UV-LED Charge Control For LISA

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Introduction

Test masses inside the LISA gravitational reference sensor (GRS) must maintain almost pure geodesic motion for gravitational waves to be successfully detected. The residual accelerations have to stay below 3 $fm/s^2/\sqrt{Hz}$ at all frequencies between 0.1 and 3 mHz. One of the well known noise sources is associated with the charges on the test masses which couple to stray electrical potentials and external electro-magnetic fields. The LISA pathfinder(LPF) will use Hg-discharge lamps emitting mostly around 254 nm to discharge the test masses via photoemission in its 2015/16 flight. A future LISA mission launched around 2030 will likely replace the lamps with newer UV-LEDs. Presented here is a preliminary design for effective charge control through photoelectric effect by using latest generation UV-LEDs which produce light at 240 nm with work function above that of pure Au. Their lower mass, better power efficiency and small size make them an ideal replacement for Hg lamps. Without contamination, which generally causes a reduction in the work function of Au [2], UV photons with energy below 5.1eV would not have sufficient energy to liberate electrons from pure Au.

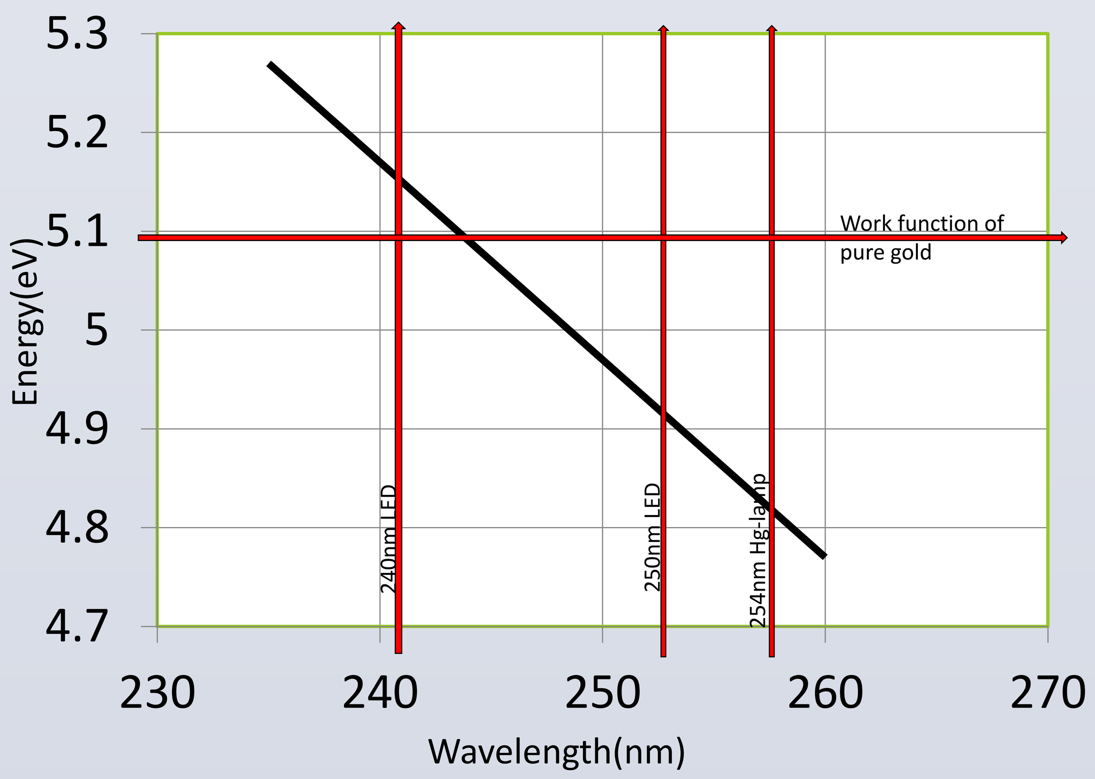
$E \triangleq hc/\lambda = 1240/\lambda$

A pure gold surface of E = 5.1 eV [2]

requires a minimum wavelength of

$\lambda \approx 1240/5.1 \approx 243.14$ nm

For electron emission.

