Charge control of an electrically isolated proof mass using a UV LED at 255 nm

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Motivation for DUV LEDs in Space

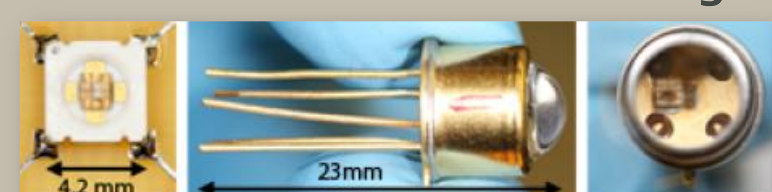
Highly sensitive space-based instruments use drag-free techniques for the control and the science signals

- Laser Interferometer Space Antenna (LISA): 5-20 pm/$Hz^{-1/2}$

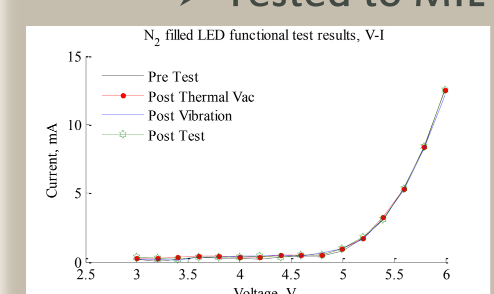
During drag-free flight, the spacecraft follows a free floating proof mass:

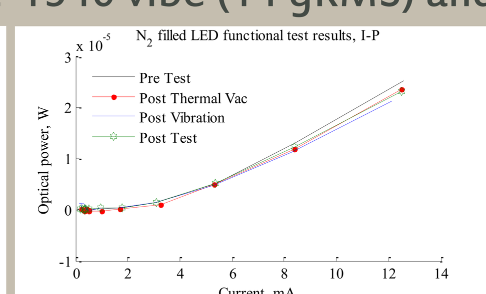
- Many disturbances removed
- Charge accumulation on proof mass: 50-200 e^-/sec

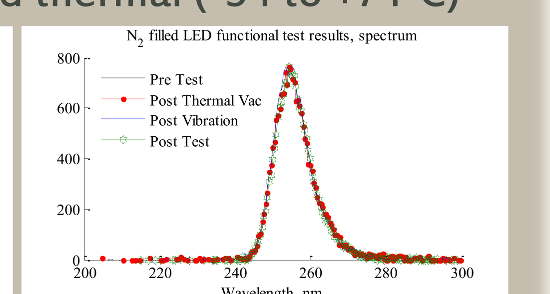
Use UV photoemission to control charge:



- AlGaN UV LEDs with 254 nm peak and 12 nm FWHM
- Output power: ~5 nW to >100 µW
- Tested to MIL-1540 vibe (14 gRMS) and thermal (-34 to +71°C)







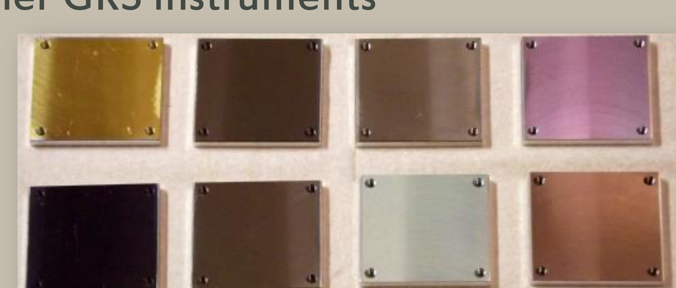
Proof Mass Coatings

Several requirements for coatings:

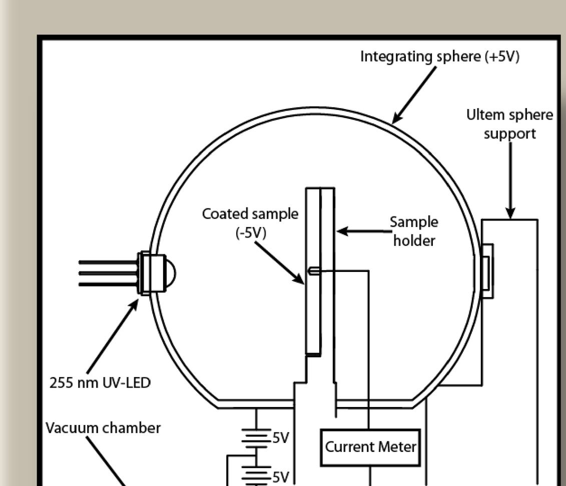
- Workfunction for UV photoemission (E_{ph} = 4.86 eV @ 255 nm)
- Minimize patch effects
- Maintain surface properties during proof mass un/caging
- Minimize reflections from other GRS instruments

