Effect of Charging on Thermal Noise

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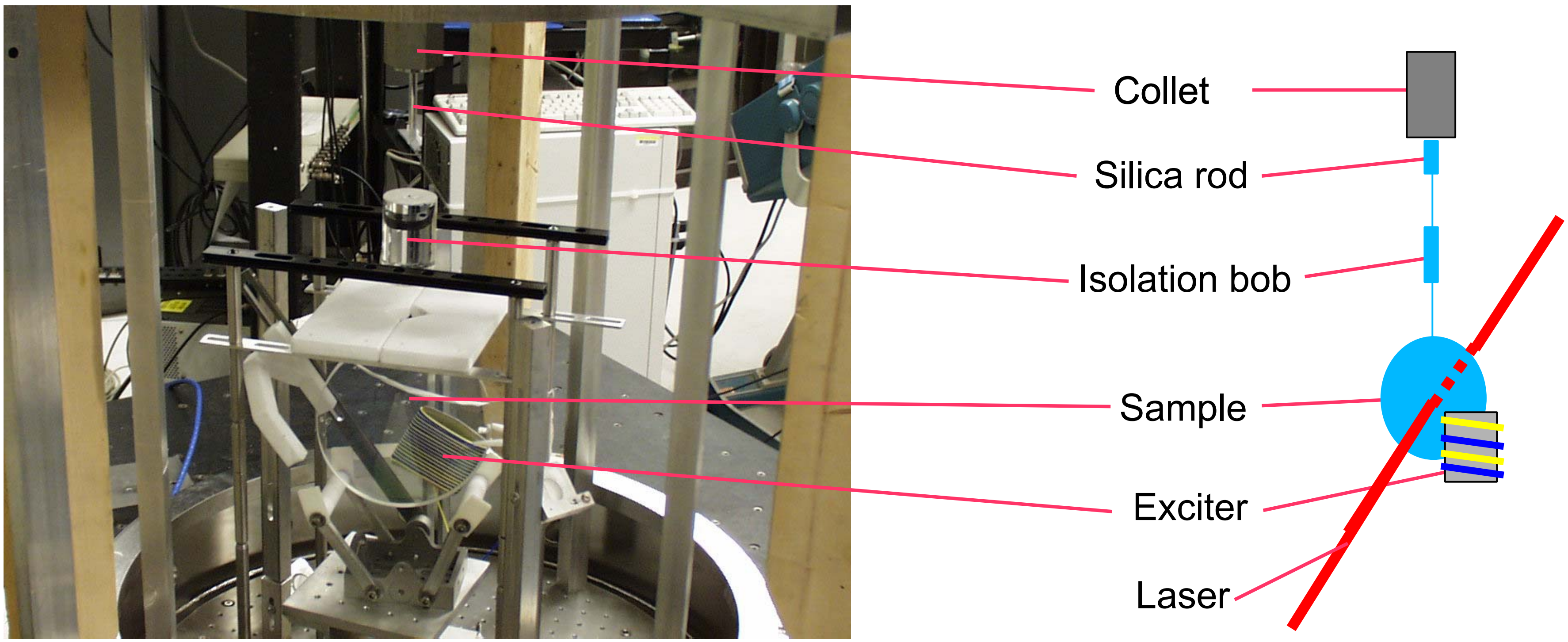
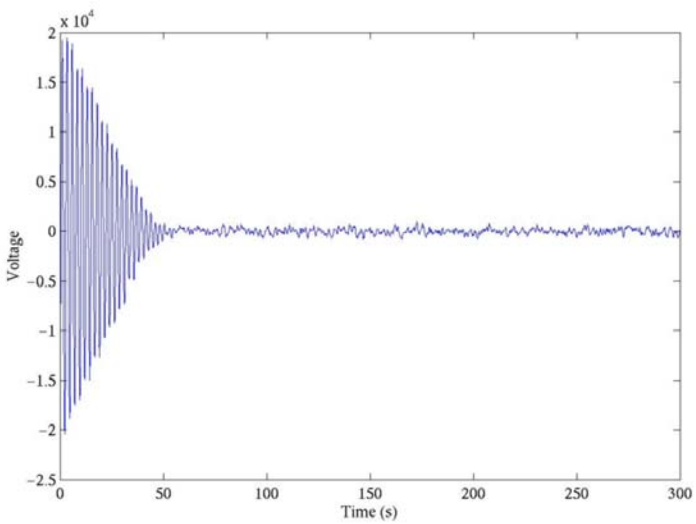
Experiment

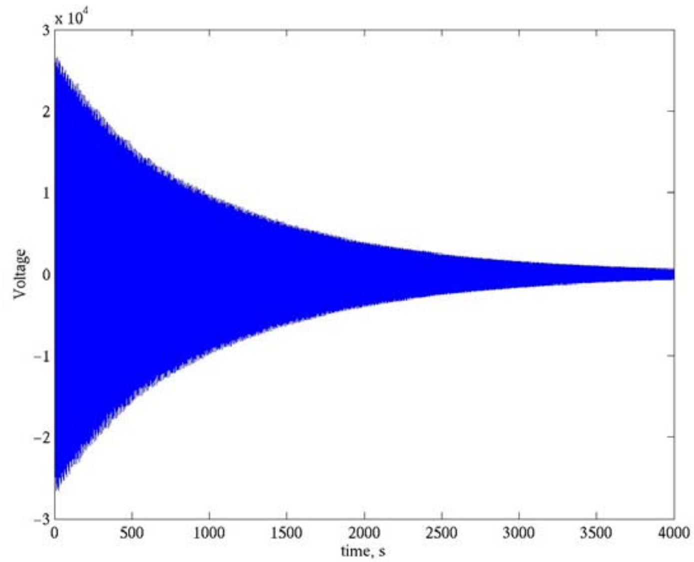
- Q's measured on normal modes of thin silica disk
- Modes are rung up using electorstatic exciter composed of two wires
- Ringdown is measured using HeNe laser and birefringence readout