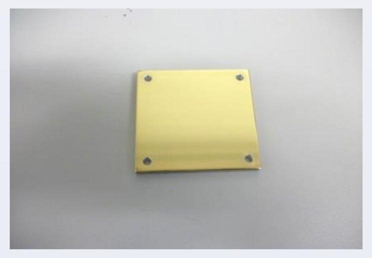


Shorter wavelength⟶ Higher Frequency⟶ Higher energy ⟶More electrons generated⟶ More effective charge control

In the GRS design, the UV LED illuminates the test mass directly and light reflects back to the housing, thus, Reflective properties of Au at 240 nm were studied in order to better understand the charge control process.

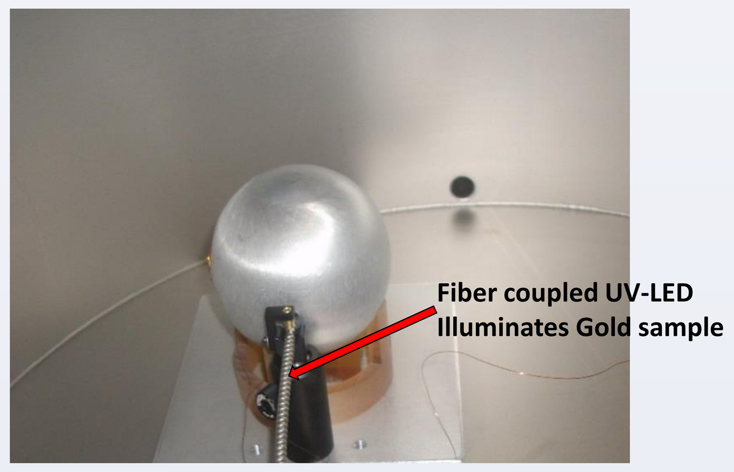
Quantum Efficiency(QE) Measurements in vacuum at 10E-5 torr

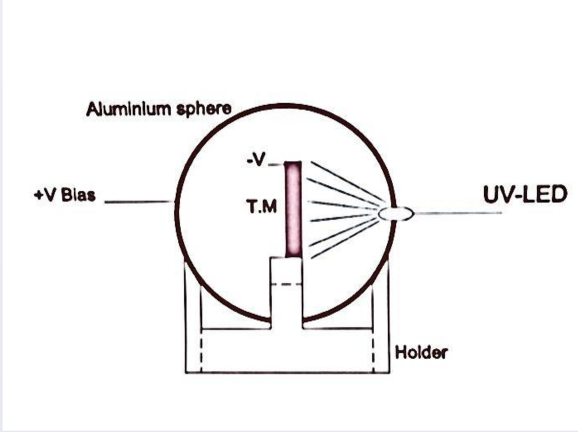
3.5" diameter hollow Aluminium integrating sphere Collects electrons



Gold Coated Sample (TM)

TM mounted on holder



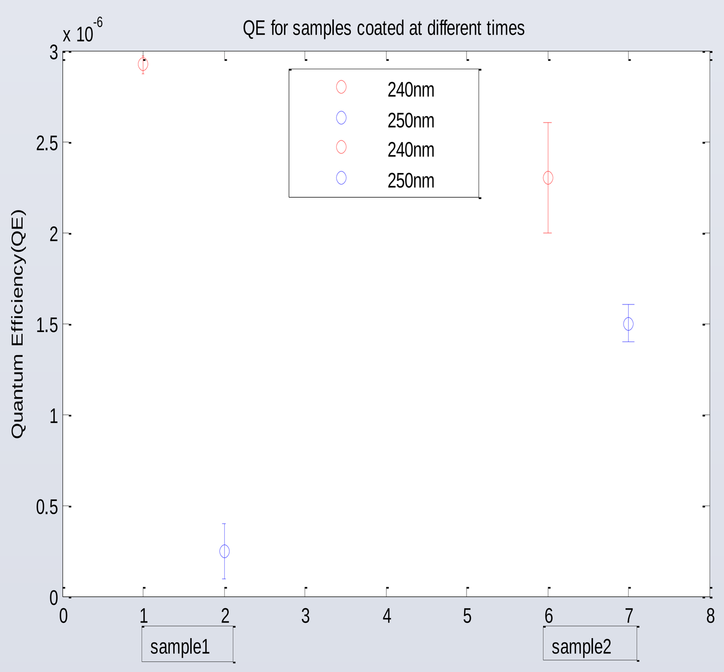


TM Holder (Ultem)

