UW LISA Torsion Balance Experiment

Scott E Pollack

with

Stephan Schlamminger, Charlie Hagedorn,

&

Jens Gundlach

Center for Experimental Nuclear Physics and Astrophysics
University of Washington

Workshop on Charging Issues
in Experimental Gravity
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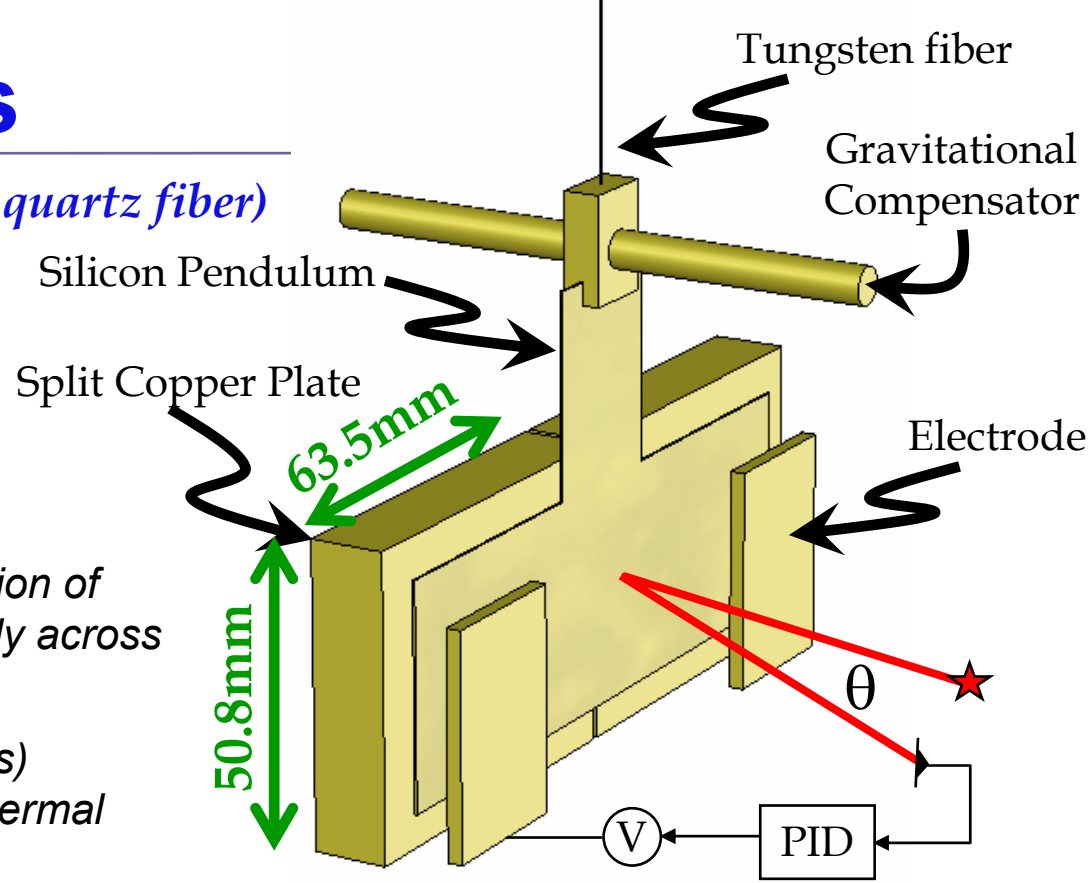
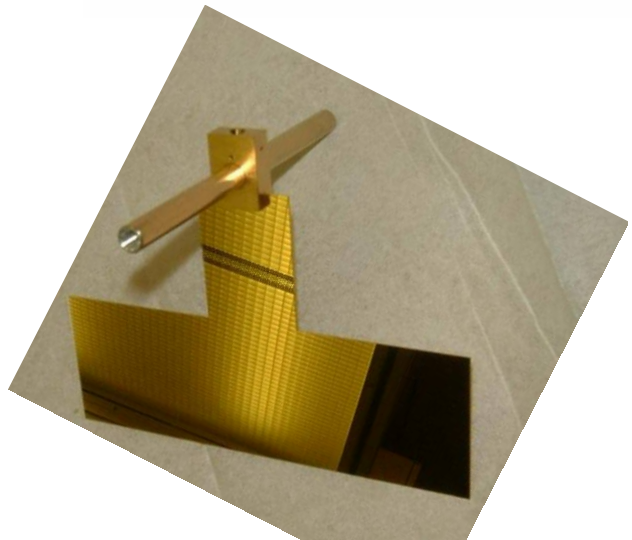
UW Apparatus

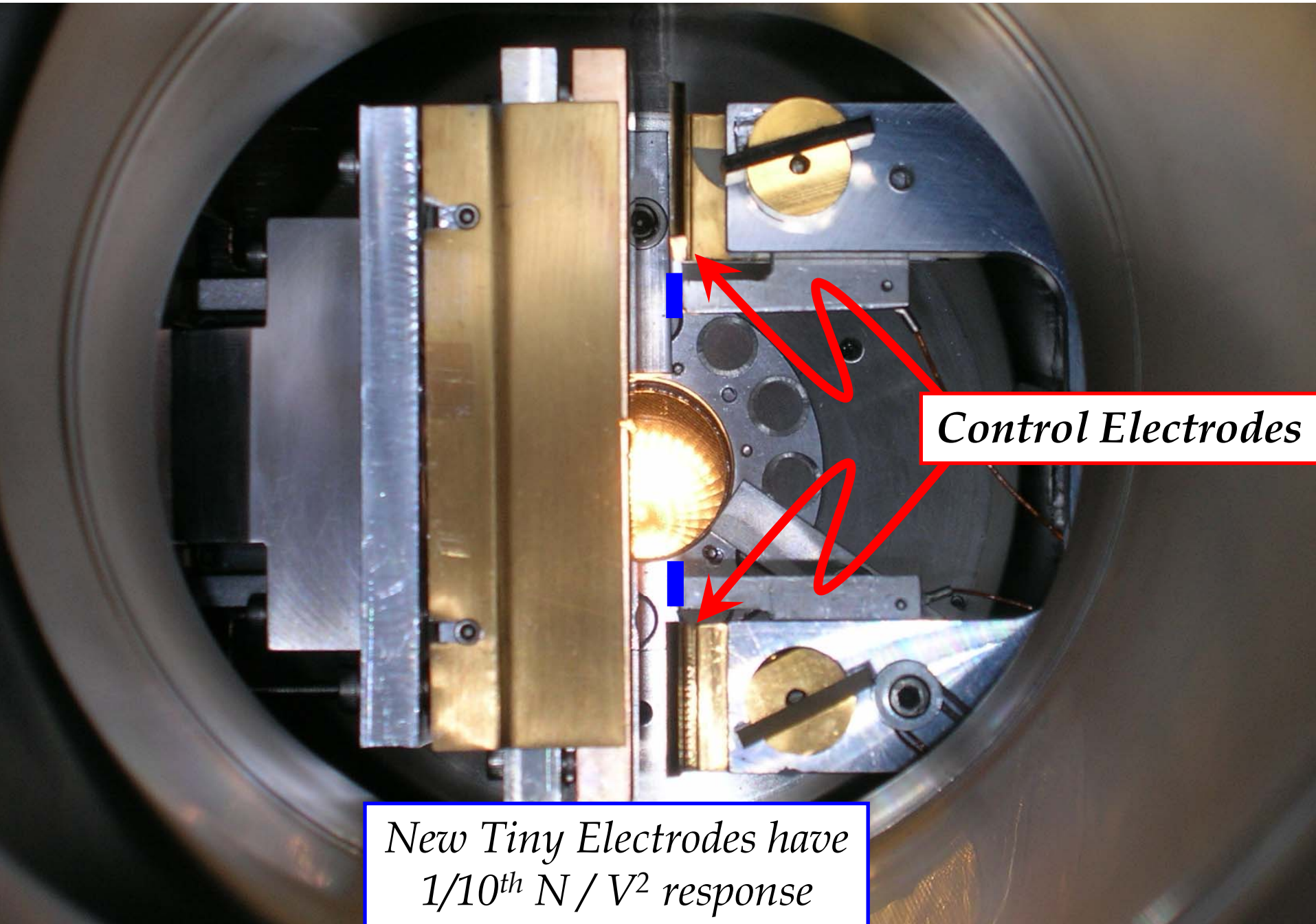
- **0.5m 13 μm W fiber** *(now quartz fiber)*
- **Au-coated Si-pendulum**
  - *0.6 mm thick*
  - *Low mass*
- **Split Au-coated Cu-plate**
  - *Split-plate allows investigation of potential differences laterally across pendulum*
  - *Heater elements (light bulbs) imbedded in plates allow thermal control*
  - *Movable up to 10 mm from pendulum*
- **Control Electrodes**
  - *Used to feedback pendulum to fixed position, i.e., cold damping*
  - *Residual pendulum motion at level of ~ 2 nrad/√Hz ≈ 1.5 aNm/√Hz*

