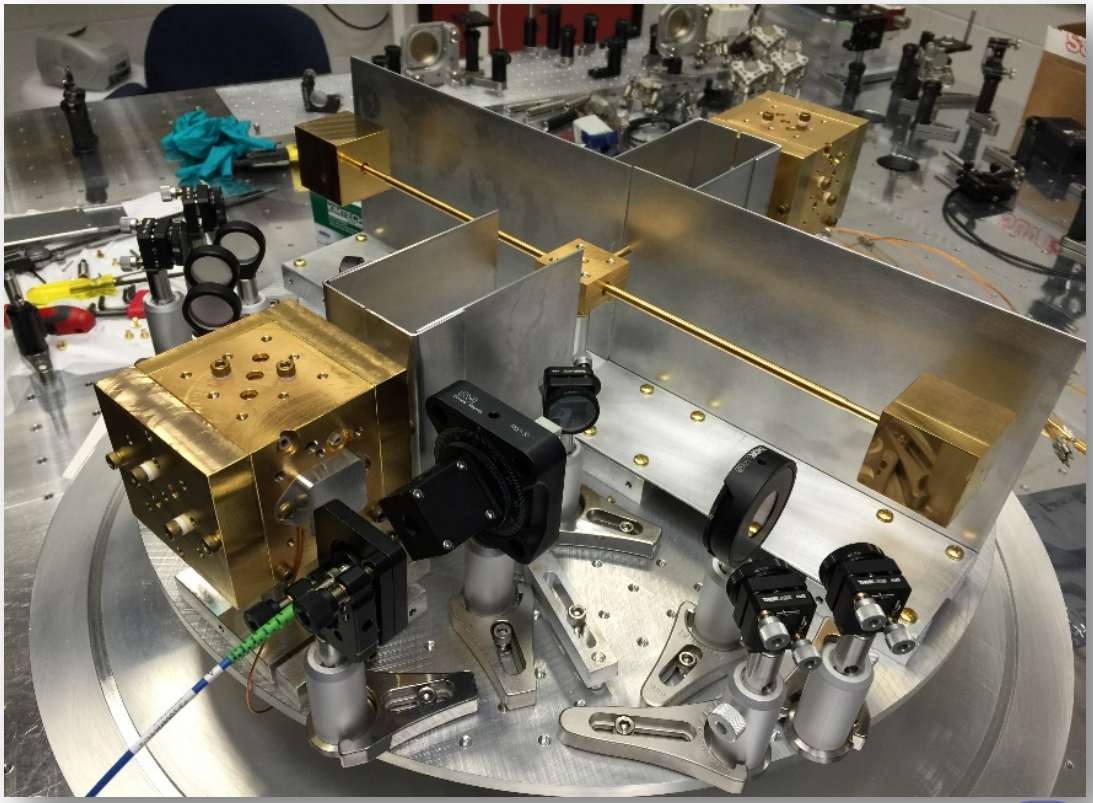
Interferometer Readout

- Polarization multiplexed Mach-Zehnder interferometer measures differential displacement of two test masses
- Light delivered by fiber feedthrough
- Recombined beam sensed outside chamber (free-space)
- Typical sensitivity:

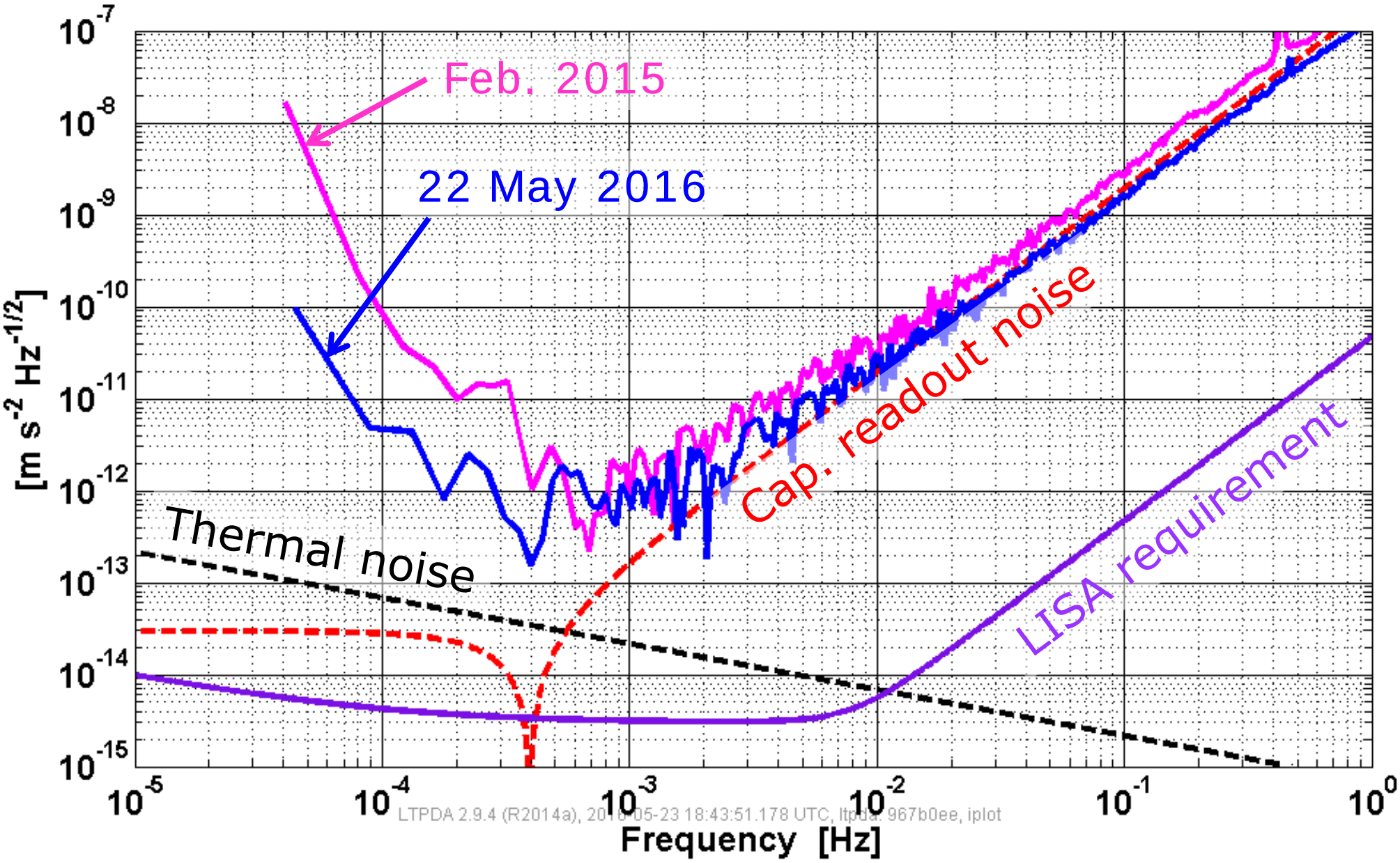
  $0.5\ \mathrm{nm/Hz^{1/2}}$

External bench

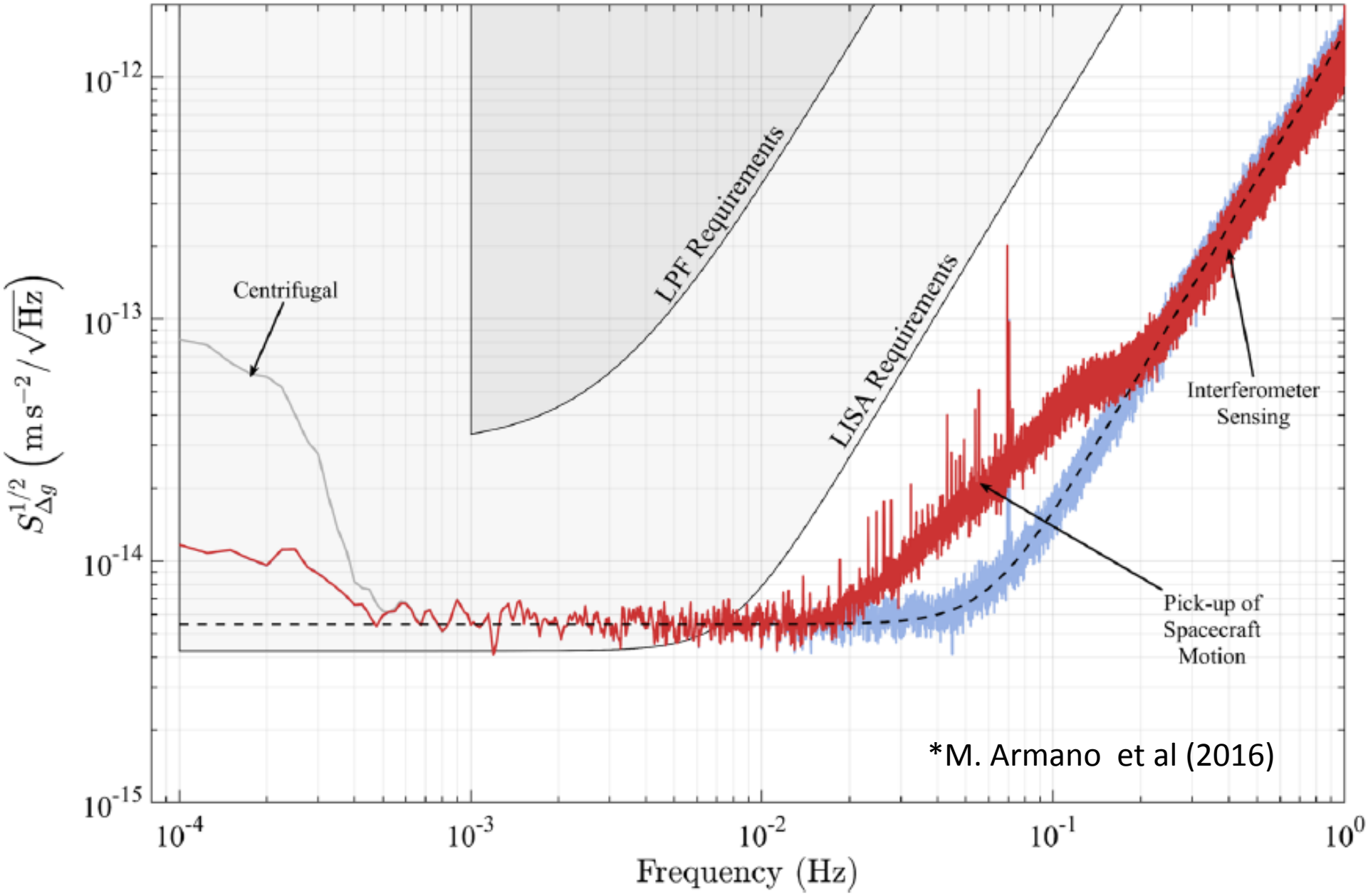




Equivalent LISA TM Acceleration Noise



