UV LED charge control of an electrically isolated proof mass at 255 nm

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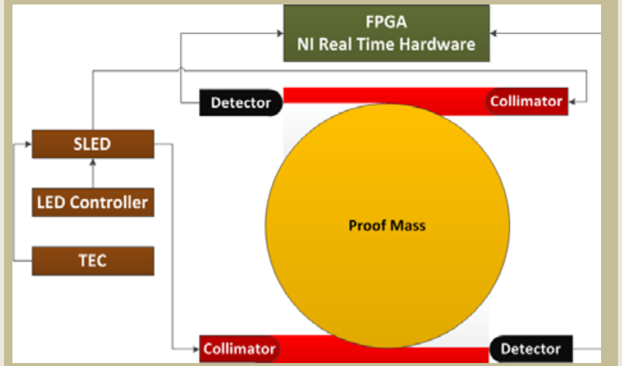
MGRS System Overview

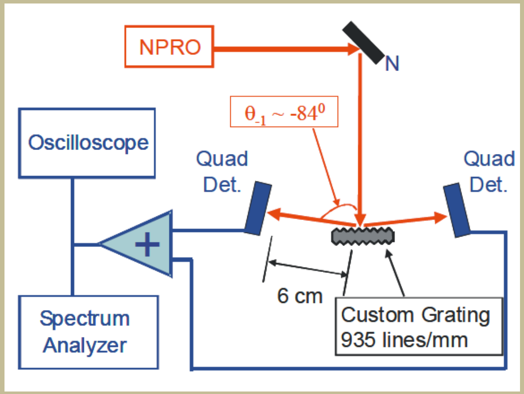
Differential Optical Shadow Sensor



- nanometer sensing for drag free signal
- Lower resolution, high dynamic range

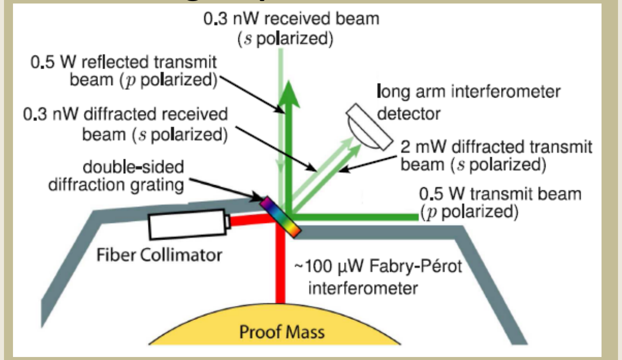
Andreas Zoellner

Grating Angular Sensor



- Nanoradian level angular sensing

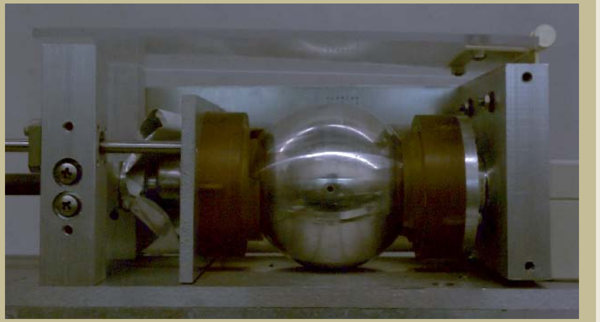
Grating Displacement Sensor



- picometer sensing for science signal
- High sensitivity, low dynamic range

Graham Allen (alum)

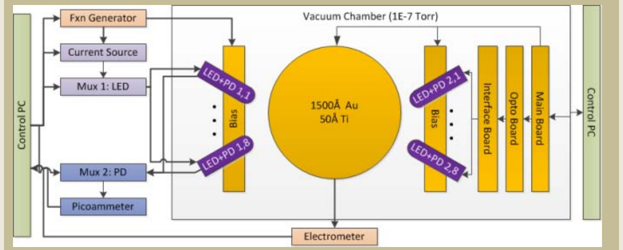
Proof Mass Caging



- 700 g clamping of proof mass during launch
- Minimal residual velocity on release
- No damage to proof mass surface