    ≈ 0.02 fm/s²/√Hz





Top down view with pendulum removed



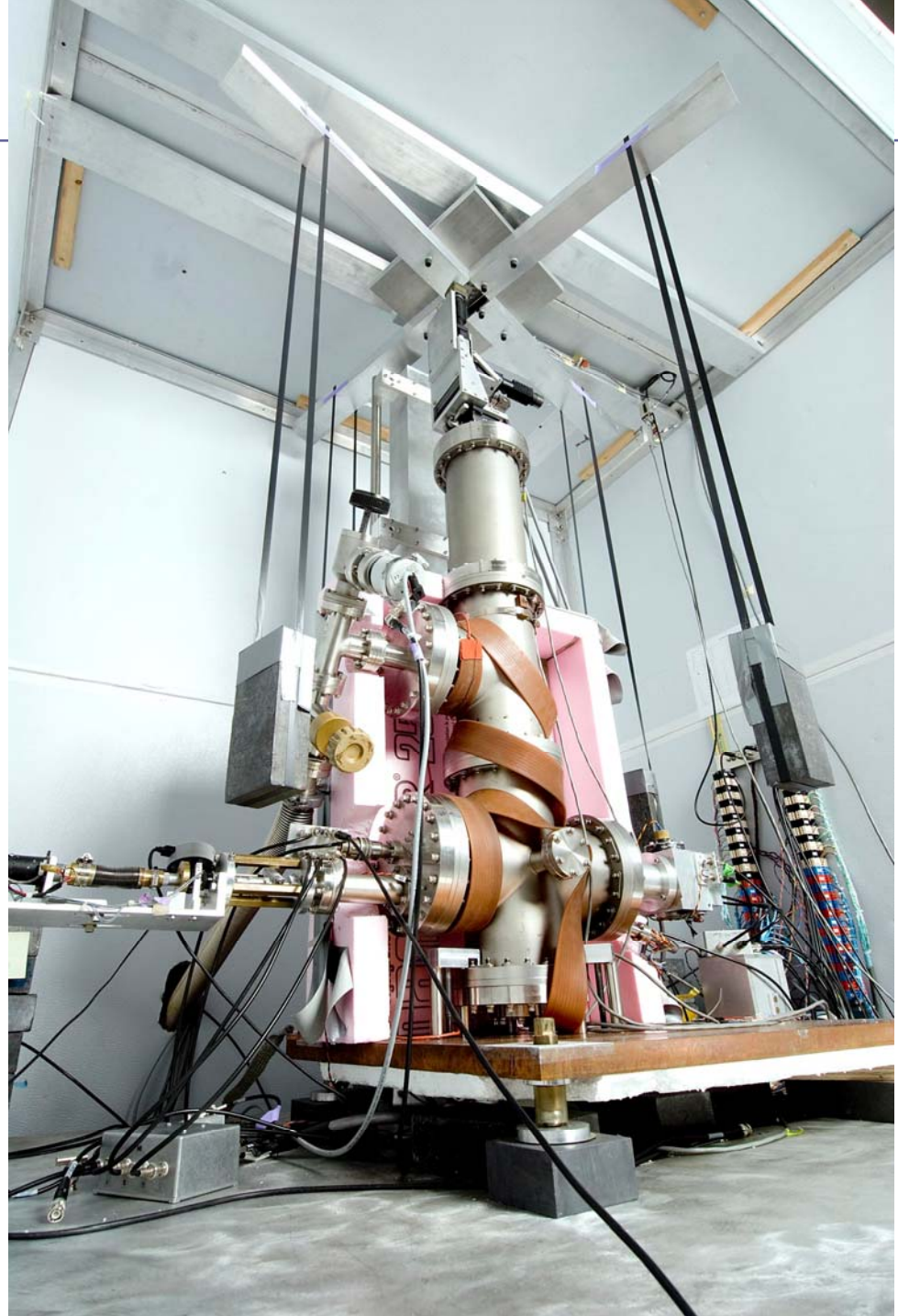
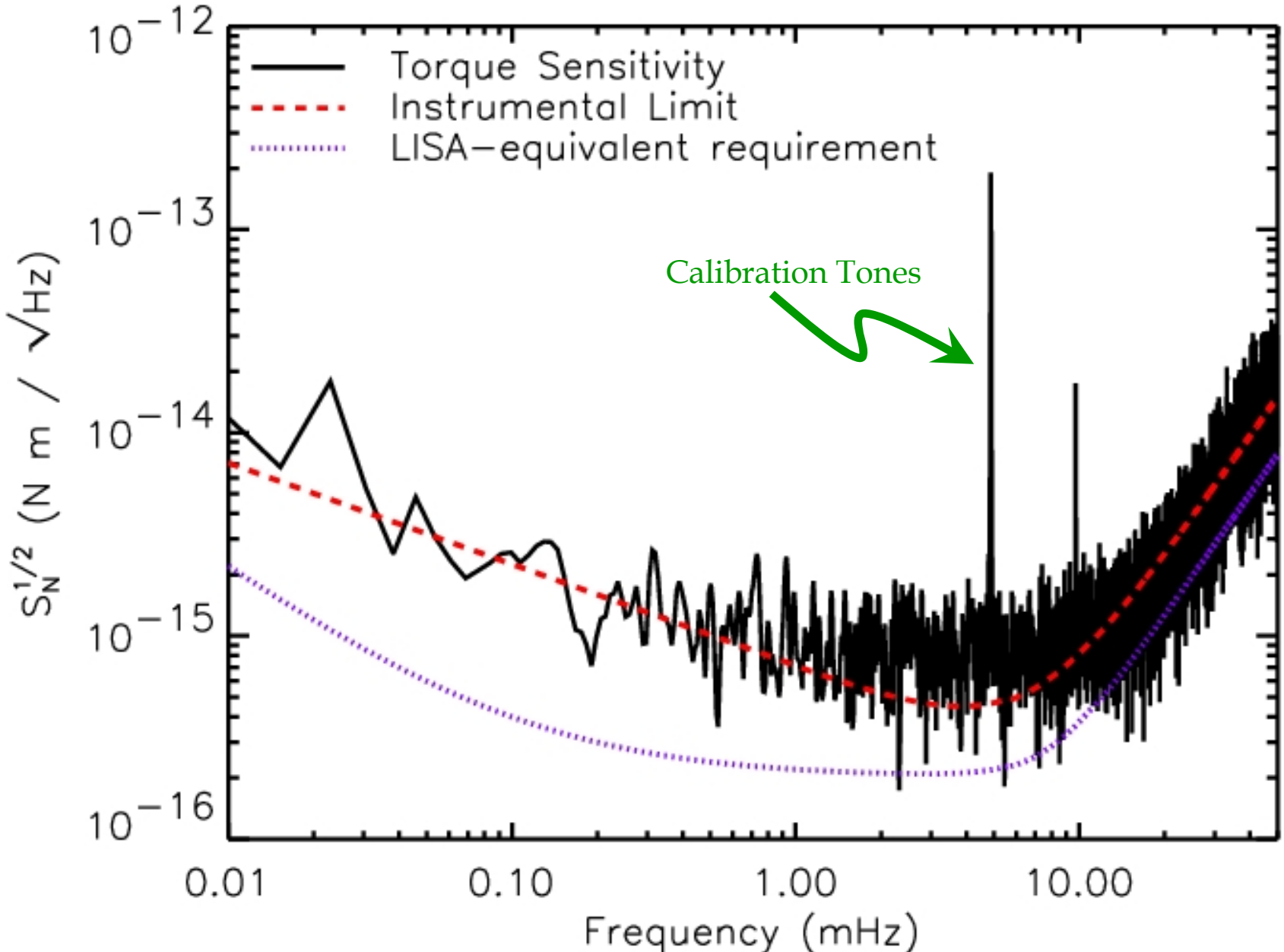


Photo courtesy Mary Levin

Torque Noise Performance

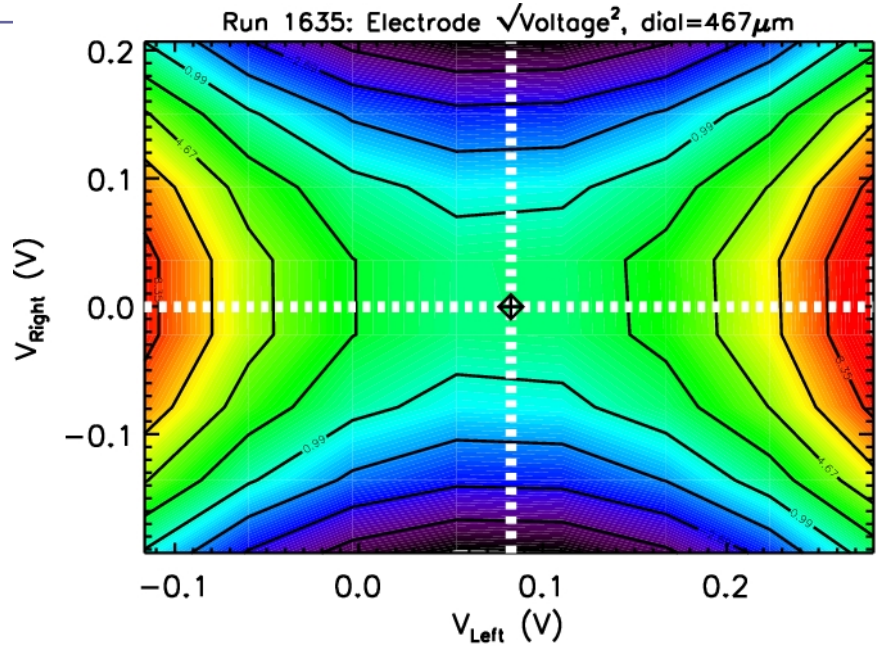


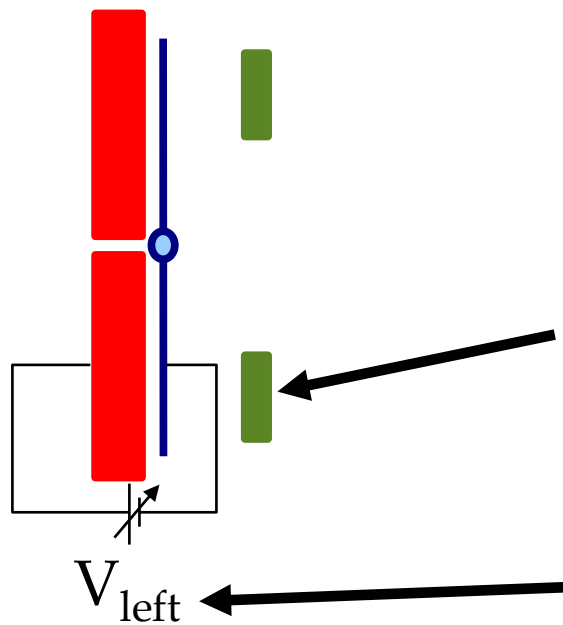
Surface Potential Measurements

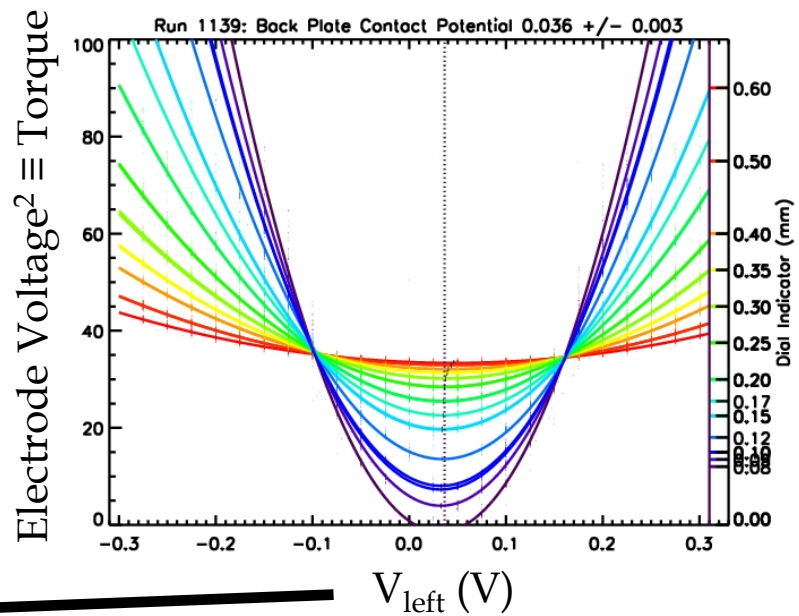
- Electrostatic surface potential defined by potential energy of plate-pendulum capacitor:

$$N = \frac{d}{d\theta}\frac{\epsilon_0 A}{2s}(V - V_{SP})^2$$

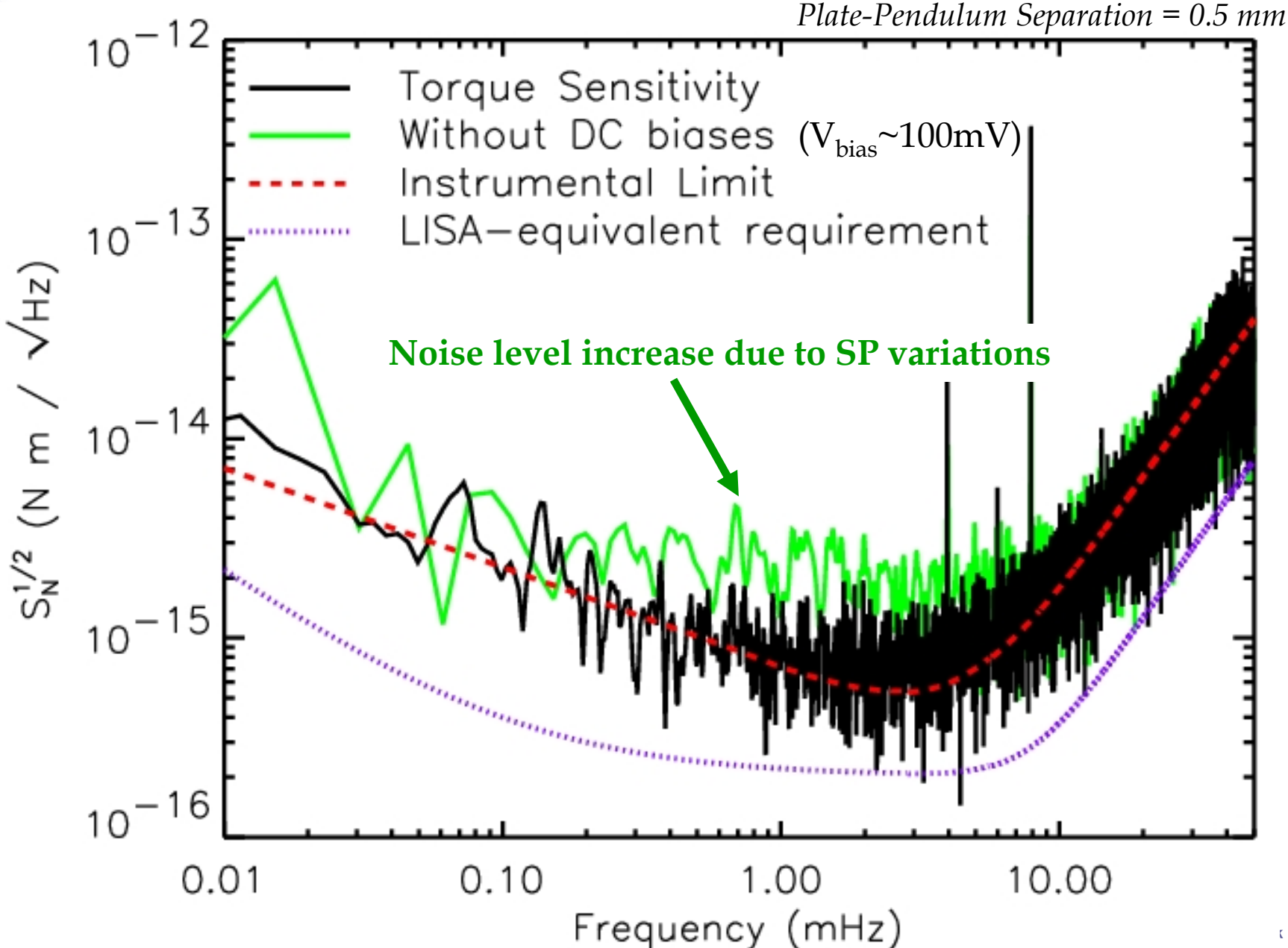
- Determine SP of each half of split Cu-plate by measuring torque vs. applied voltage