Experimental Results

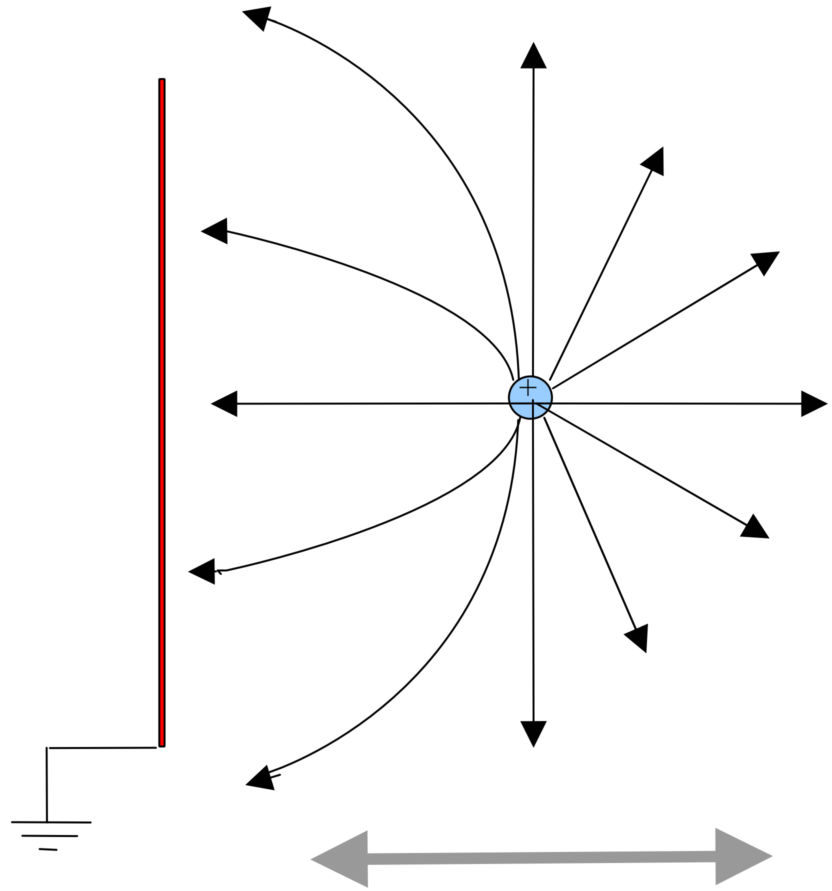
- Character and time scale of ringdown changed when sample charged
- Traced down to dust spanning the gap between exciter and sample
- Dust was attracted by charged optic
- Only a problem when sample very close (300 μm) to other body





Modeling

- Examined a number of possible mechanisms related to charging that could cause mechanical loss
  - Eddy current damping in exciter ground plate and wires
  - Polarization current in bulk silica and silica surface
  - Electrostatic coupling with lossy mechanical structure
  - Rubbing from a dust particle



Eddy current damping

- Charged silica sample interacting with aluminum ground plane
- Charge density 2 X 10^{-7} C/m^2, 2 mm separation, 3 kHz
- Q ~ 10^{22}
- Not a factor for modal Q's or for thermal noise

- Charged silica sample interacting with grounded wire
- Same charge density and separation, 1 Ω resistance
- Q ~ 10^{18}
- Not a factor for modal Q's or for thermal noise

Polarization losses

- Charged sample creating image charge with ground plane
- Charge density 2 X 10^{-7} C/m^2, 3 cm separation, 3 kHz
- Bulk silica electrical properties; 2 X 10^{12} Ω m, χ = 2.8
- Q ~ 10^7
- Strong function of distance, could be important for close spacings and high charge densities

- Charged sample creating image charge with ground plane
- Charge density 2 X 10^{-7} C/m^2, 3 cm separation, 3 kHz
- Silica surface electrical properties; 2 X 10^{10} Ω m, χ = 2.8, layer thickness 10^{-5} m
- Q ~ 10^{10}
- Strong function of distance, probably not important

Coupling to mechanical systems

- A charged sample could couple to a lossy, charged support system like wire insulation
- Modeled as coupled oscillator
- Loss angle of mechanical system 10^{-3}, separation 2 mm, spring constant to ground 3 10^{7} N/m
- Q ~ 10^{9}
- Probably not a factor for modal Q's or for thermal noise

Suspension thermal noise and charging

- Q reduction from charging has been seen in pendulum mode (S. Rowan et al, CQG 14 (1997) 1537) and torsional mode (V. P. Mitrofanov Phys. Lett. A 278 (2000) 25)
- Pendulum mode sample was being charged by UV from ion pump
- Torsional mode sample was deliberately placed close to charged actuator
- Both are at level where thermal noise effects would be noticeable

Conclusions

- Charging can effect the Q's of mechanical modes
- Probably not important for mirror thermal noise except for very high charge densities and/or close spacings
- Potentially an issue for suspension thermal noise