UV LED charge control at 255 nm

Karthik Balakrishnan
Department of Aeronautics and Astronautics
Hansen Experimental Physics Labs
Stanford University
karthikb@stanford.edu
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
- Muflih Alrufaydah, Patrick Lu (alum)

**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

- 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)
  - High dynamic range (> 1 kHz modulation is possible)
- Operate CM outside the science band
AC charge Management Overview

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

1. +$V_{bias}$
2. UV LED
3. LED
4. Bias
5. $V_{PM}$

“Positive Charge Transfer”

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

1. -$V_{bias}$
2. UV LED
3. LED
4. Bias
5. $V_{PM}$

“Negative Charge Transfer”
Charge management experimental setup
Charge management results

System capacitance to ground is 17 pF

10 $\mu$W incident UV power (255 nm), modulated at 100Hz, 50% duty cycle, 3.0 $V_{pp}$ bias

Sphere potential was measured using floating probe relative to surrounding housing.
Proof mass coatings

- Gold is soft and prone to sticking and scratching
  - Alternatives: carbide coatings
  - Very tough, wide bandgap (close to AlGaN)
- Test: carbide pellets coated on to Aluminum substrates via e-beam deposition
  - Measured: reflectivity, quantum efficiency, surface resistivity
  - Carbides are an attractive alternative for the traditional gold proof mass coatings

<table>
<thead>
<tr>
<th>Material</th>
<th>QE</th>
<th>R (255 nm)</th>
<th>Φ (eV)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au</td>
<td>3.40E-07</td>
<td>0.17</td>
<td>4.57</td>
</tr>
<tr>
<td>Nb</td>
<td>5.64E-07</td>
<td>0.17</td>
<td>4.30</td>
</tr>
<tr>
<td>SiC</td>
<td>4.34E-07</td>
<td>0.12</td>
<td>4.80</td>
</tr>
<tr>
<td>TiC</td>
<td>4.48E-07</td>
<td>0.15</td>
<td>3.80</td>
</tr>
<tr>
<td>ZrC</td>
<td>3.85E-07</td>
<td>0.11</td>
<td>3.70</td>
</tr>
<tr>
<td>MoC</td>
<td>6.82E-07</td>
<td>0.15</td>
<td>4.74</td>
</tr>
<tr>
<td>TaC</td>
<td>6.35E-07</td>
<td>0.13</td>
<td>5.0</td>
</tr>
<tr>
<td>Ir</td>
<td>--</td>
<td>0.6</td>
<td>--</td>
</tr>
</tbody>
</table>

Top row (from left): Au, Nb, Ir, SiC
Bottom row (from left): TiC, Mo2C, ZrC, TaC

QE measurement setup
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 early 2013
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)

arXiv:1202.0585v1

Questions?

Construction of satellite engineering model ongoing at NASA Ames, March 21, 2011