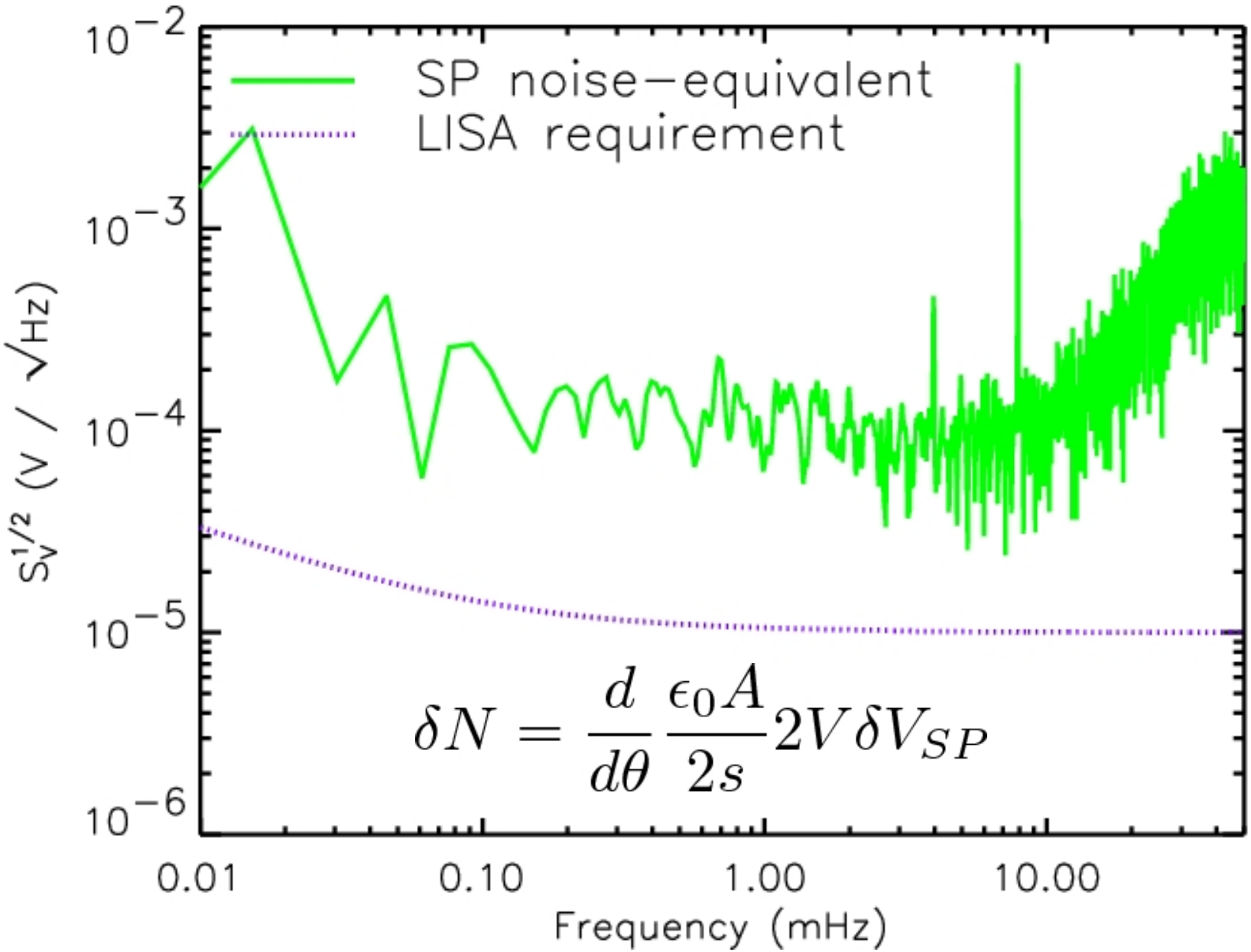




Surface Potential Noise Impacts

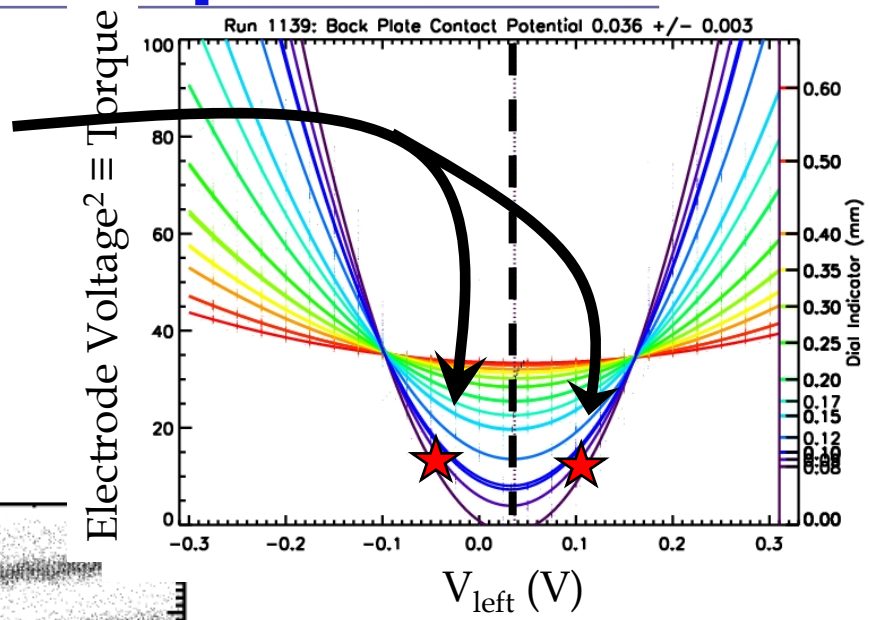


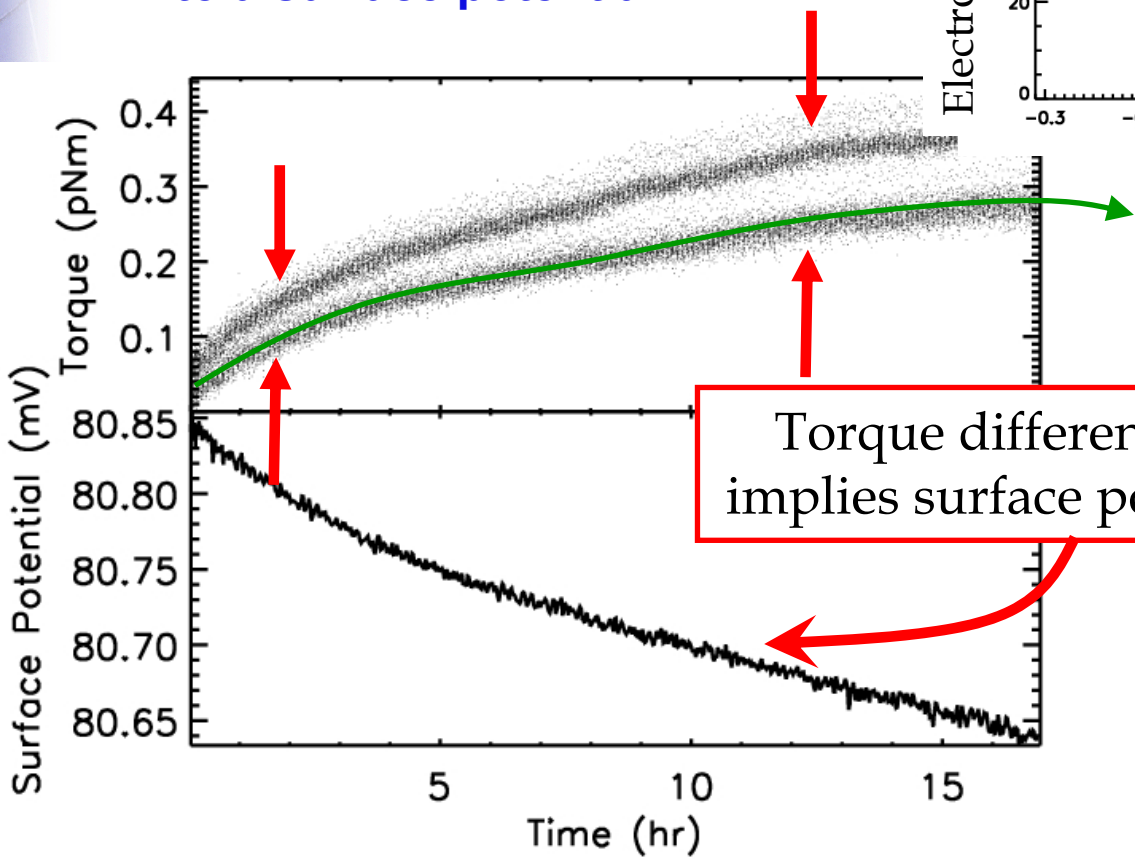
Surface Potential Noise Impacts



Measurement Technique

- Switch between two voltages with relatively equal torques on pendulum (minimize transients)
- Monitor difference in torque as function of time, convert this into a surface potential