Carbide coatings:

- Workfunctions near 4.86 eV
- High mechanical toughness



Top (L-R): Au, Nb, Ir, SiC.
Bottom (L-R): TiC, Mo2C, ZrC, TaC



Quantum efficiency measurement test setup

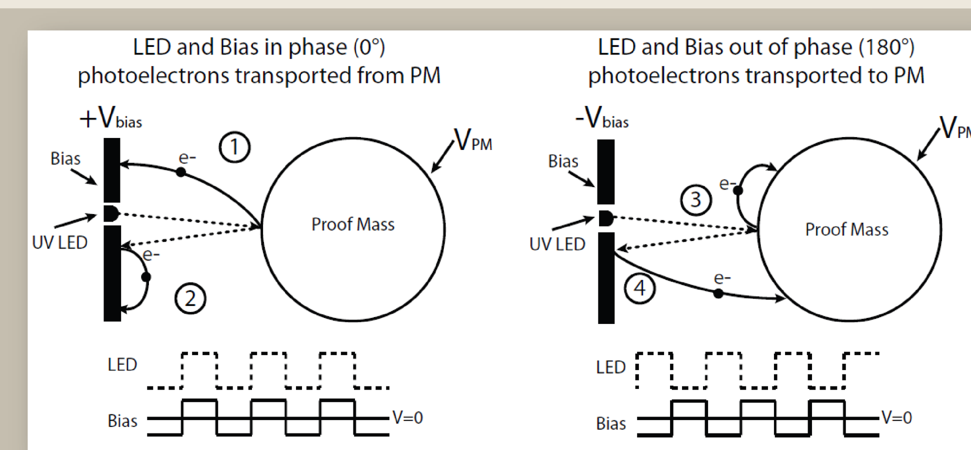
Coating property measurement:

- QE: Keithley 6485 picoammeter, UV LED at 50 µW, 10^{-4} torr
- Reflectivity: UV LED with 45° incident angle, Newport 1931C power meter
- Resistivity: Prometrix Omnimap RS35e with Van der Pauw probe

Measured coating properties

Material	Quantum Efficiency	Reflectivity	Resistivity (Ω/sq)
SiC	3.4×10^{-7}	0.12	$2.0\pm0.3\times10^{-4}$
Mo_2C	6.8×10^{-7}	0.15	$1.5\pm0.03\times10^{-5}$
TaC	6.3×10^{-7}	0.13	$5\pm1\times10^{-3}$
TiC	4.5×10^{-7}	0.15	$1.16\pm0.01\times10^{-3}$
ZrC	3.8×10^{-7}	0.11	$7.94\pm0.07\times10^{0}$

AC Charge Management Operation



Schematic showing AC Charge Management operation concept

AC charge management uses UV photoemission and two control signals to direct electron flow:

- **LED:** modulated on/off **Bias:** modulated $+V_{bias}$/$-V_{bias}$
- UV light incident on proof mass – some light reflects back to bias plate
- Photoelectrons generated from both surfaces

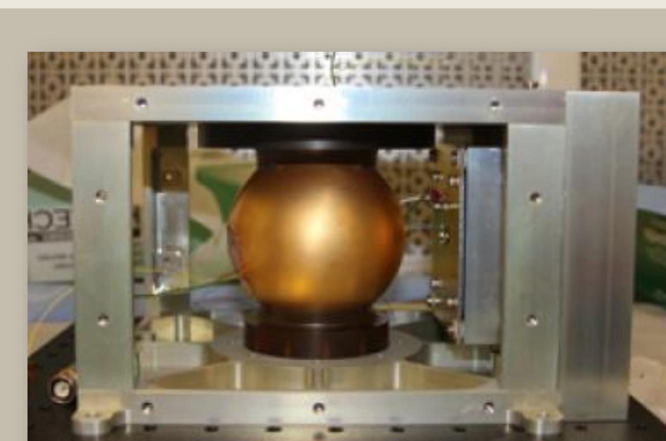
Positive transfer case

1. Bias and LED are in phase – rising edges are synchronized
2. e^- generated when $V_{bias}>0$
3. e^- pulled away from PM