Eric Hultgren, Chin-Yang Lui

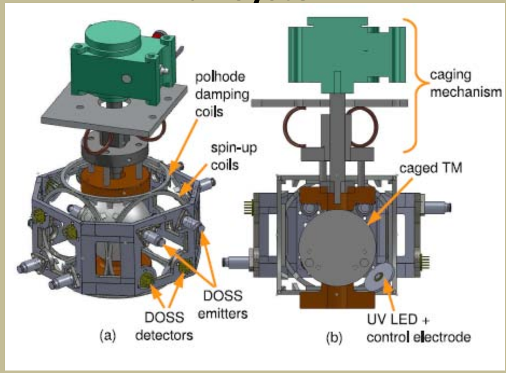
UV LED Charge Management



- Solid state 255nm light source
- Charge control of proof mass and housing potential

Karthik Balakrishnan

Full System



- 2.9 kg 70mm dia 70-30 Au-Pt sphere
- Carbide coated sphere

Charging sources and effects

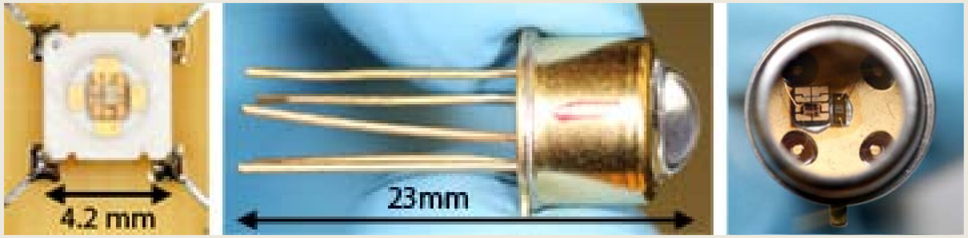
- The spacecraft and housing protect the proof mass from many disturbances: solar, atmospheric, micrometeoroids, etc.

- However, direct and secondary charging of the proof mass is still possible leading to a ***potential imbalance*** between the proof mass and housing walls
  - ***Direct***: High energy particles pass through the shielding and directly accumulate on either proof mass or housing
  - ***Secondary***: High energy particles interact with spacecraft materials, knocking off electrons which then accumulate on the proof mass or housing
  - **Approx 50-200 electrons/second** expected charging rate

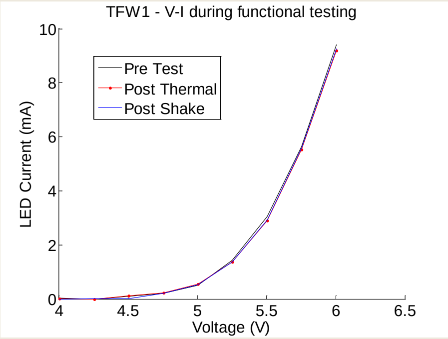
- Potential imbalance leads to an electrostatic force on the proof mass

UV LED Properties

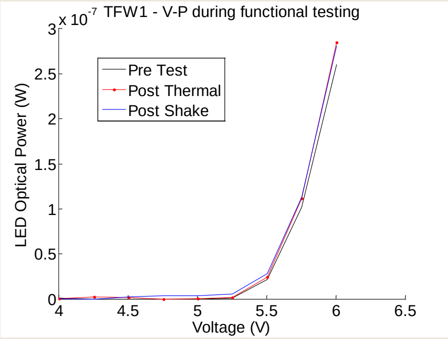
- **UV LEDs are:**
  - AlGaN based wide-bandgap (4.86eV) device with 255 nm line (12 nm FWHM)
  - Small power consumption (< 1W) for a full system, small mass (< 1kg)
  - Wide range of output powers (<1nW to >100 µW)
  - High dynamic range (> 1 kHz modulation is possible)
    - Operate CM outside the science band