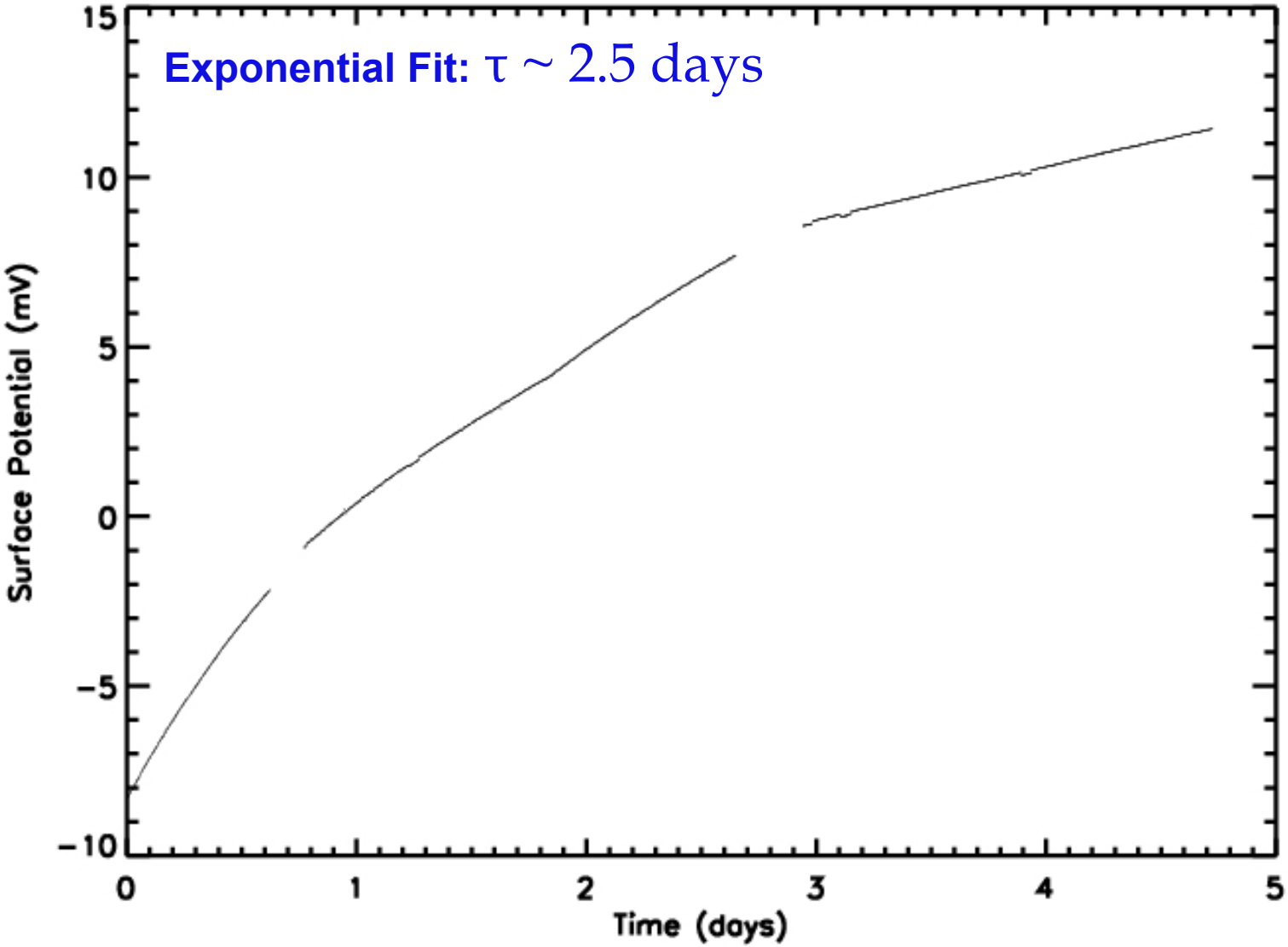




Overall change in torque due to fiber relaxation

Torque difference change implies surface potential drift

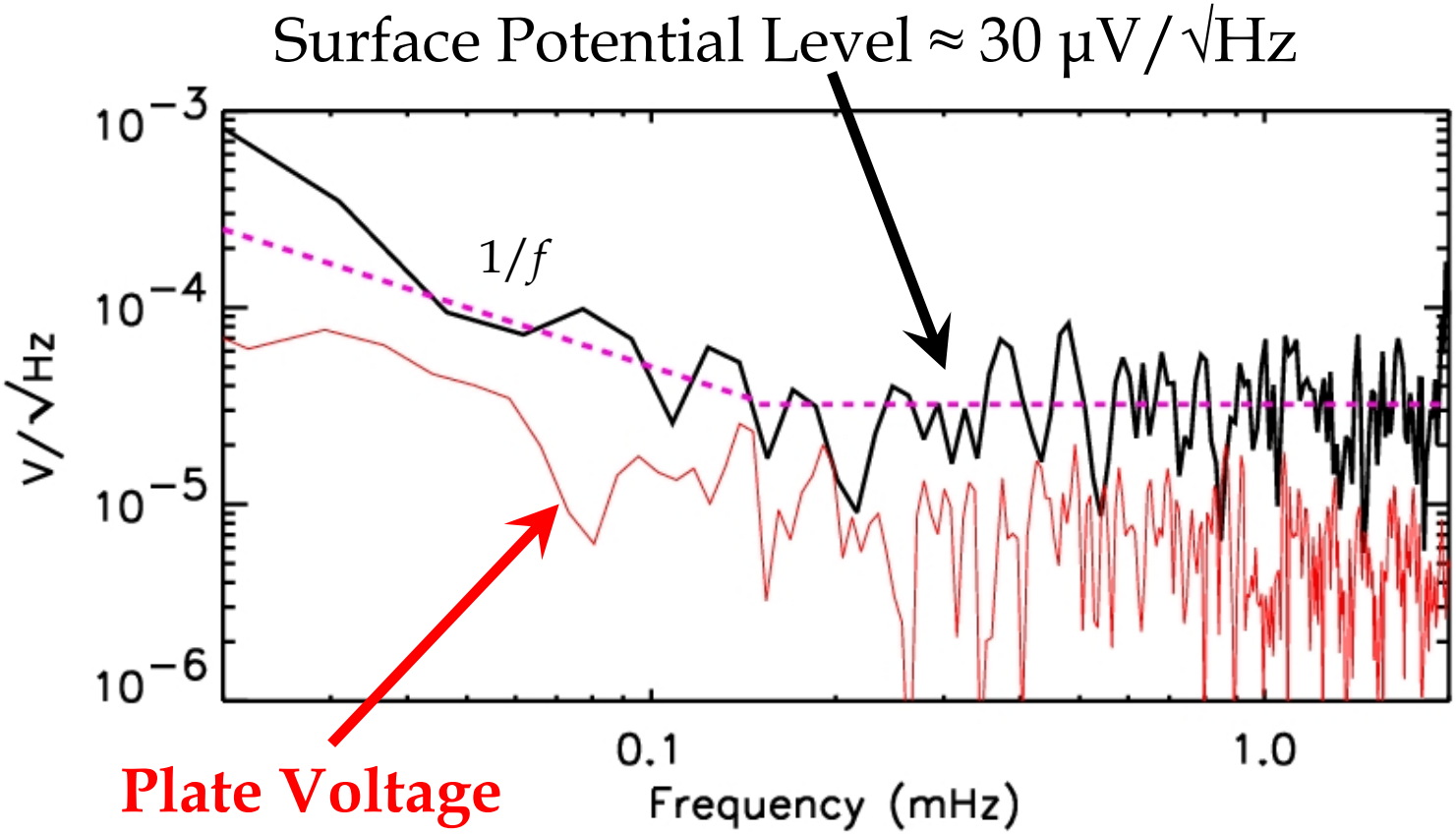
Initial Drift after Pumping Down



Drift after 30 days ~ 0.30 mV/day

Drift after 50 days ~ 0.15 mV/day

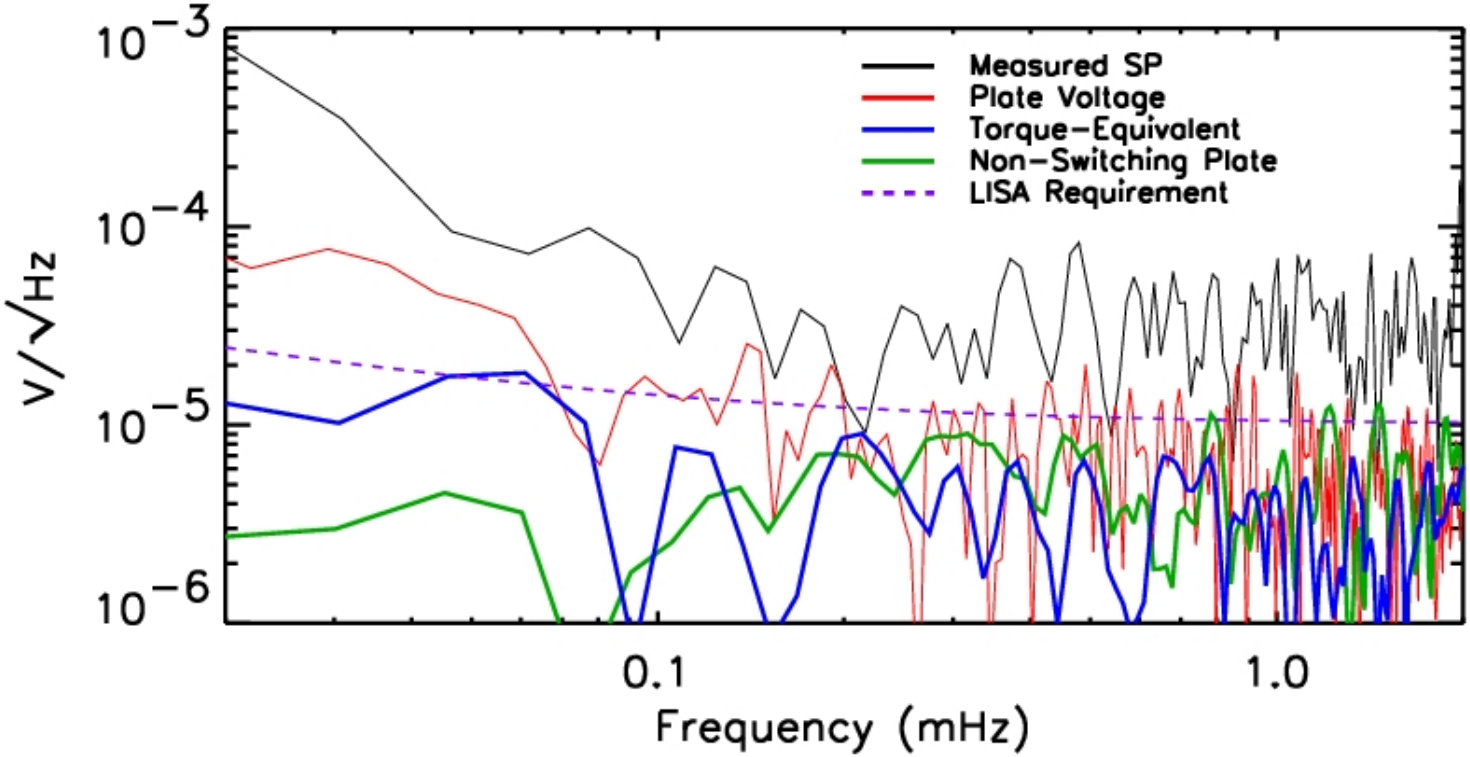
Surface Potential Spectrum



- **SP level determined by**
  1. *Voltage noise on plate*
  2. *Voltage noise on electrode*
  3. *Surface potential fluctuation*
- **Improved by**
  1. *Better plate voltage reference*
  2. *Smaller area electrodes*
  3. *Better contamination prevention*

Surface Potential Spectrum

Thermal Torque Noise Contribution $\approx 6\ \mu V/\sqrt{Hz}$



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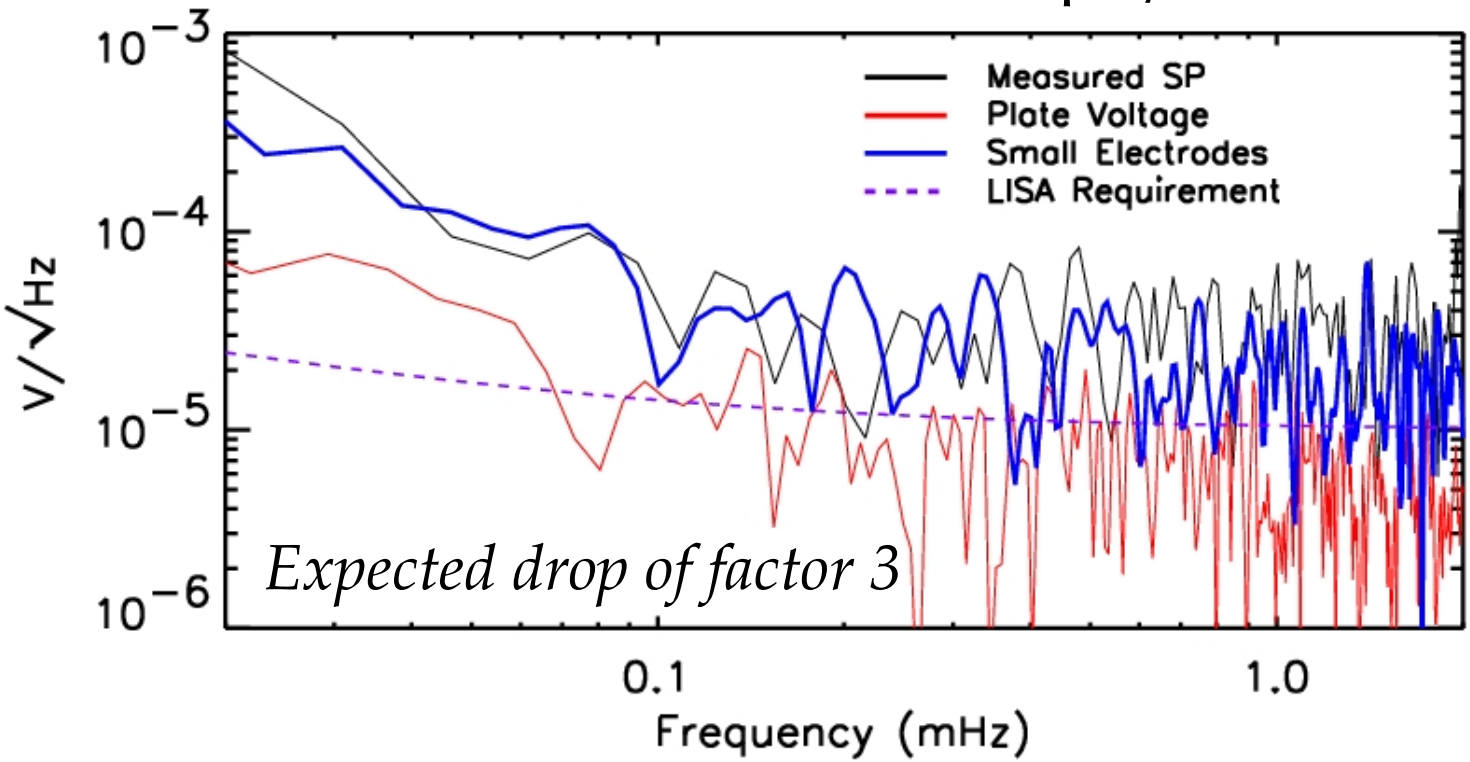
Surface Potential Spectrum

