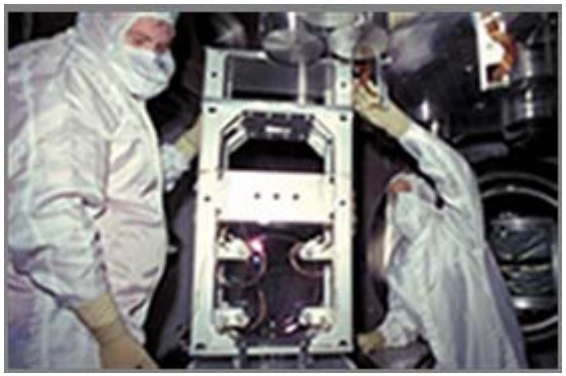
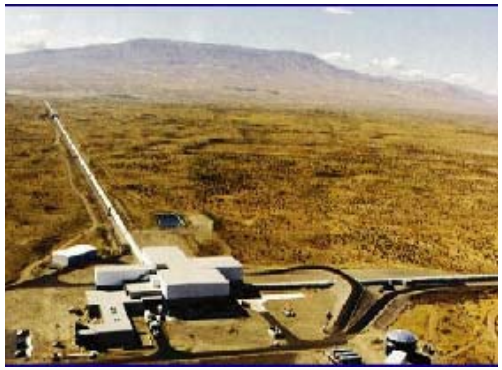
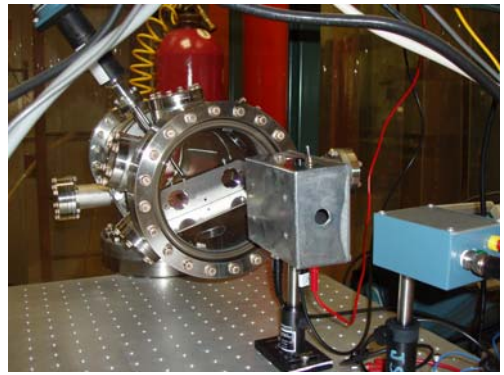
Update of LIGO Test Mass Charging Mitigation Activities at Stanford

Ke-Xun Sun, Nick Leindecker, Sei Higuchi, Ashot Markosyan, Roger Route, Mike Hennessey, Jim Perales, Sasha Buchman, Marty Fejer, and Robert Byer, *Stanford University*

Gregg Harry, *LIGO MIT*

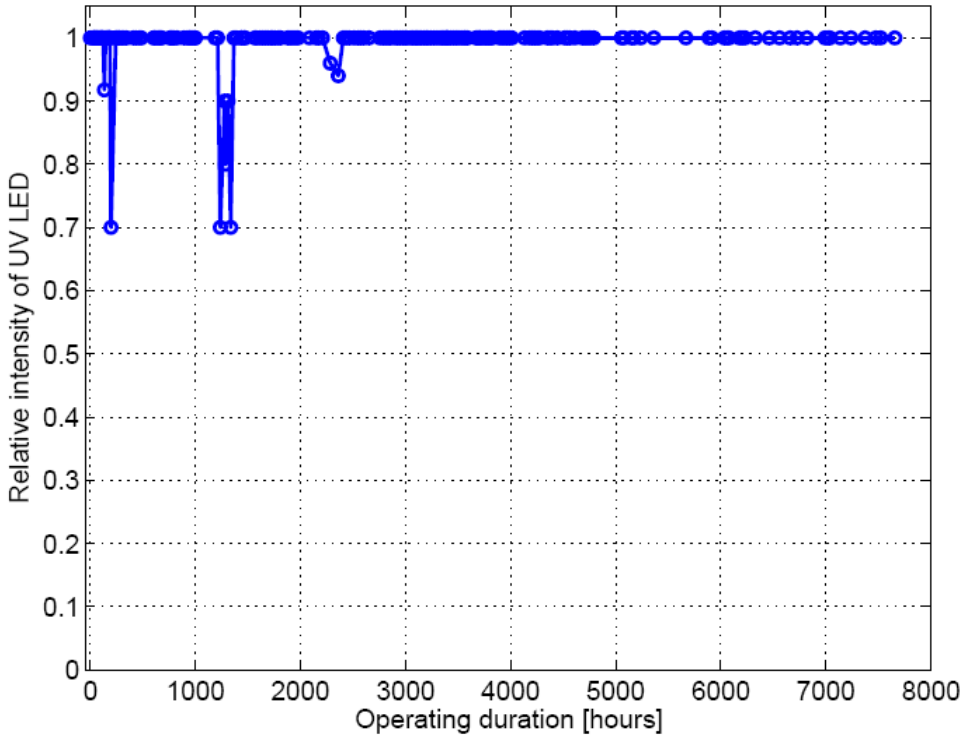
LIGO Science Collaboration Meeting
Baton Rouge, March 19-22, 2007