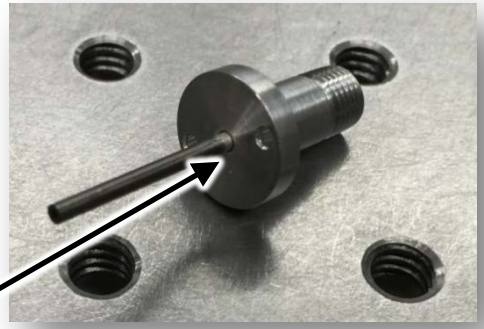
Not as Good as LISA Pathfinder



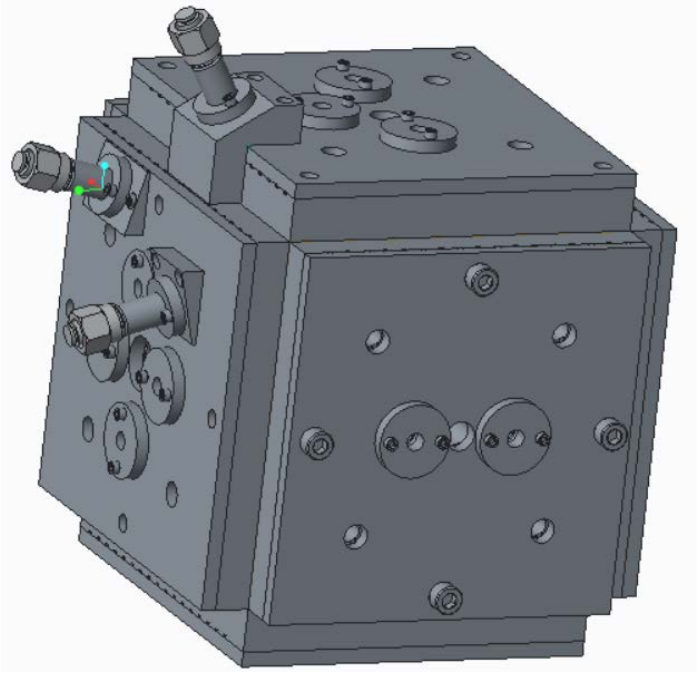
*M. Armano et al (2016)