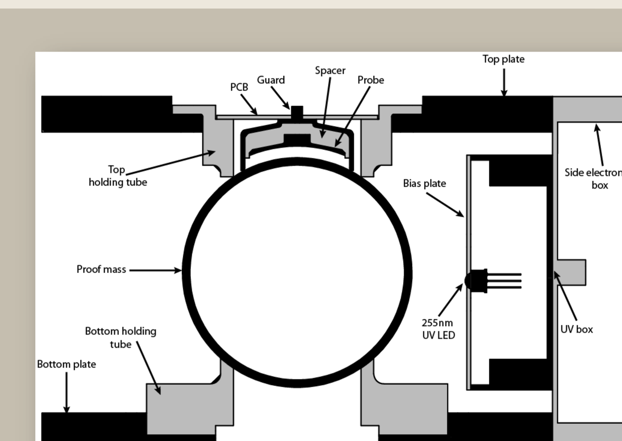
Negative transfer case

1. Bias and LED are out of phase – LED rising/bias falling edges synchronized
2. e^- generated when $V_{bias}<0$
3. e^- pushed towards PM

AC Charge Management Experiment



Experiment in laboratory configuration



Cutaway showing experiment parts

Demonstration of charge management was performed in a "GRS-like" configuration

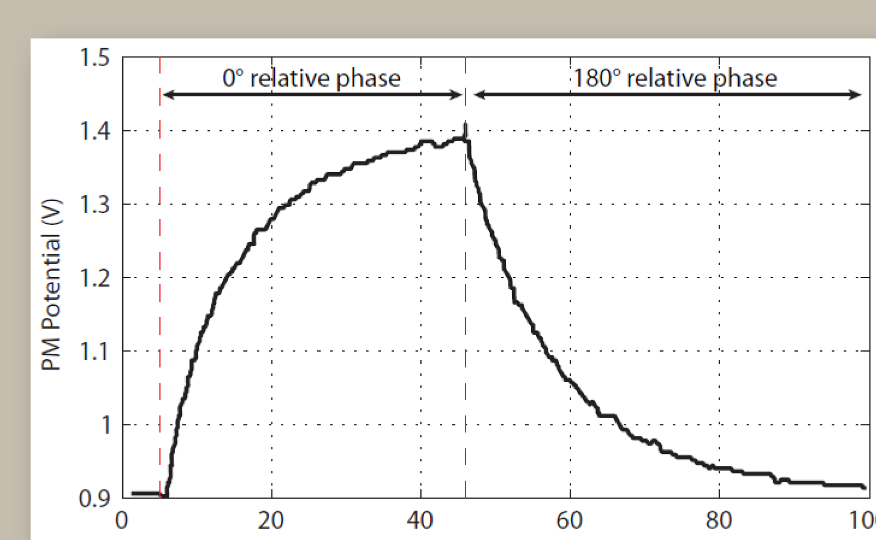
- Single 3.5 in (89 mm) gold plated hollow Al proof mass
- Single UV LED and bias plate
- Sphere supported on Ultem-1000 holding tubes with high R (>10^{14} Ω)
- Potential measured via guarded floating probe held 4 mm from sphere

Experiment parameters

- 10^{-6} torr vacuum
- UV power of 10 µW
- 100 Hz 50% duty cycle
- 3.0 V_{pp} bias
- 17 pF system capacitance