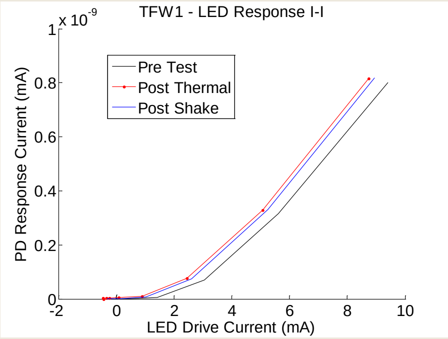
Voltage-Current



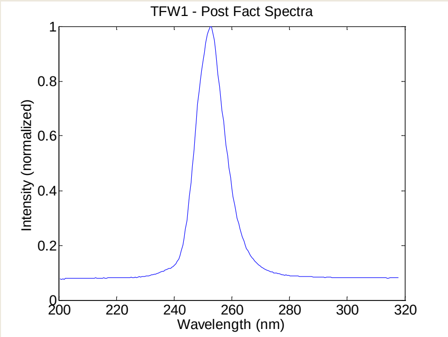
Voltage-Power



Current (L)-Current(P)

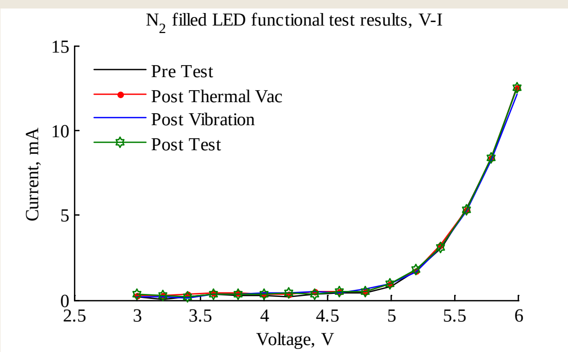


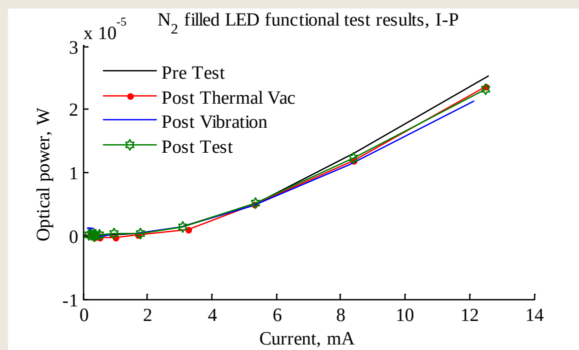
Spectrum

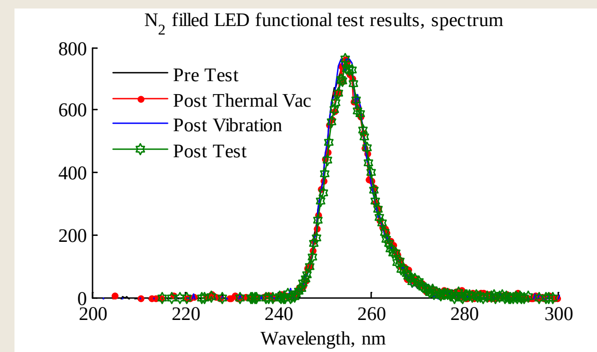


UV LED Space Qual Level Testing

- Extensive campaign with to test LEDs to MIL-1540 (E) levels of thermal and vibe
  - 27 cycles of -34 to +71 under vacuum
  - 14 g RMS vibration, 3 minutes per axis, 3 axes