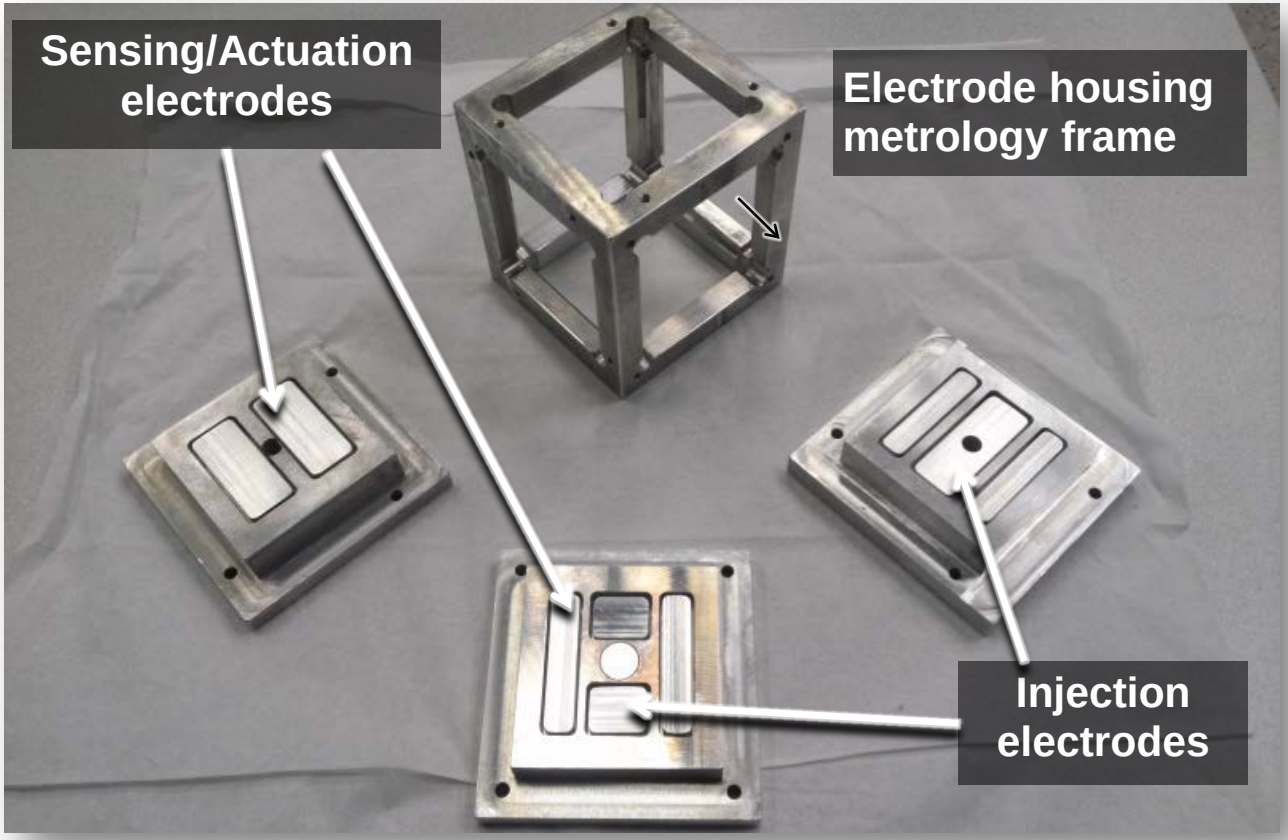
LISA Pathfinder-like GRS

- Internal geometry equivalent to Pathfinder
- 3 UV light injection ports
- Prototype: Aluminum + PEEK
- Integrated into pendulum late summer



UV injector
(Ti ferrule + UV fiber + SMA connector)