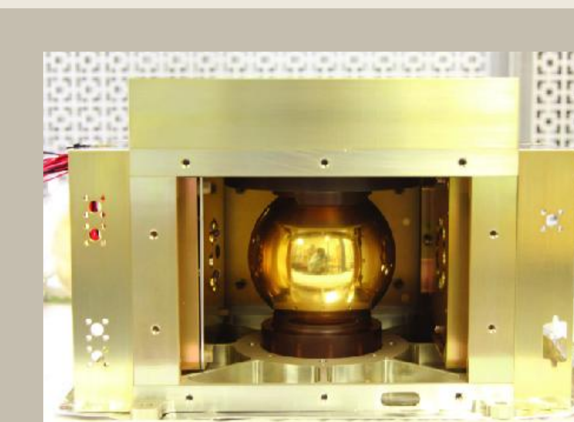
Experiment Results

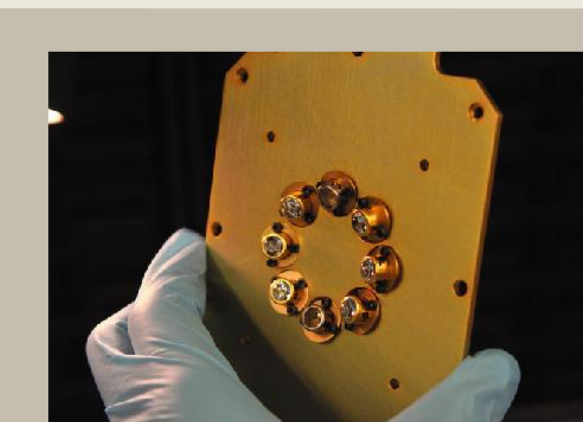
- Positive: 0.21 pC/sec
- Negative: 0.15 pC/sec



Representative experimental result showing positive and negative charging

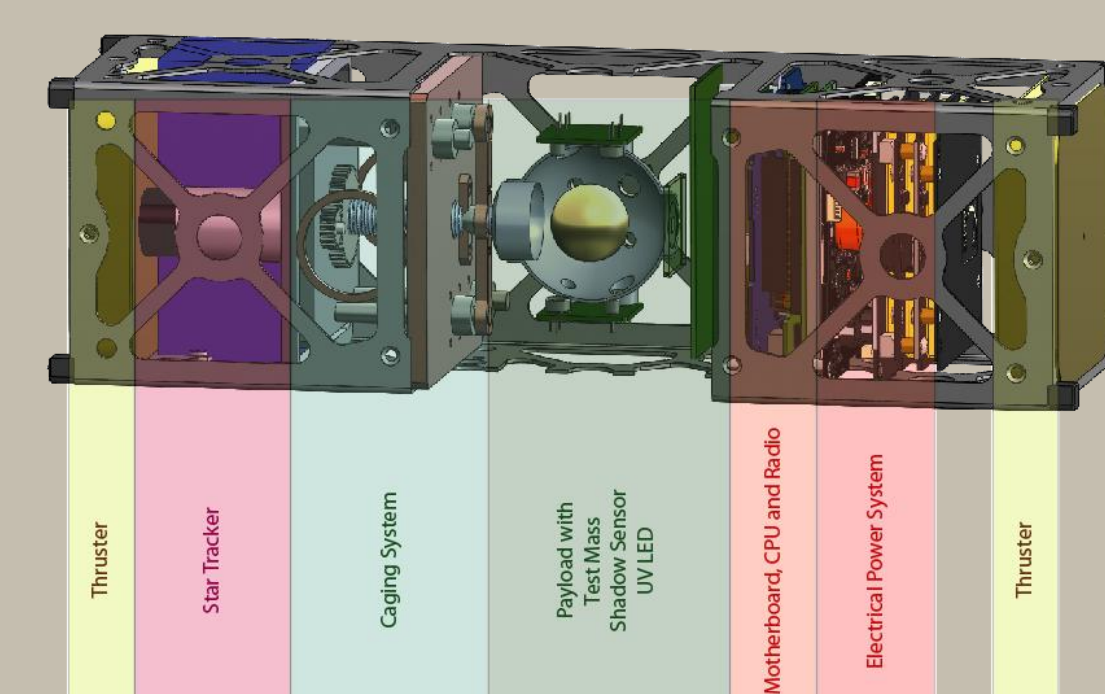
Upcoming Missions





UV LED Satellite

- 16 UV LEDs with integrated photodiodes, four bias plates
- Gold coated (deposited) hollow aluminum proof mass
- Raise UV LED and AC charge management system to TRL 8/9
- Joint development with Stanford, NASA Ames and KACST
- Launch in 2013



Drag-free Cubesat

- 3U Cubesat to demonstrate a fully integrated MGRS
- 10^{-12} $ms^2Hz^{-1/2}$ from 1 mHz to 1 Hz
- Includes UV LED system for proof mass charge control
- Presented by Andreas Zoellner at the 9th Annual Cubesat Workshop, Cal Poly, San Luis Obispo

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Please see submitted paper for reference list