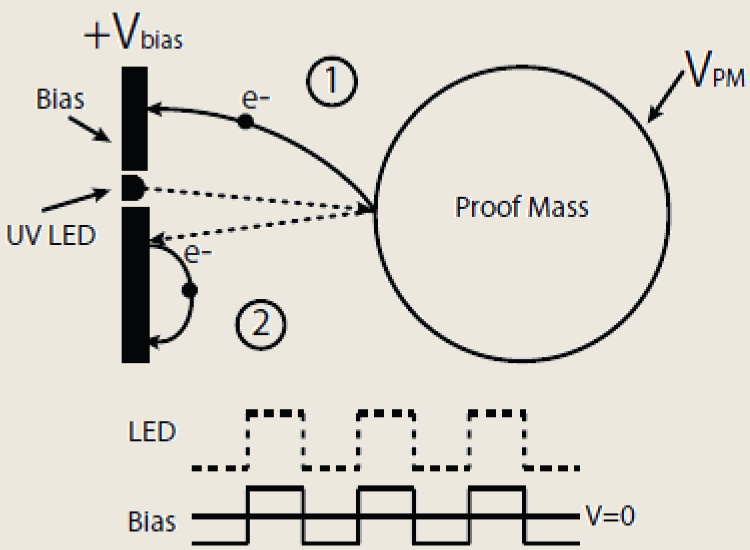




No change seen in I-V and spectrum, minimal change in output power

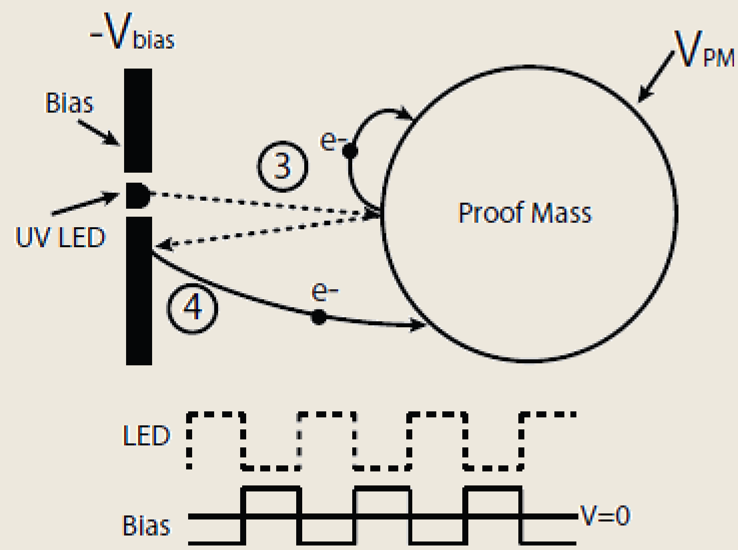
Charge Management Overview

LED and Bias in phase (0°)
photoelectrons transported from PM



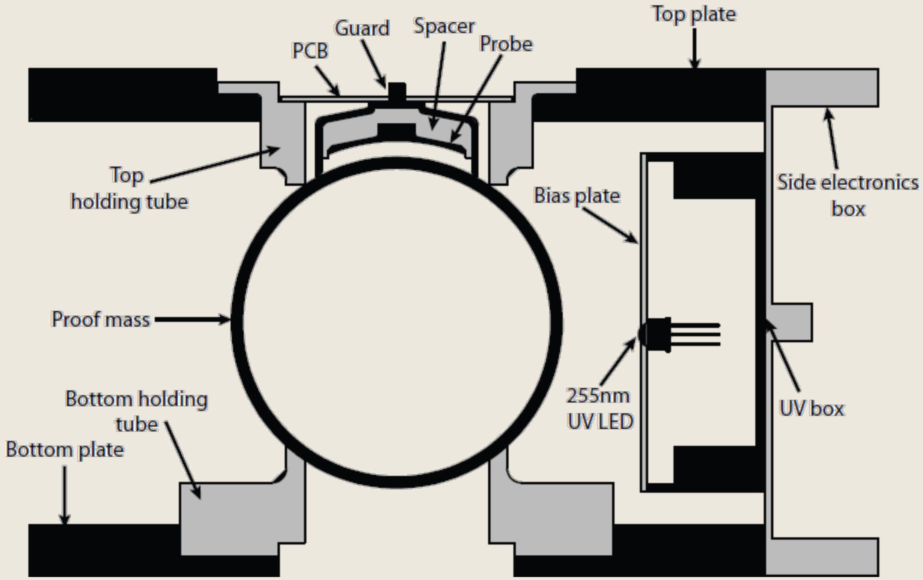
"Positive Charge Transfer"