Surface Potential Level ≈ 30 μV/√Hz



- **SP level determined by**
  1. *Voltage noise on plate*
  2. *Voltage noise on electrode* ✓
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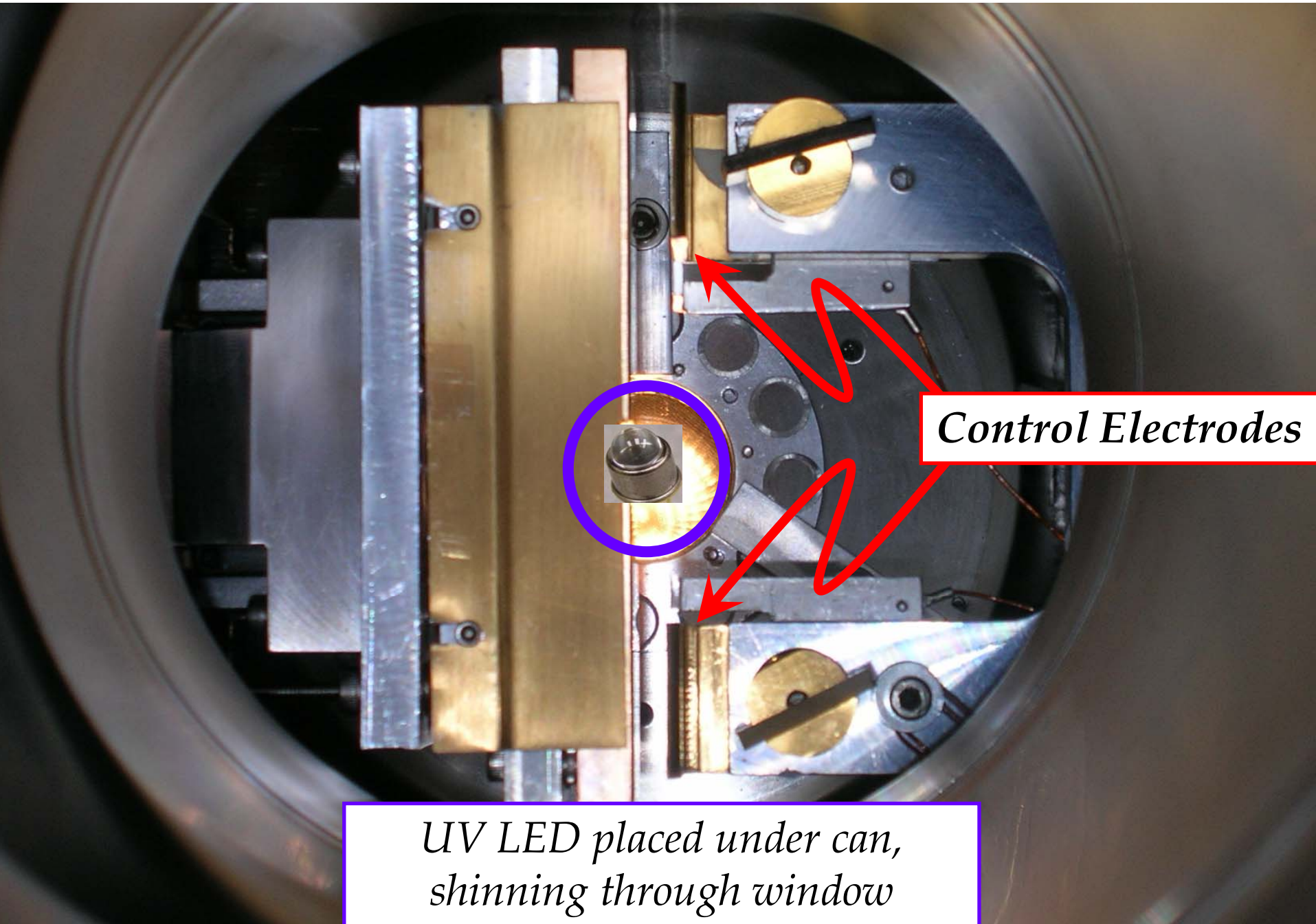
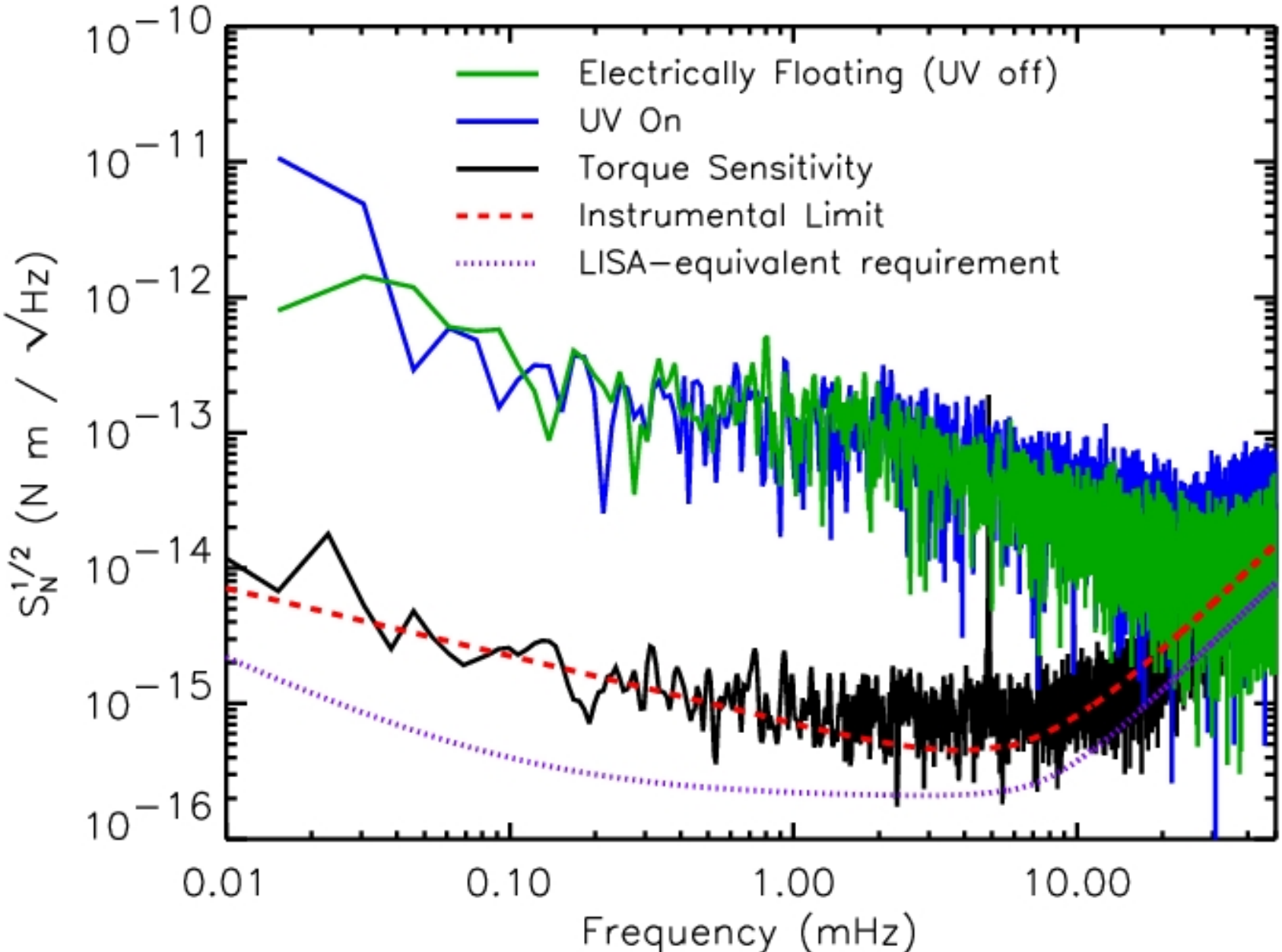
- **Improved by**
  - *Better plate voltage reference*
  - *Smaller area electrodes* ✓
  - *Better contamination prevention*