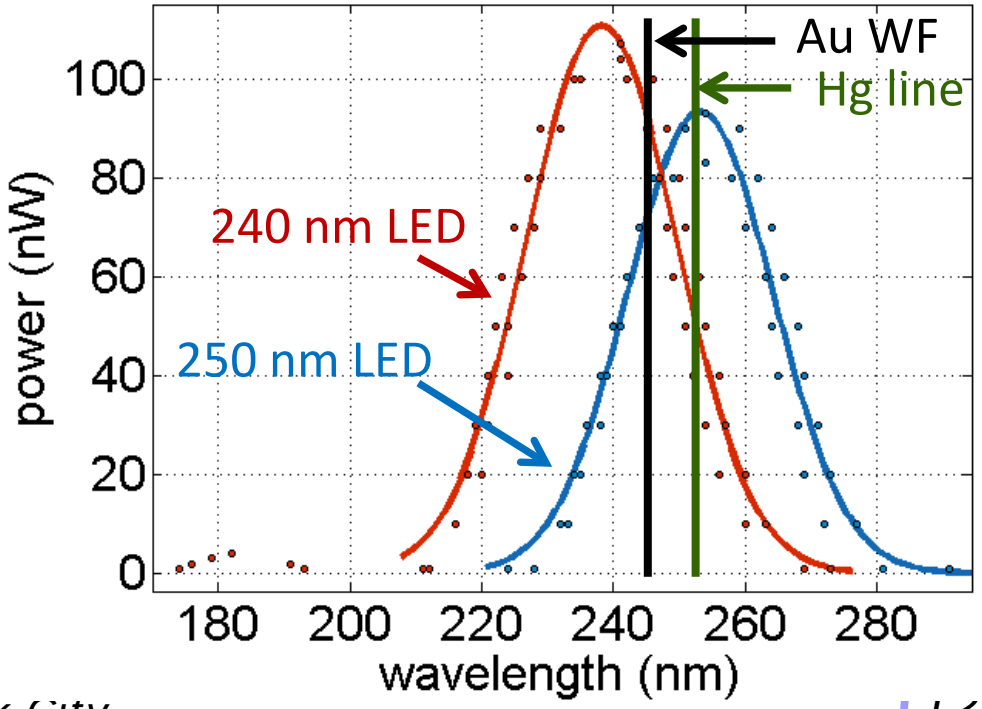




UV LED-based Charge Control

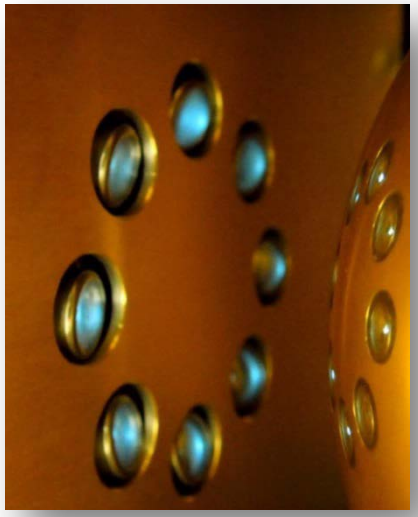
- TM charges due to release after launch & cosmic rays (~50 e/s)
- Charge increases electrostatic stiffness & interacts with *E* fields
- TM Charge control via UV photoemission demoed by GP-B
- UV LEDs are attractive alternate to Hg lamps
  - 240 ± 10 nm UV LED
    < Au work function 243 nm
  - ~10x reduction in SWaP
    (~150 mW in → 25 µW out)
  - Enables AC charge control

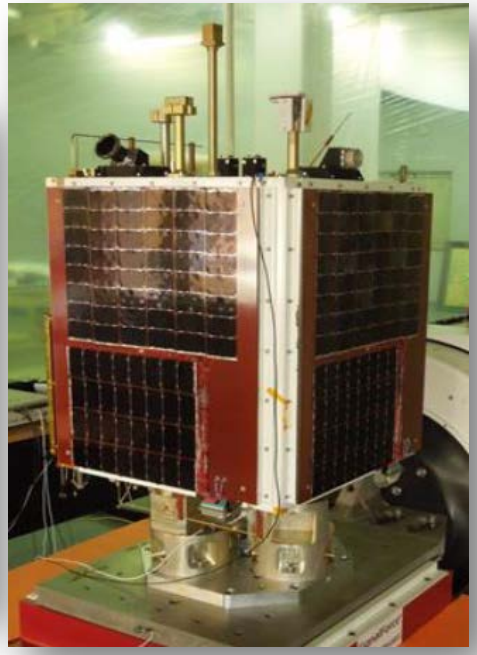
Fiber-coupled UV LEDs (SETi)