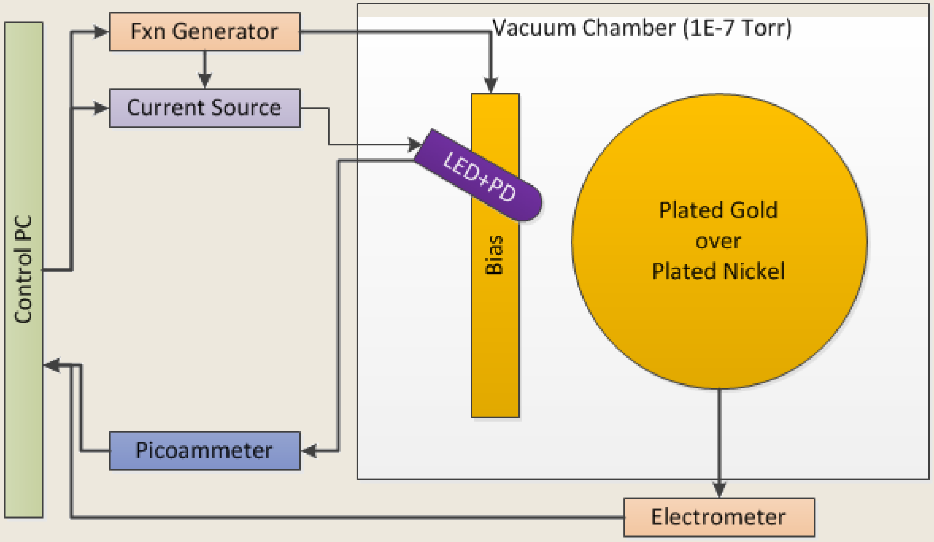
LED and Bias out of phase (180°)
photoelectrons transported to PM

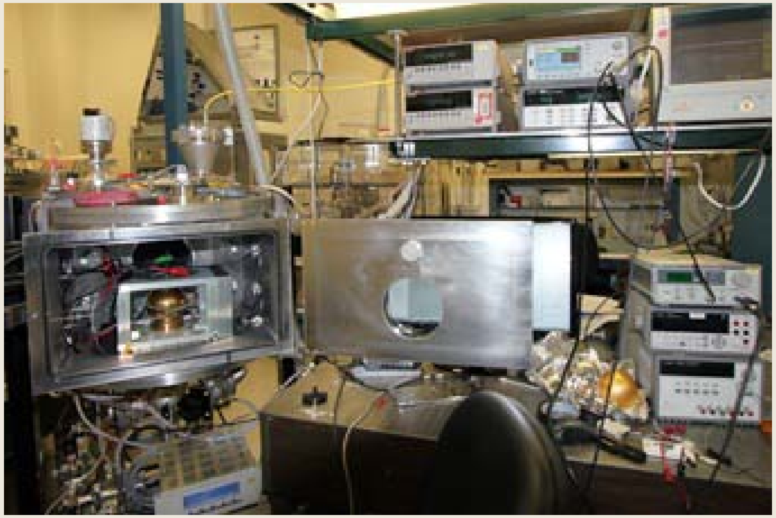


"Negative Charge Transfer"