Holder for sphere(Ultem)

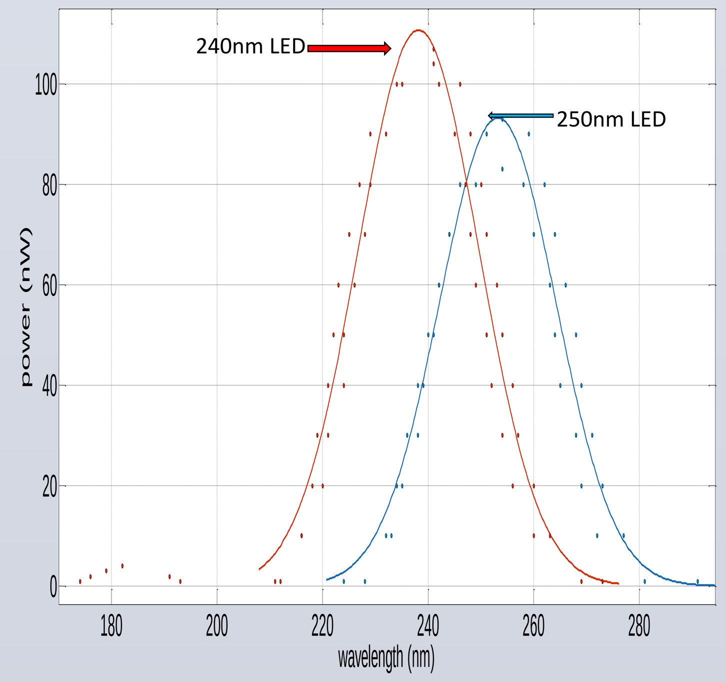
Deep UV LEDs from Sensor Electronic Technologies

QE measurement Results

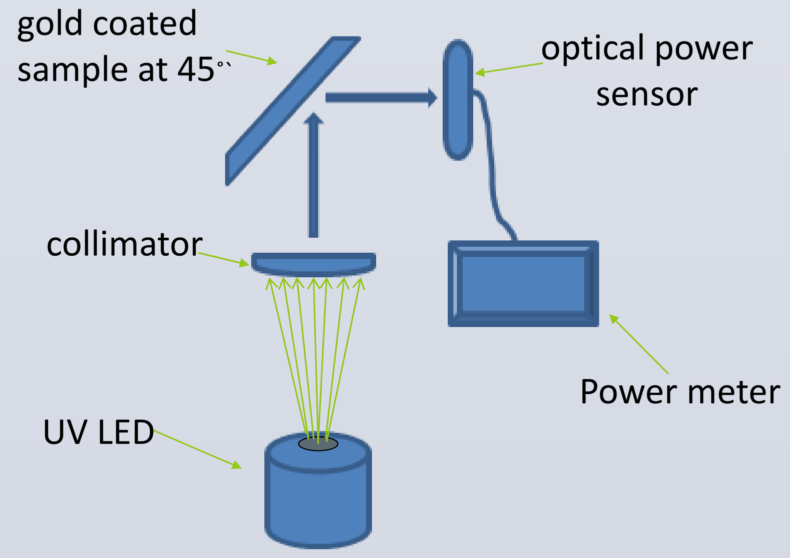


- Power loss by a factor of approximately 0.5 through fiber optic cable
- LED current varied over a range of 10-24 mA
- Quantum Efficiency (QE) = Number of electrons liberated/Number of photons
- Resulting Photocurrent measured via Keithley 6485 Picoammeter
- Current driver for UV LED, ILX Lightwave precision current source LDX-3200 series
- 0 degree incident angle for QE measurements
- Sample 1 with a gold layer 200 nm thick was coated in March 2013, Sample 2 with a gold layer 500 nm thick was coated in September 2013 (6 months later)

Spectrum analysis



Reflectivity Measurements



- Reflectivity measurements made with Thorlabs PM100D power meter with S120VC detector head