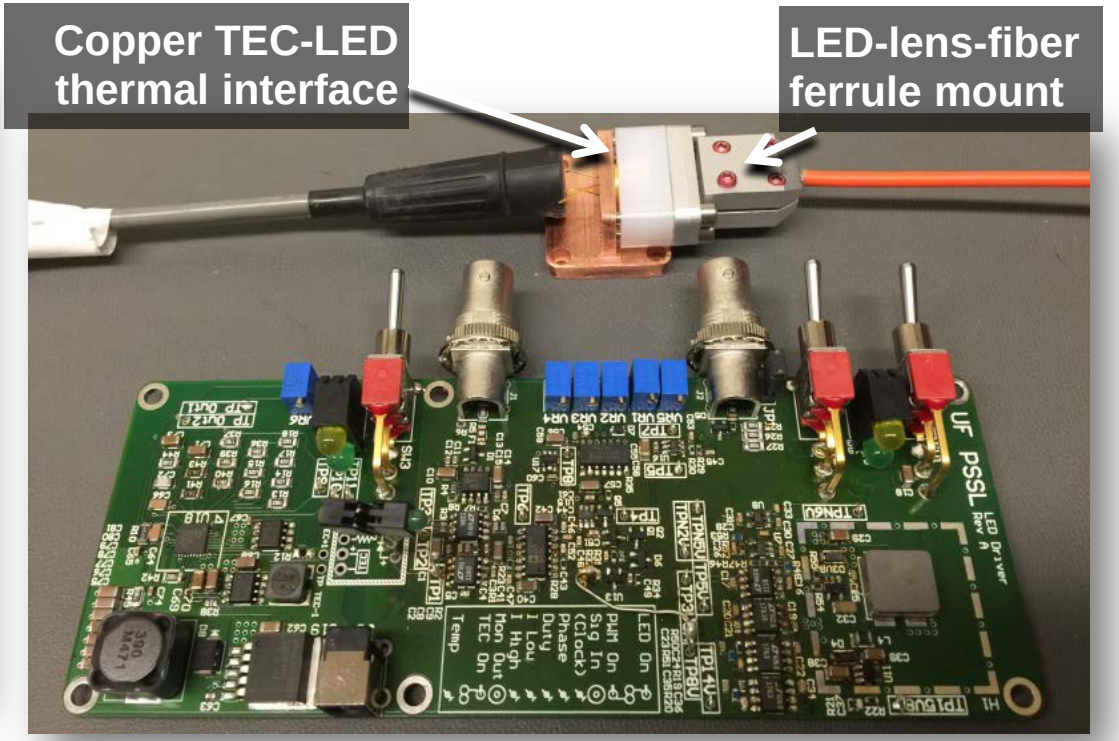
UV LEDs in Space

- UV LED Small Satellite – 19 June 2014 launch
  - Stanford, NASA Ames, KACST collaboration
  - Successful demo of UV LED-based charge transfer in space
- Space capable UV LED driver electronics / fiber coupler (UF)