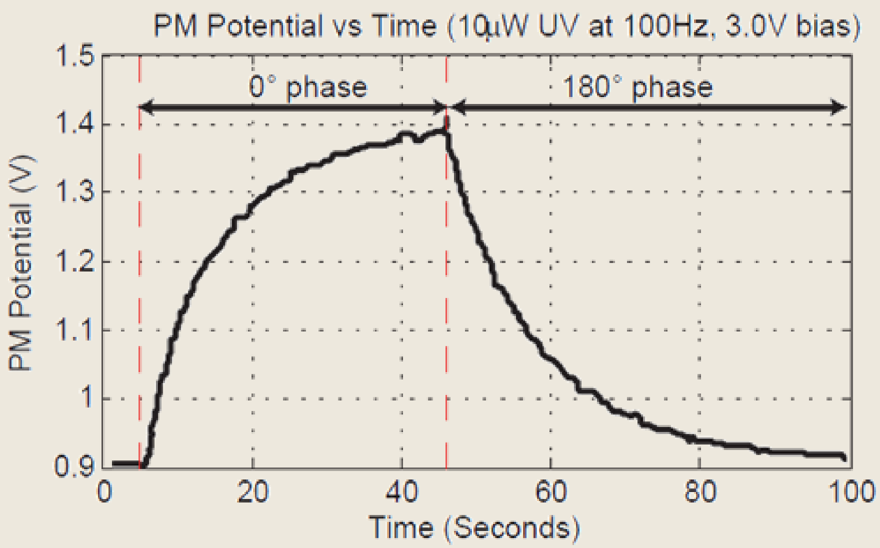
Charge management experimental setup

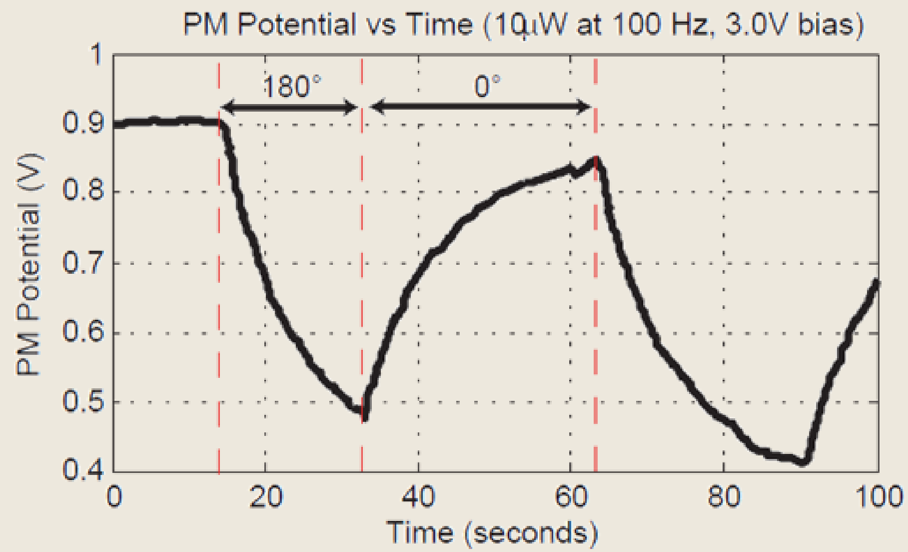






Charge management results





- System capacitance to ground is 17 pF
- 10 μW incident UV power (255 nm), modulated at 100hz, 50% duty cycle, 3.0 V_{pp} bias
- Sphere potential was measured using non-contact probe relative to housing

Peak charging rates are 0.53 pA (positive) and 0.40 pA (negative)
(Approx. 3e6 e^-/sec)

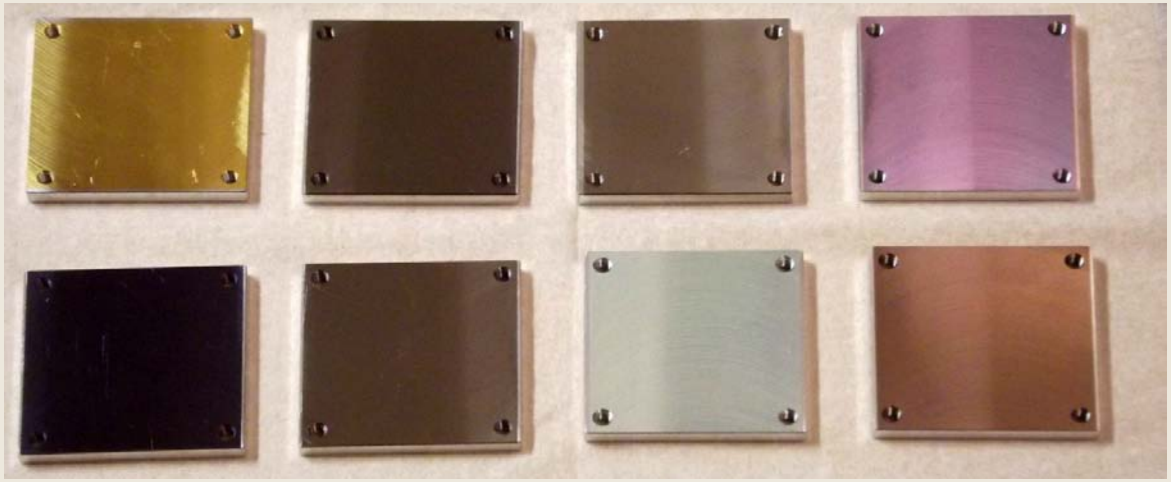
Proof mass coatings –alternative to Au

- The traditional choice for proof mass coatings has been gold (or Au-Pt alloy)
  - High reflectivity
  - Standard coating and cleaning processes
  - Well characterized and understood material
- Problem with gold: soft and prone to sticking, scratching, and deforming
  - During caging, 100 g's preload on proof mass
  - Want proof mass surface to be robust in the event it contacts housing walls
  - Alternatives: carbide coatings
  - Very tough, wide bandgap (close to AlGaN)
- Desired properties at 255 nm
  - Sufficient QE at 255 nm (> approx. 1E-9)
  - Reflectivity > 5%
  - Workfunction near or lower than 4.86 eV (can be slightly higher due to Fermi Tail)