Reflectivity Results

250nm	240nm
24.08 ± 0.24	25.12 ± 0.11

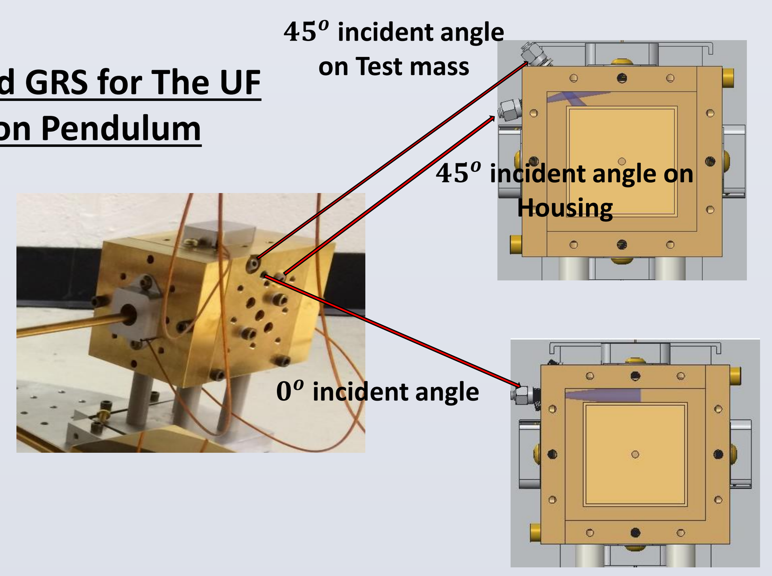
Conclusion/Future work

The 250 nm LED is similar to the 240 nm LED in terms of power consumption, reflectivity and cost but the 240 nm LED offers improved QE .

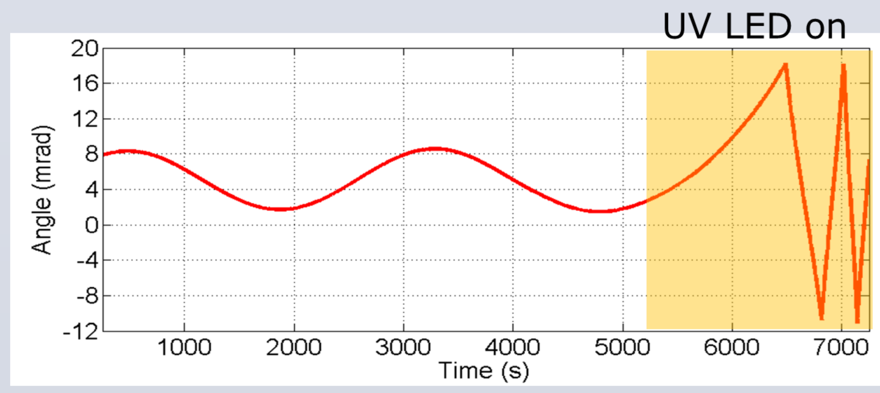
Future work includes;

- Tracking QE measurements with different coated samples over long periods of time, with focus on how length of storage, mode of storage, type and thickness of coating can affect QE
- Demonstrating charge control /measurement with The UF torsion pendulum.
- Implementation and testing in the UF torsion pendulum and space-qualification in a small satellite mission which will launch in the summer of 2014, through a collaboration with Stanford, KACST, and NASA Ames Research Center.
- Space capable fiber couplers will be shake tested at the Kennedy Space Center, SETi fiber-coupled LEDs failed shake tests at Stanford.
- There is a significant drop in LED power at 50-100 hours and it degrades more as time goes by. A TEC device will be developed and incorporated to reduce the operating temperature of the UV LED to extend its lifetime.

Simplified GRS for The UF Torsion Pendulum



- Plot of UV-LED building up charge on the pendulum test mass and destabilizing it



References

[1] K Balakrishnan, K-X Sun, A Afauwaz, A Aljadaan, M Almajeed, M Alrufaydah, S Althubiti, H Aljabreen, S Buchman, R L Byer, J Conklin, D B DeBra, J Hanson, E Hultgren, T A Saud, S Shimizu, M Soulage, A Zoellner. **UV LED charge control of an electrically isolated proof mass in a Gravitational Reference Sensor Configuration at 255 nm**. Stanford University

[2] Daniel Hollington, **The Charge Management System for LISA and LISA Pathfinder,** High Energy Physics Group, Department of Physics, Imperial College London