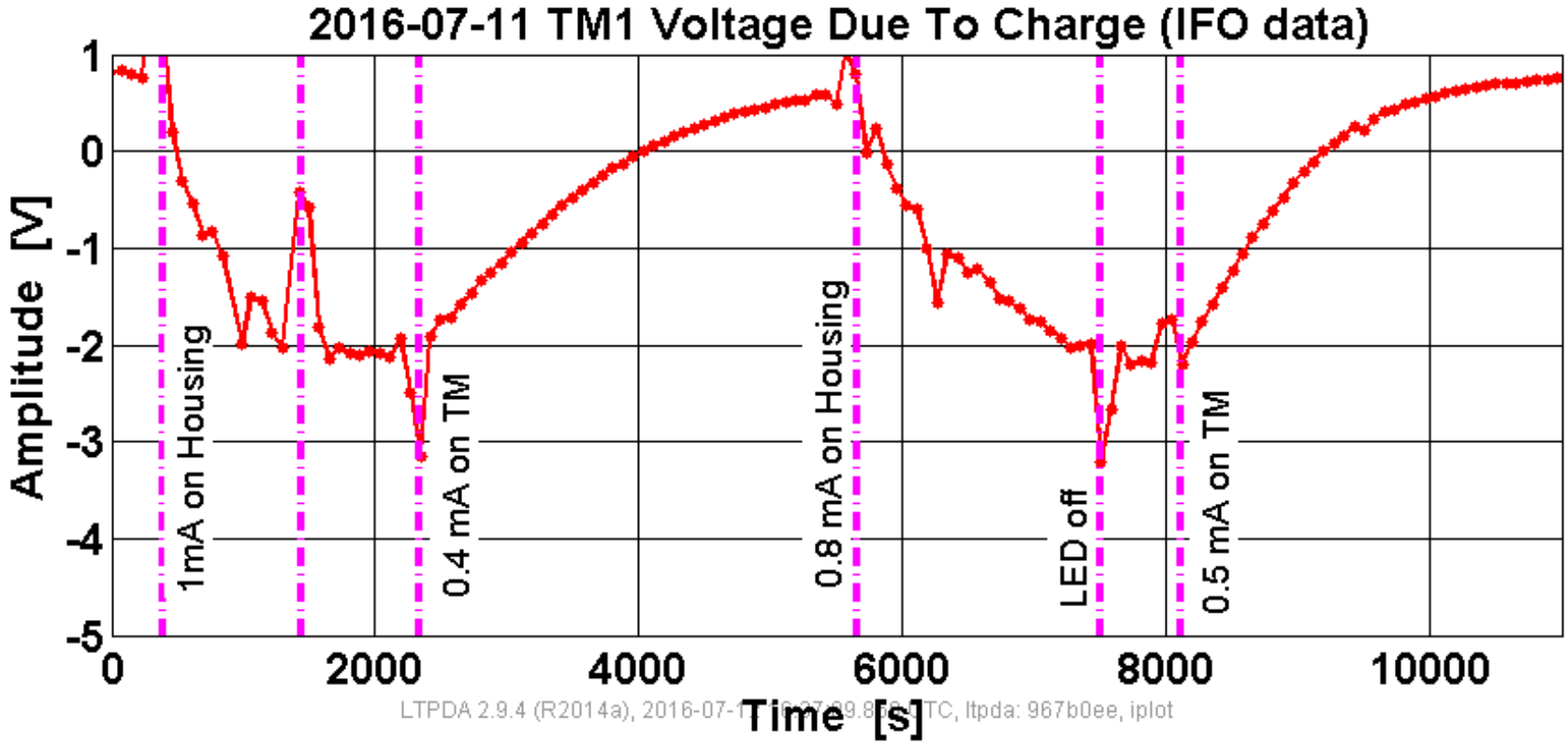
UV LED payload & Saudi-Sat4



Initial UV LED driver & fiber coupler

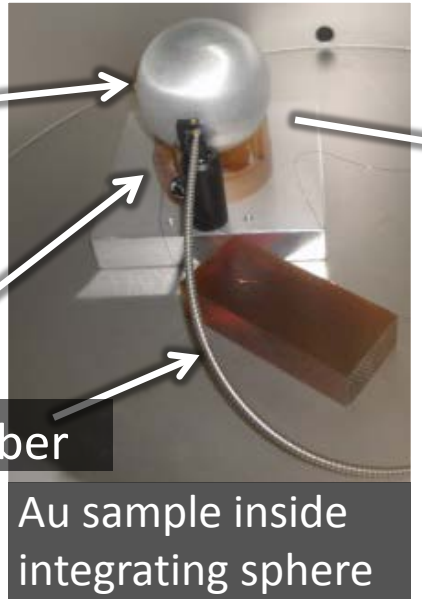
DC Charge Control on Pendulum

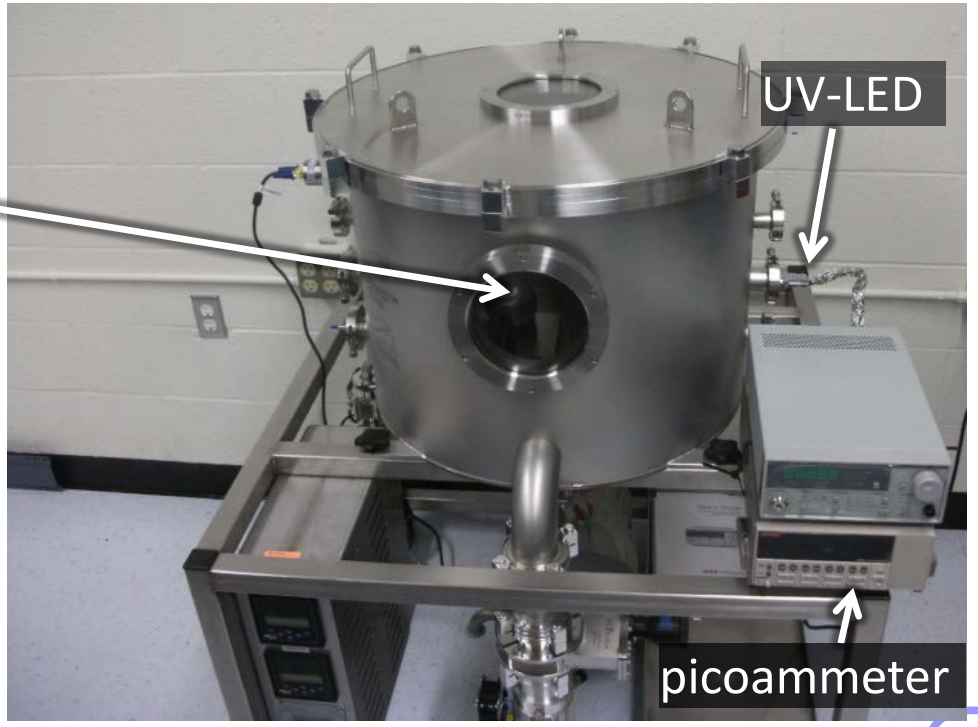
- Applied AC field drives pendulum with amplitude $\propto q$
- Illuminating the housing drives electrons to the TM
- Illuminating the TM drives electrons to the housing
- Bi-polar charge control demonstrated, but not well balanced (–2 V < q < 1 V)