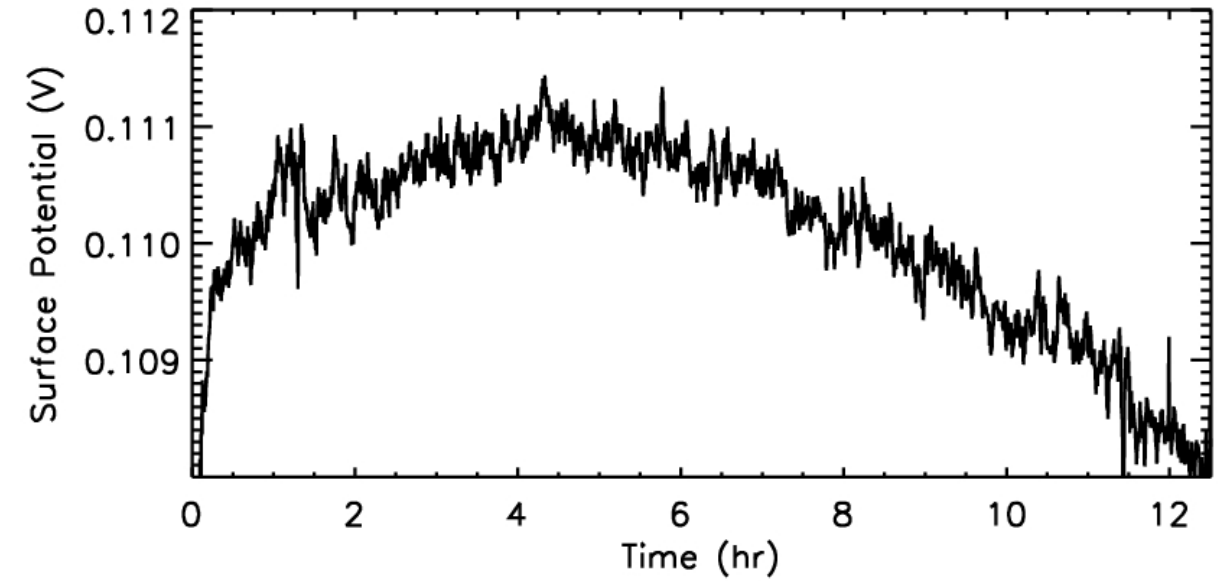
Top down view with pendulum removed

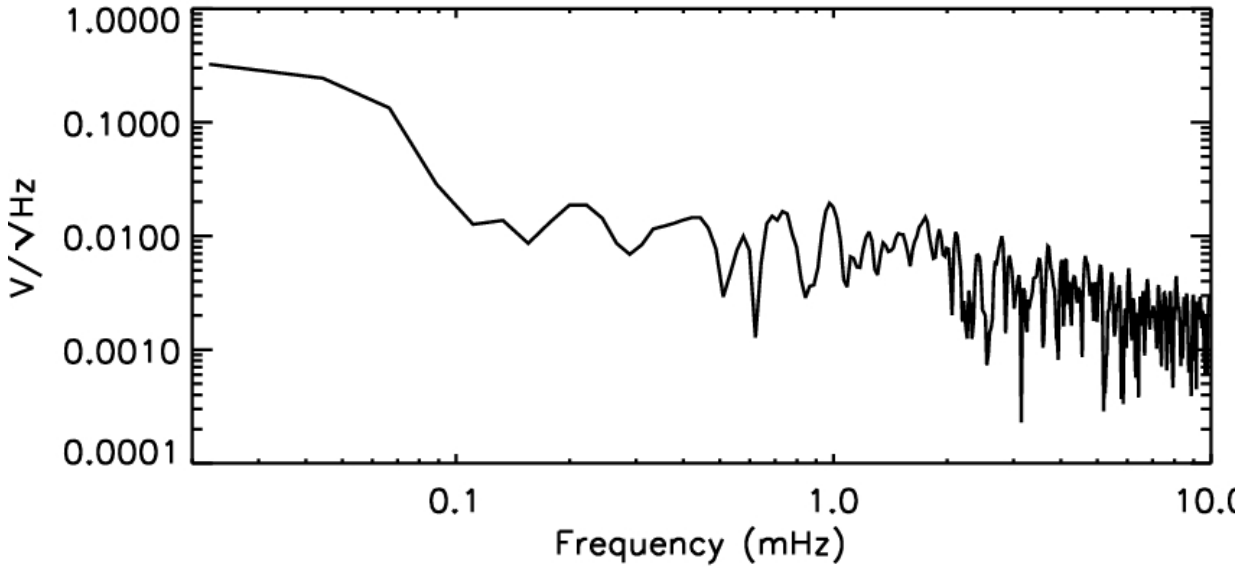


UV has little effect on torque noise

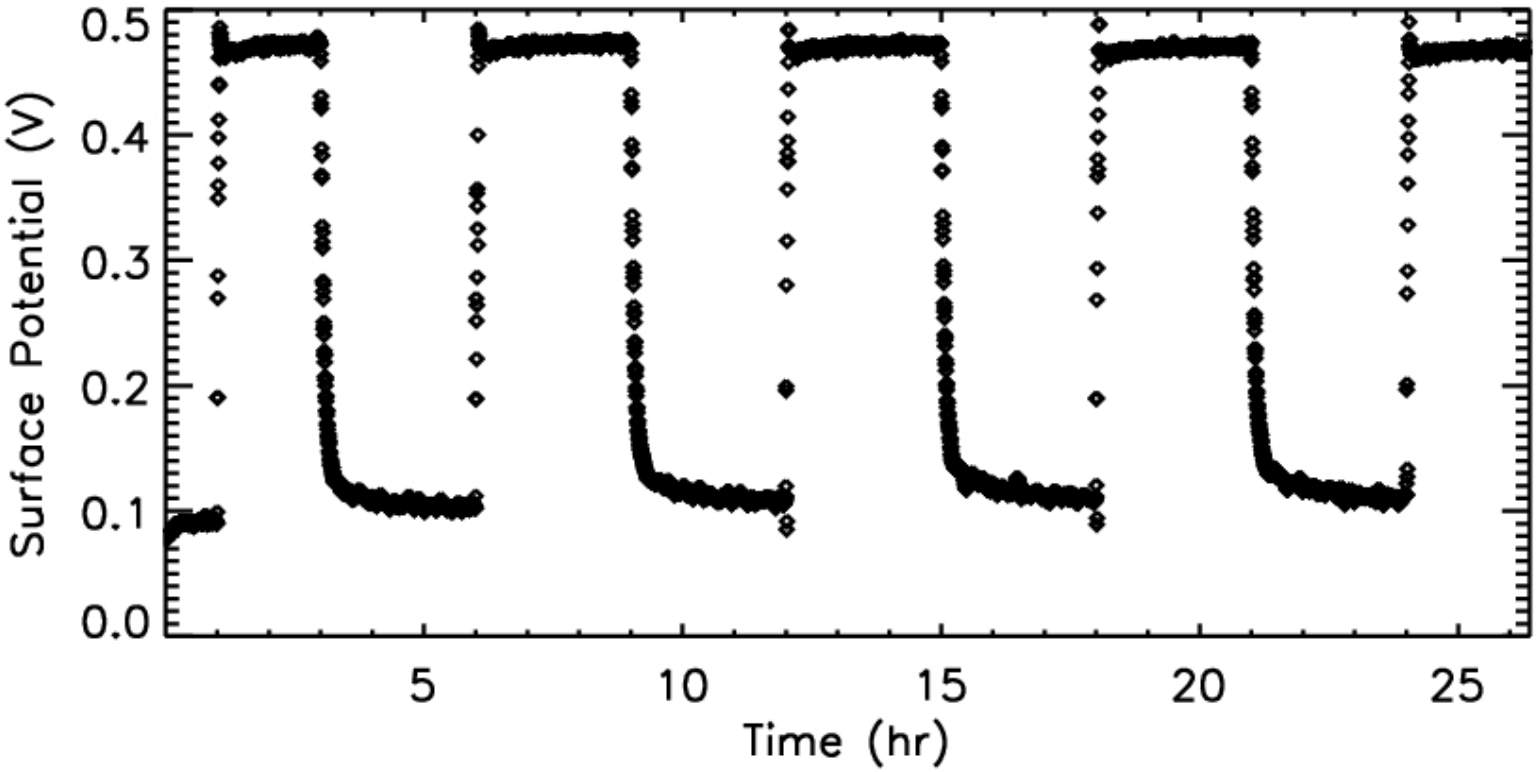


SP fluctuations of floating pendulum



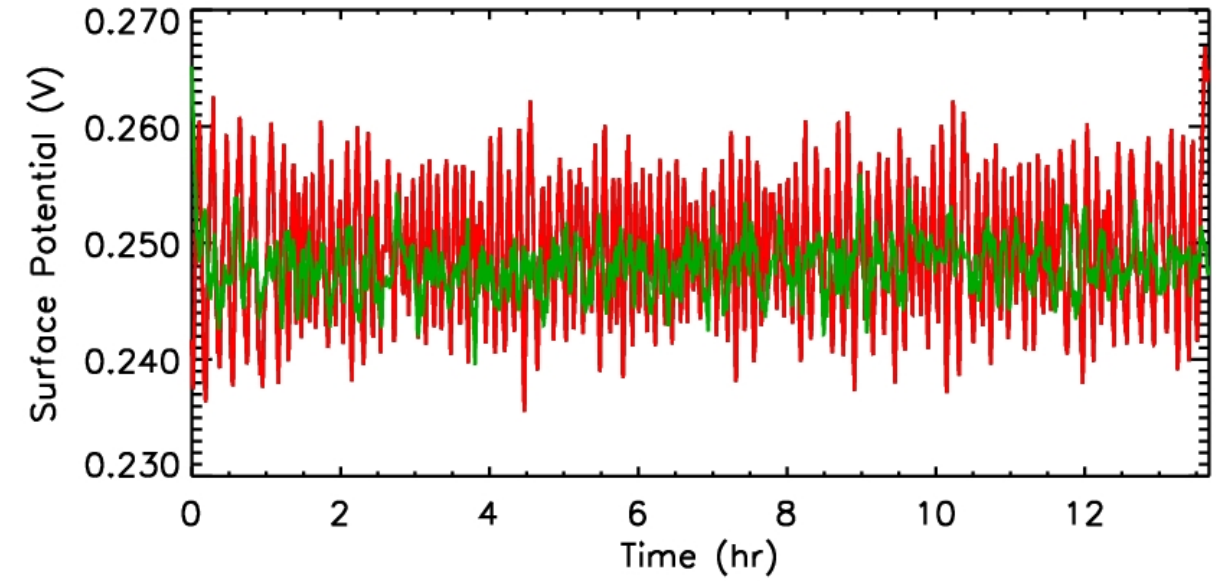


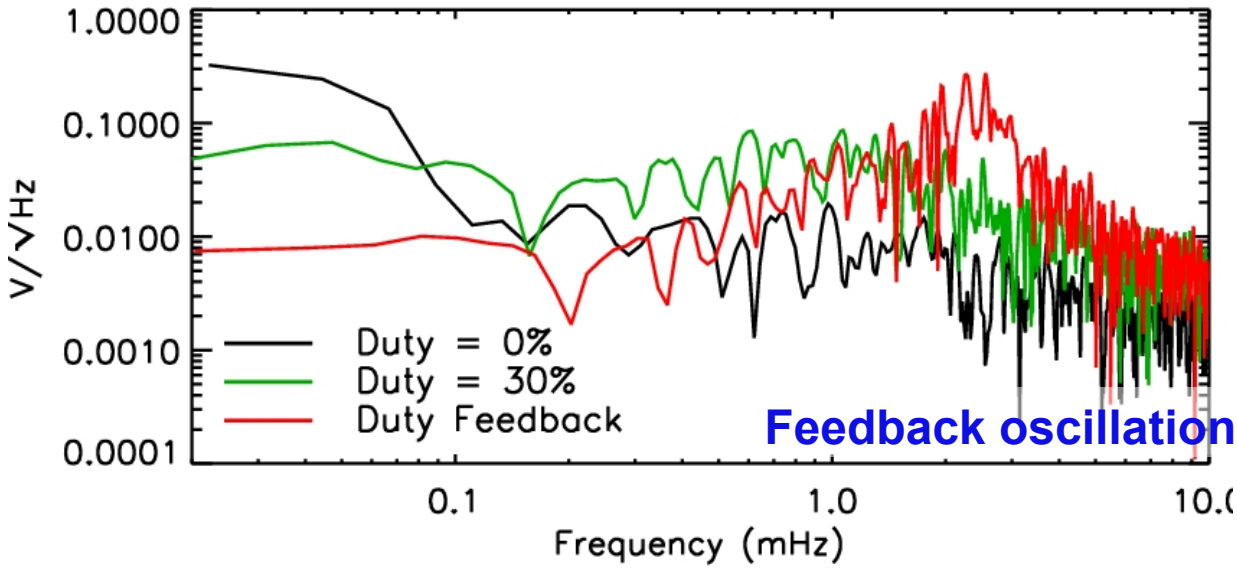
UV Charging of Floating Pendulum



- **Charge rate ~ 2—3 mV/s, running LED at ~ 20mA**
- **Couldn't get electrons onto pendulum for discharge**
  - *Discharging through o-ring of support shaft for fiber.*
  - *Time constant ~ 230s → 1 TΩ from pendulum to ground*