Coatings – samples

- Test: carbide pellets coated on to aluminum substrates via e-beam deposition
  - Substrate material: Al 6061-T6 machined into 1” squares, with a machine finish of Ra 64
  - Pellets: 2-4 mm diameter
  - Samples cleaned via HF etch prior to coating, then immediately vacuum bagged for cleanliness
  - Samples immediately vacuum bagged after coating for cleanliness

- Sample materials:
  - Carbides: SiC, TiC, MoC, ZrC, TaC
  - Metals: Au (traditional proof mass coating), Nb (GP-B)
  - Ir – reflectivity standard

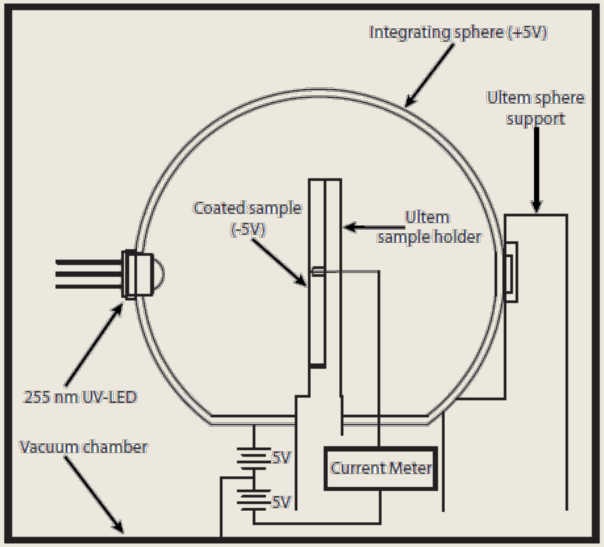


Top row (from left): Au, Nb, Ir, SiC
Bottom row (from left): TiC, MoC, ZrC, TaC

SiC coated Al sphere

Proof mass coating measurements

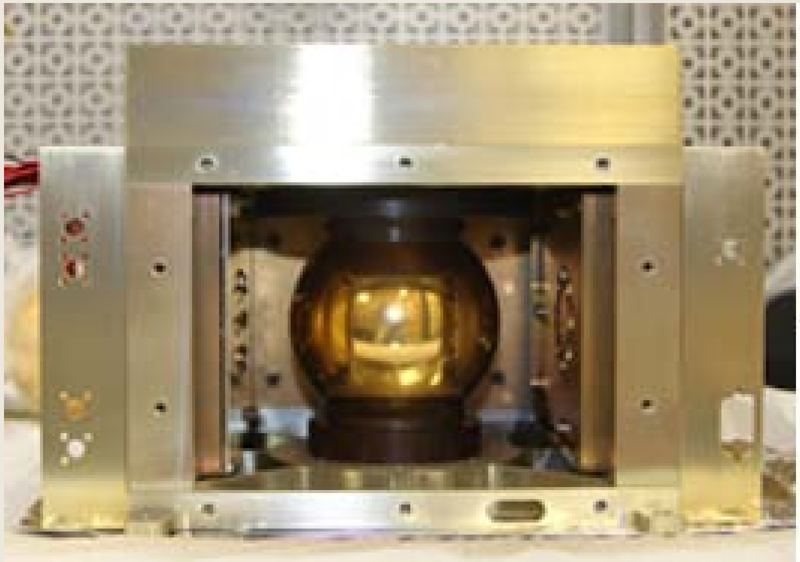
- **Measurements:**
  - Quantum efficiency (λ_{cent} =255 nm)
    - Measured twice: 2 weeks after coating, and 16 months after coating
    - Used an integrating sphere with 10 V bias between coated sample and sphere
    - Samples isolated from ground via 10^{14} Ω Ultem tubes
    - 50 µW UV incident power
    - Current measured using Keithley 6485 Picoemmeter
  - Reflectivity (λ_{cent} =255 nm, θ=45°)
    - Used Newport 918D head connected to Newport 1931-C power meter