QE Measurements

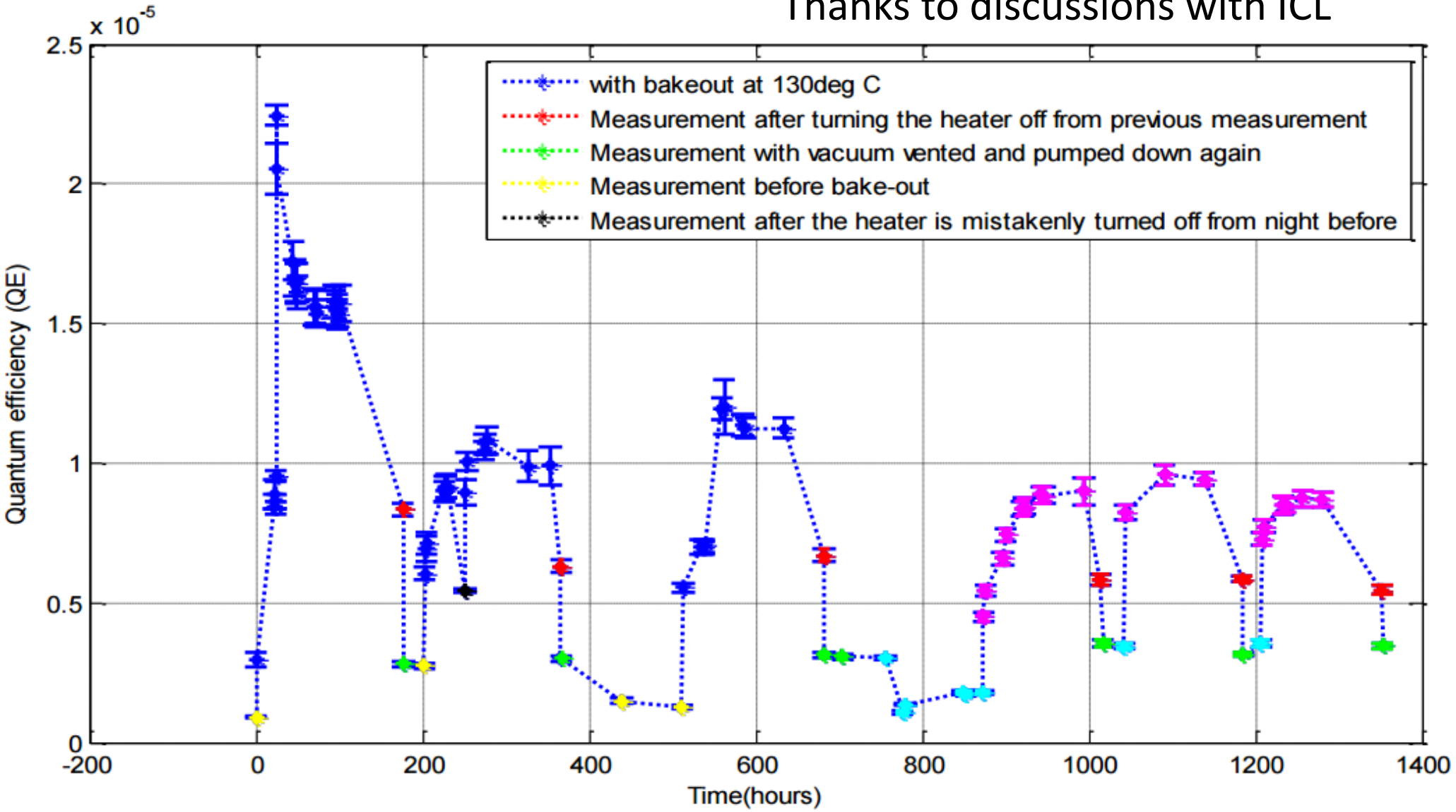
- # liberated electrons / # incident photons (typ. ~10^{-5} for Au)
- Drives charge control performance (want $R < \mathrm{QE}_1/\mathrm{QE}_2 < R^{-1}$)
- Measurement technique:
  - Fiber-coupled UV LEDs illuminate coated sample
  - Samples (-9 V), sphere (+9 V)
  - Picoammeter measures current flow from sample to sphere
  - Vacuum: < 10^{-5} Torr





Improved Consistency with Bake-out

Thanks to discussions with ICL



Summary & Plans

- UF Torsion pendulum for testing GRS technologies
  - few×10^{-13} m/s^{2}Hz$^{1/2}$ @ 0.2 - 2 mHz
- UV LED-based charge control
  - Successfully tested in space and
  - Initial DC charge control tests with LISA-similar GRS in UF torsion pendulum
- Future plans
  - Integrate Pathfinder-equivalent GRS with pendulum
  - Test AC charge control & continuous charge control
  - In ~4 years, develop TRL 4/5 fiber-coupled UV LED source

Acknowledgements

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