UV in Duty Feedback at 0.1 Hz

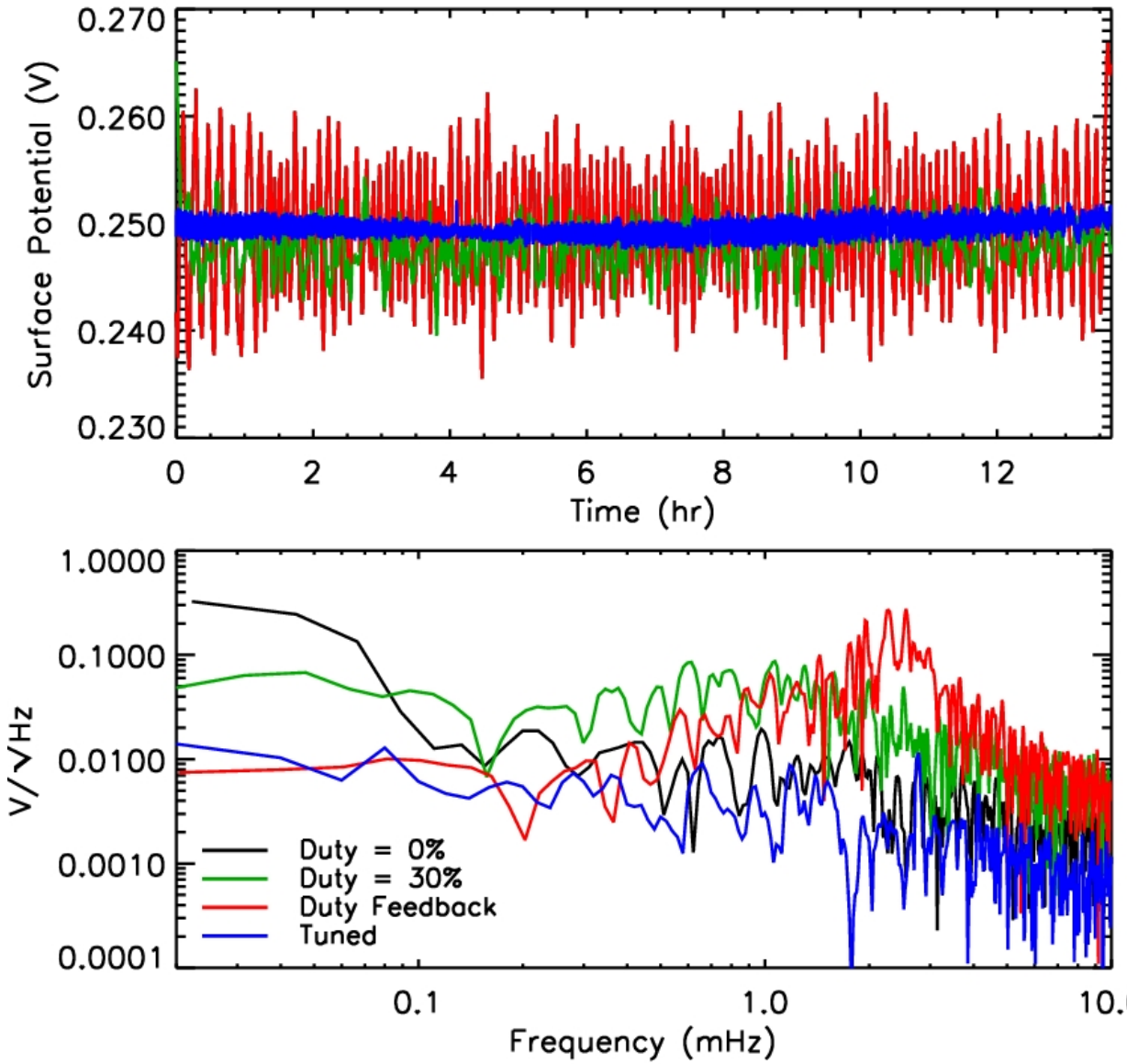




Feedback oscillation peak…

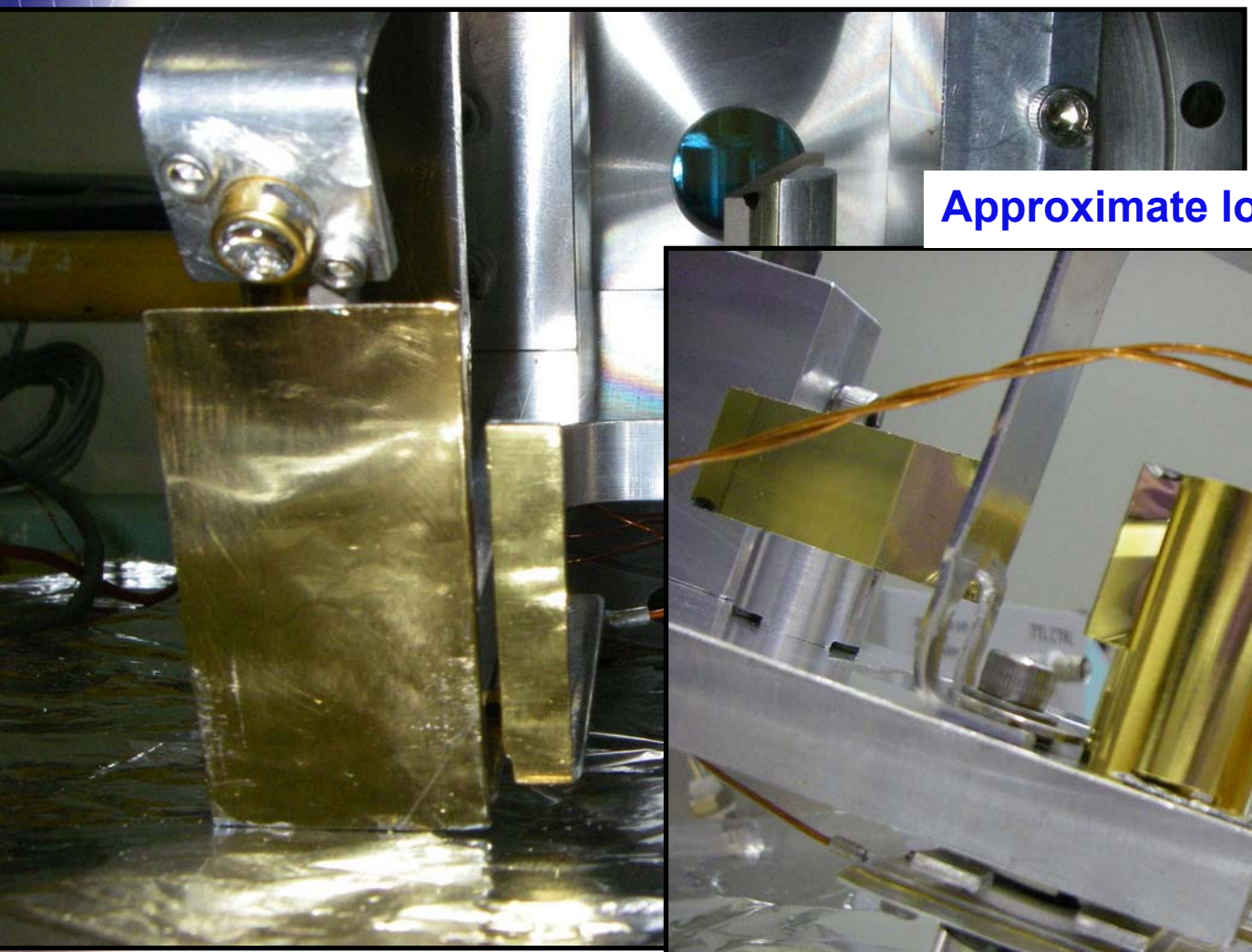
Reduction of noise at low frequencies

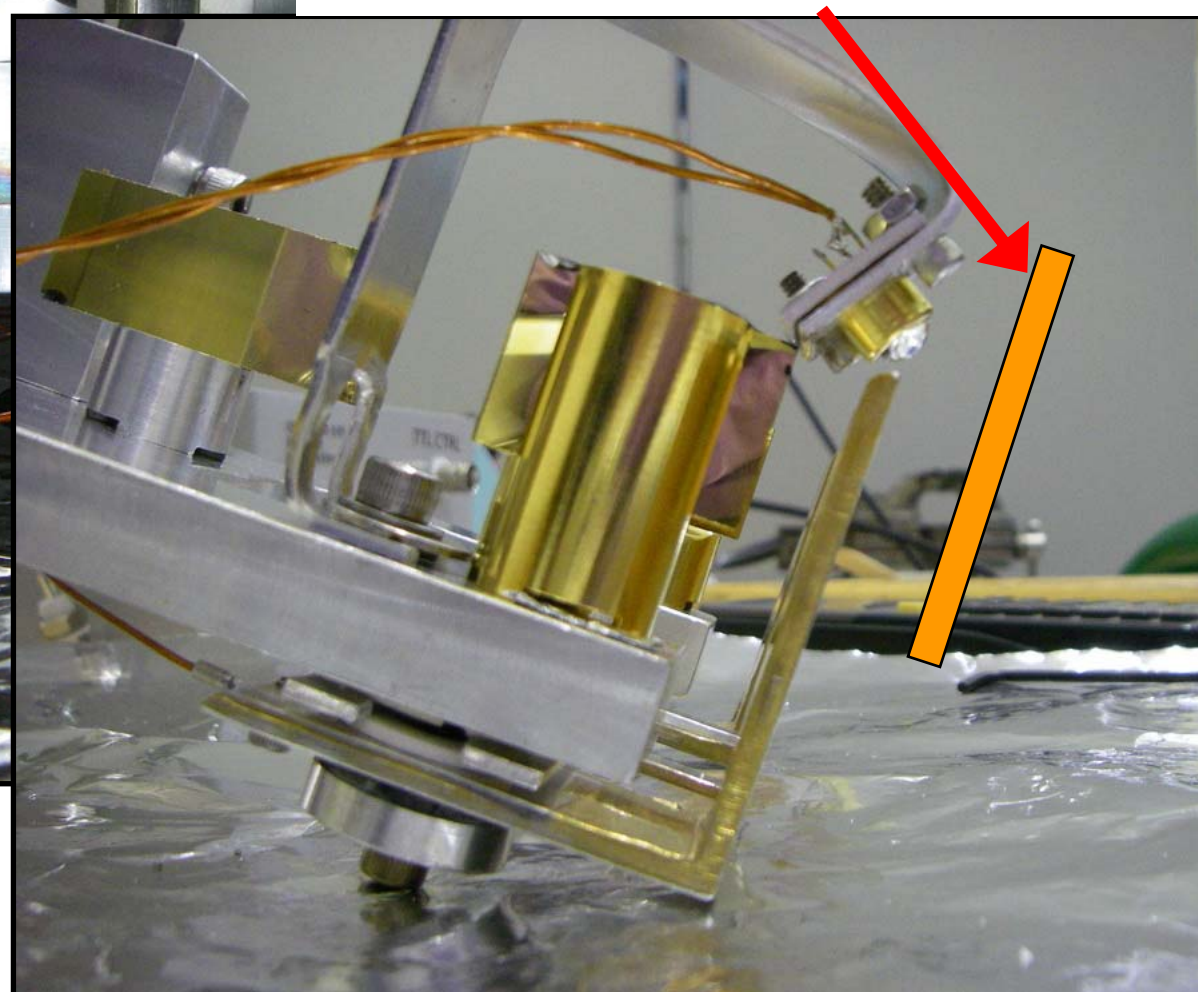
UV in Duty Feedback at 0.1 Hz



Surface Potential Noise level ~ 10 mV/√Hz

UV LED in vacuum (with quartz fiber)