QE measurement setup

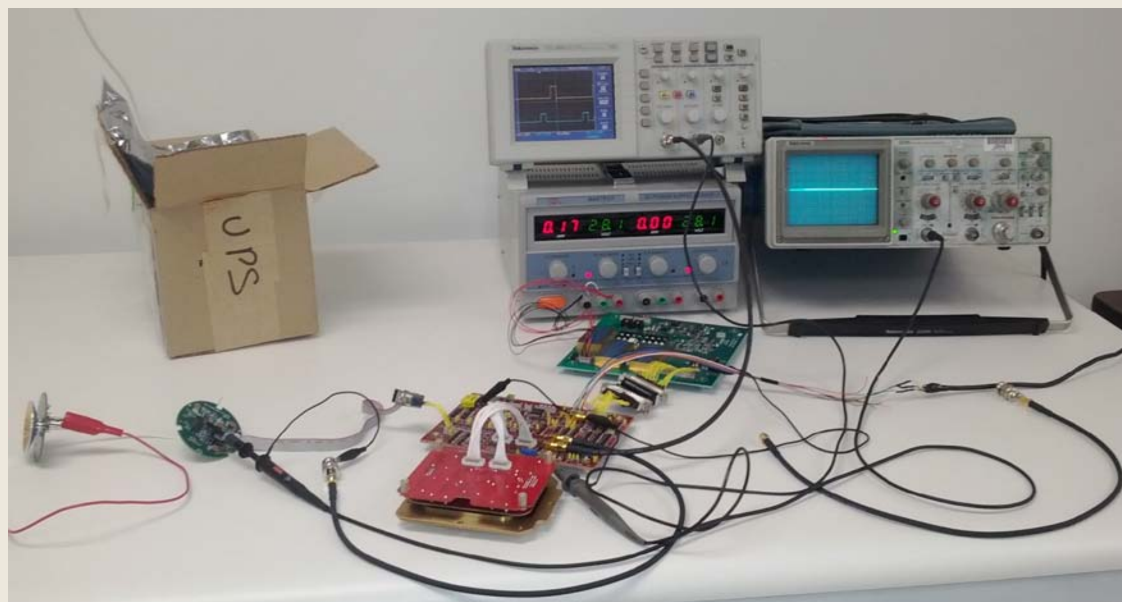
Material	QE (2 wk)	QE (16 mos)	R (255 nm)	ϕ (eV)*
Au	*3.40E-07*	*4.4E-07*	*0.17*	*4.57*
Nb	5.64E-07	2.4E-07	0.17	4.30
SiC	4.34E-07	1.4E-07	0.12	4.80
TiC	4.48E-07	1.3E-07	0.15	3.80
ZrC	3.85E-07	2.1E-07	0.11	3.70
MoC	6.82E-07	1.1E-07	0.15	4.74
TaC	6.35E-07	1.4E-07	0.13	5.0
Ir	--	--	0.6	--

Small satellite demonstration



- 16 total LEDs
- Four bias plates
- Gold coated sphere (e-beam dep'n)
- Contact probe
- Gold coated Ultem tubes - shielding

- Electronics currently in a "flatsat" configuration – easier to debug
- Shown are:
  - 1 charge amp set
  - 1 power board
  - 1 main processing board
  - UV LED holder + amplifiers
- **Scheduled for launch in June 2013**



Questions?

UV LED charge control of an electrically isolated proof mass in a Gravitational Reference Sensor configuration at 255 nm

Karthik Balakrishnan, Ke-Xun Sun, Abdul Alfauwaz, Ahmad Aljadaan, Mohammed Almajeed, Muflih Alrufaydah, Salman Althubiti, Homoud Aljabreen, Sasha Buchman, Robert L Byer, John Conklin, Daniel DeBra, John Hanson, Eric Hultgren, Turki Al Saud, Seiya Shimizu, Michael Soulage, Andreas Zoellner

(Submitted on 3 Feb 2012)

Construction of satellite engineering model ongoing at NASA Ames