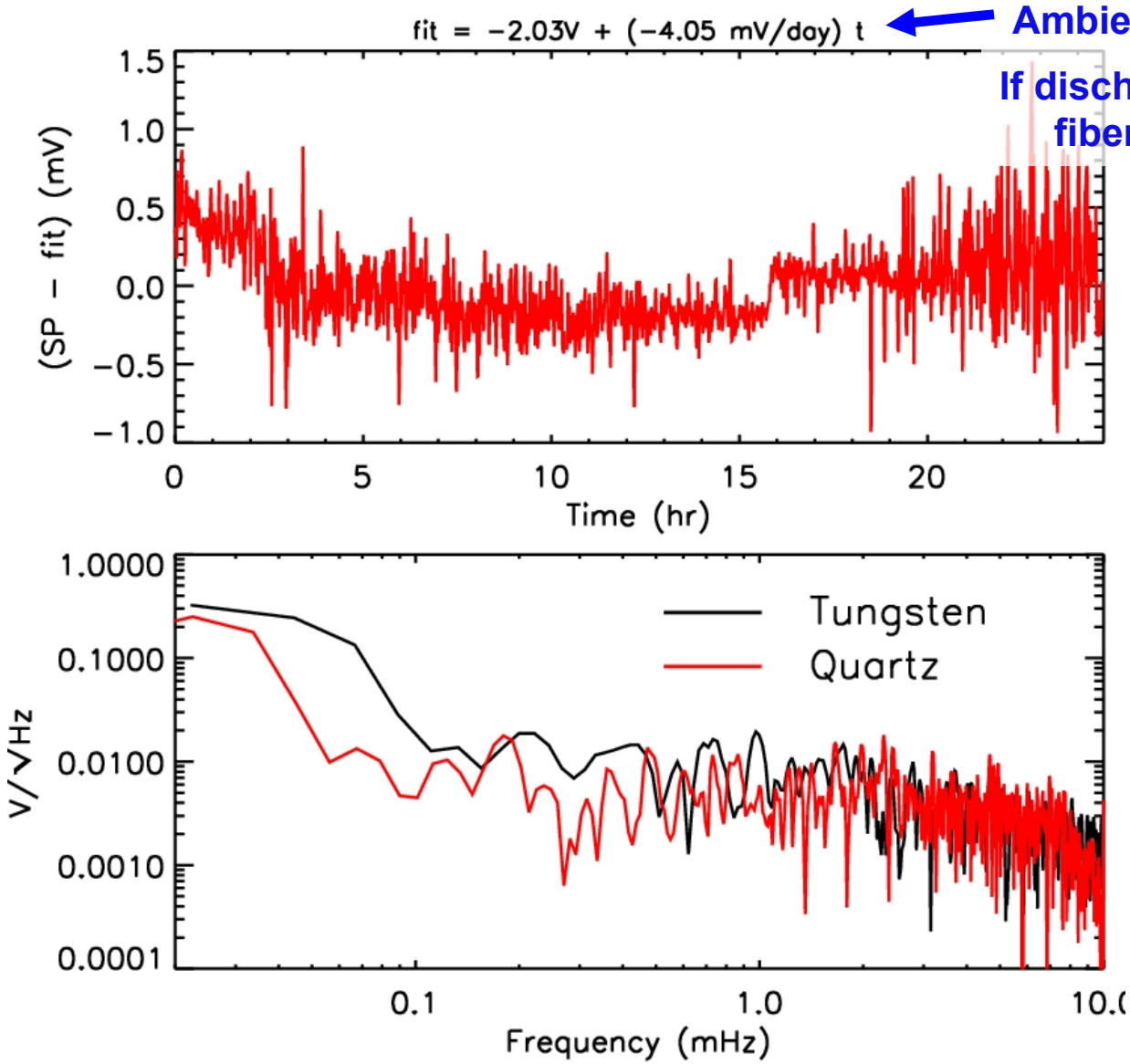




Pictures taken July 13

Pumping began the following day

Quartz Fiber Surface Potential Noise

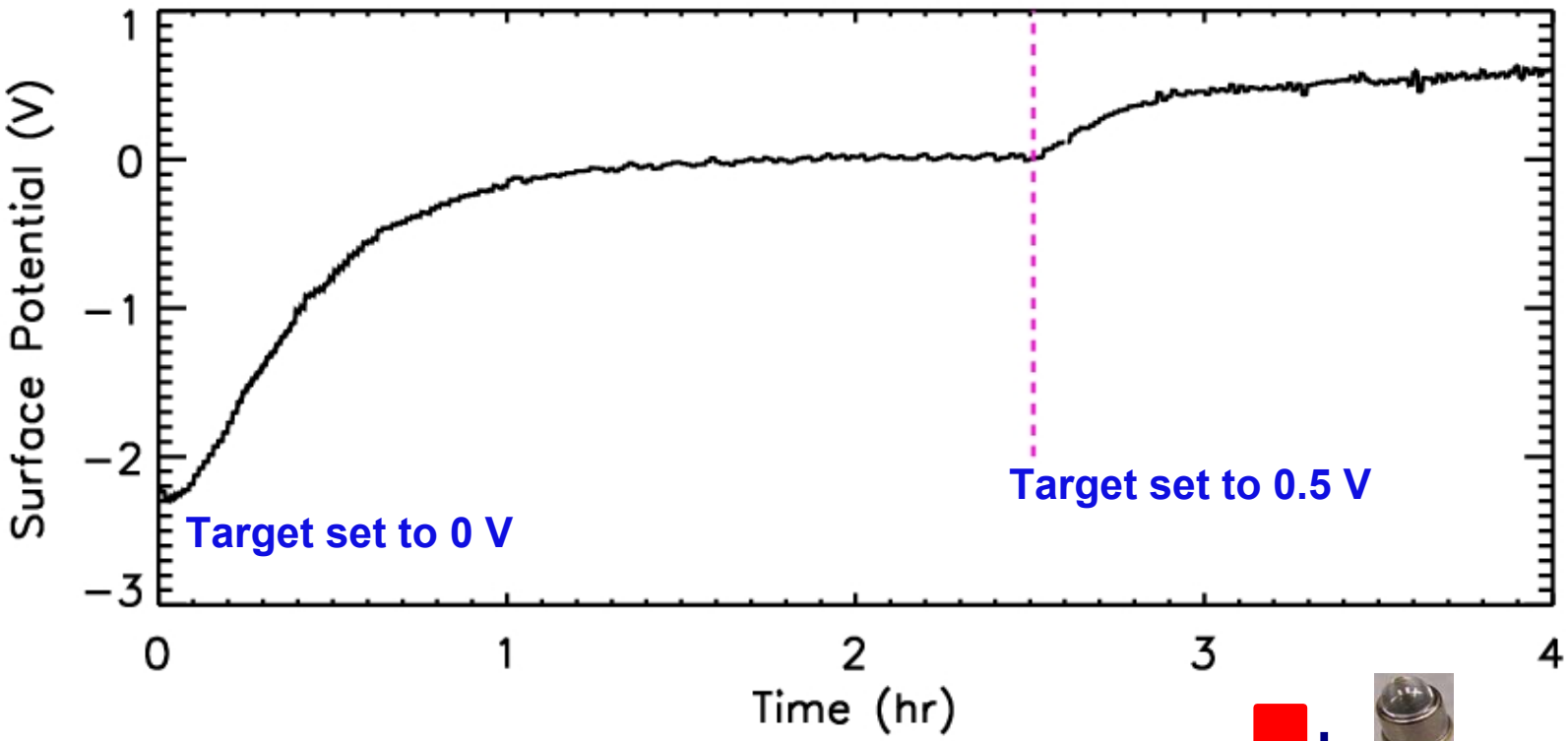


Ambient discharging

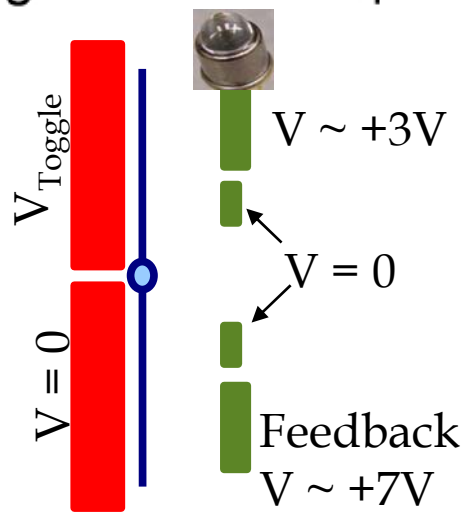
If discharging through fiber → R ~ 340 TΩ

Surface Potential Noise level ~ 10 mV/√Hz ≡ ~ 2 x 10^6 photoelectrons/√Hz

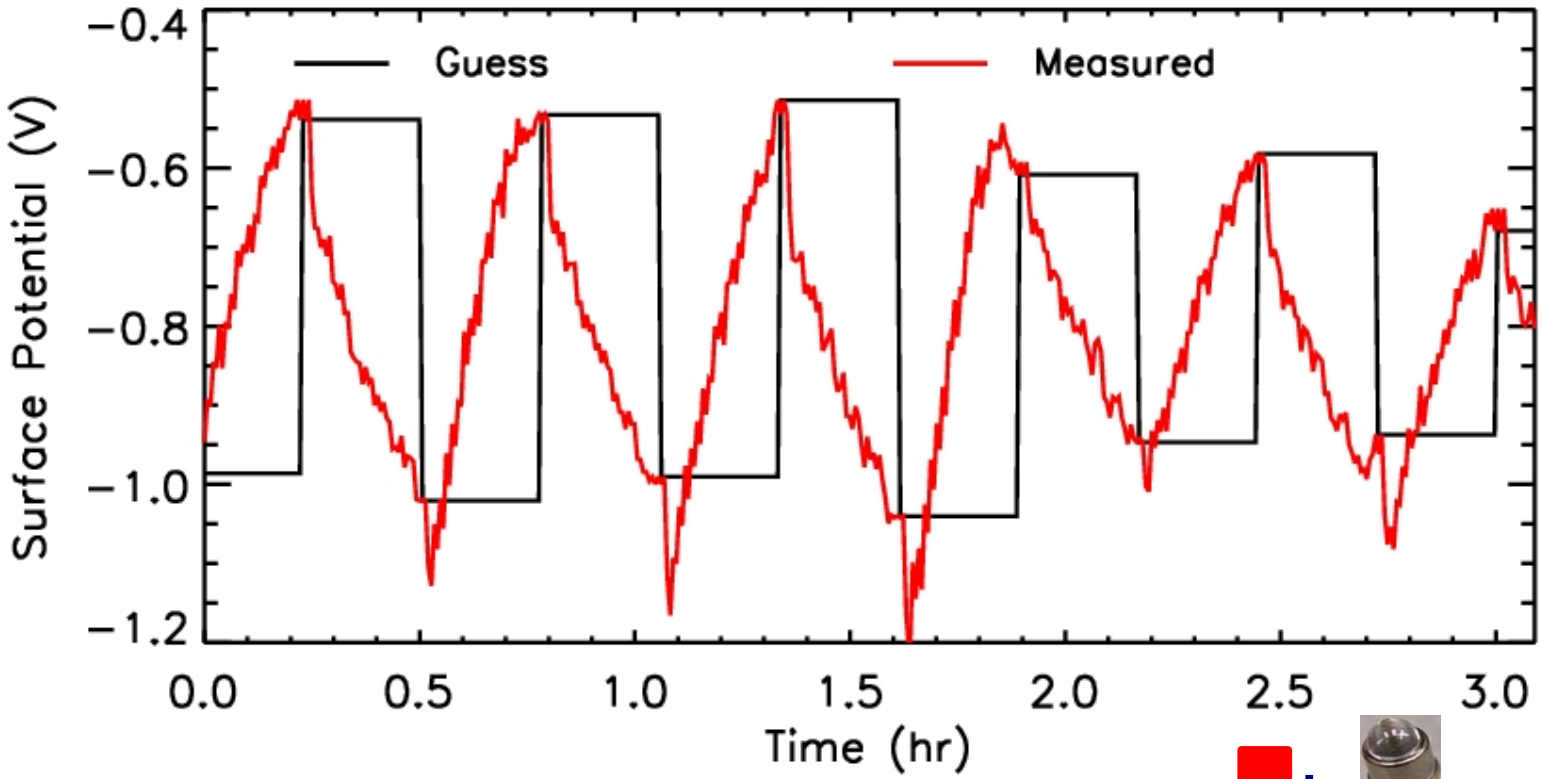
UV Output in Feedback (Going +)



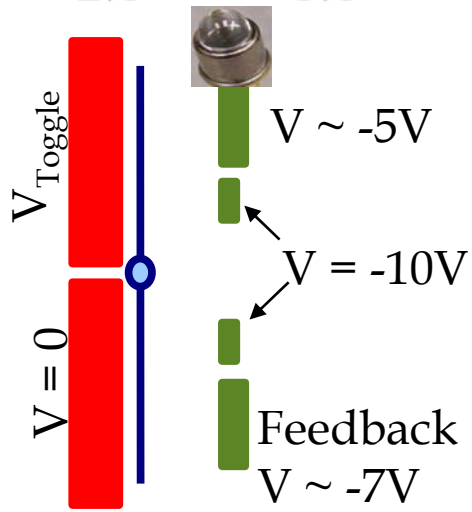
- **Initial charge rate ~ 1 mV/s**
  - *running LED at 0.1mA 5Hz (initially 50%)*
  - *Charging rate scales linearly with current and duty*
- **No tuning of PI loop taken place at this point**
  - *i.e., could get a much tighter response*



Issues Charging Negatively…



- **Sometimes I "find" the pendulum at further negative values, but I have a hard time getting it there myself**
- **Issues like one illustrated probably account for that**
  - *Still investigating (this data was taken this past Monday)*



Summary of Charge work at UW

- **Surface Potential Measurements with Grounded Pendulum**
  - *Both large and small electrodes show level* **~30 μV/√Hz @ 1mHz**
  - *Reference voltage is at* ~10 μV/√Hz
  - *It's possible that contamination is to blame*
    - i.e., large drifts after pumping system
- **UV LED used for charge measurements outside vacuum can**
  - *No appreciable change in torque noise level with UV light on ~20mA*
  - *Spectral amplitude in feedback:* **~2x10^6 electrons/Hz$^{1/2}$ @ 1mHz**
  - *Charge pendulum positively, but not negatively…*
- ***In situ UV LED***
  - *With close proximity, run LED at low power ~ 1 mA*
  - *Can charge negatively now as well.*
  - *Will be getting feedback noise level soon!*
- **Quartz Fiber "removes" discharge through o-ring (R>300 TΩ)**
  - *No change from tungsten in spectral amplitude:* ~10 mV/√Hz @ 1mHz