Outline

- Under LIGO coordination --- Gregg Harry visit in January 2007, Stanford started the LIGO test mass charging mitigation work in January 2007 (after UV presentations at LSC twice)
- Work so far:
  - Deep UV LED driver electronics in one box, including current source with modulation input, variable frequency and variable duty ratio oscillator, now operating at out of GW band frequency (10 kHz)
  - UV detector box allowing two photodiodes currently, testing SiC, Si, and InP photodiodes
  - Commissioned a vacuum jar ($3x10^{-7}$ torr)
  - Borrowed and commissioned a high vacuum chamber ($4x10^{-8}$ torr)
  - UV irradiation of LIGO 1” optics with HR and AR coatings
  - Loss measurement before and after UV irradiation
- Next steps
  - UV system development
  - UV effect assessment for substrate and coating
  - Explore other alternatives for LIGO test mass charge management
  - Voltage probe
  - Alternative schemes

UV LED Lifetime Test

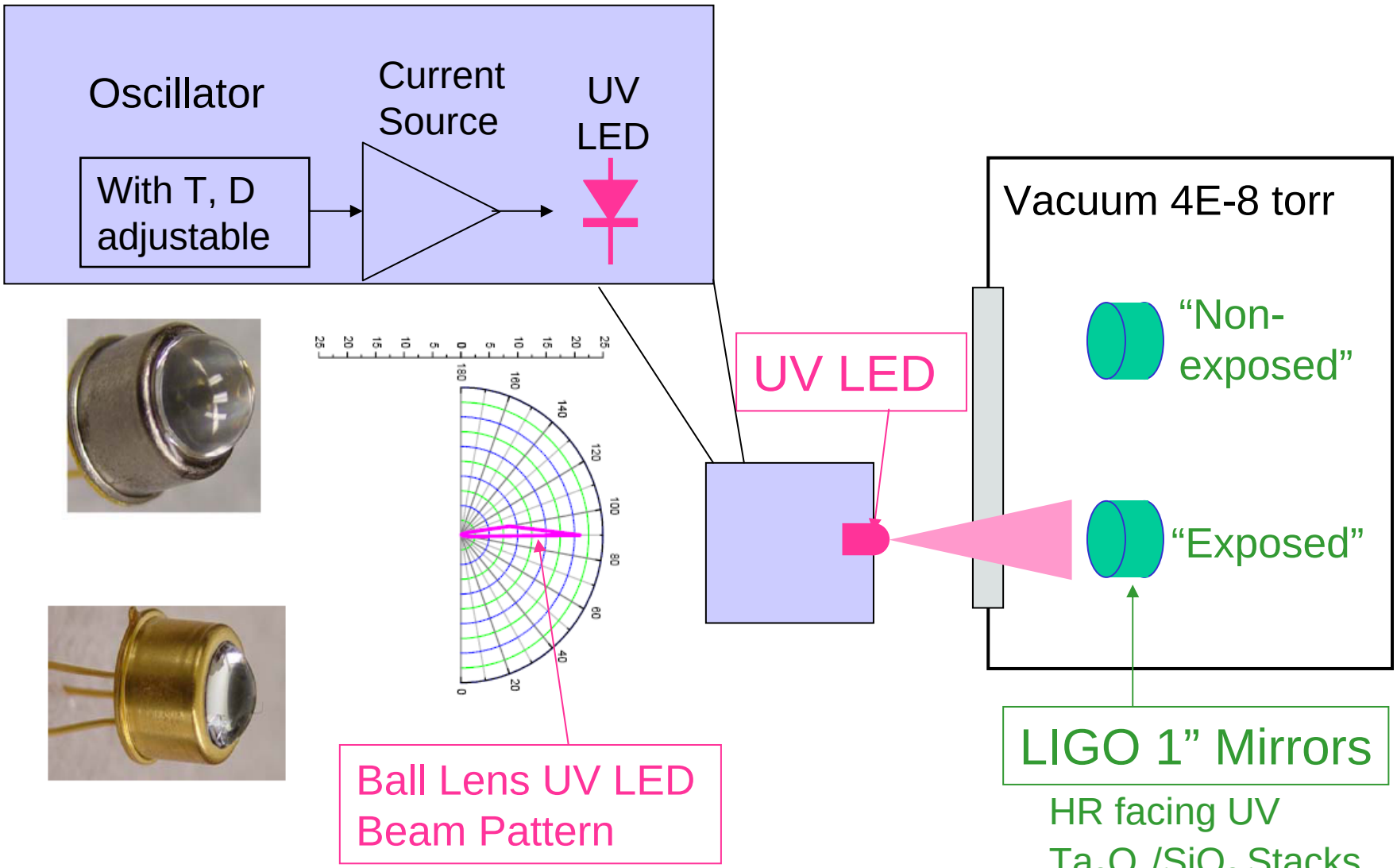
- UV LED life time test approaching 7800 hours, since March 2006
- UV LED demonstrated excellent power and spectral stability
- UV LED is on the map for space flights



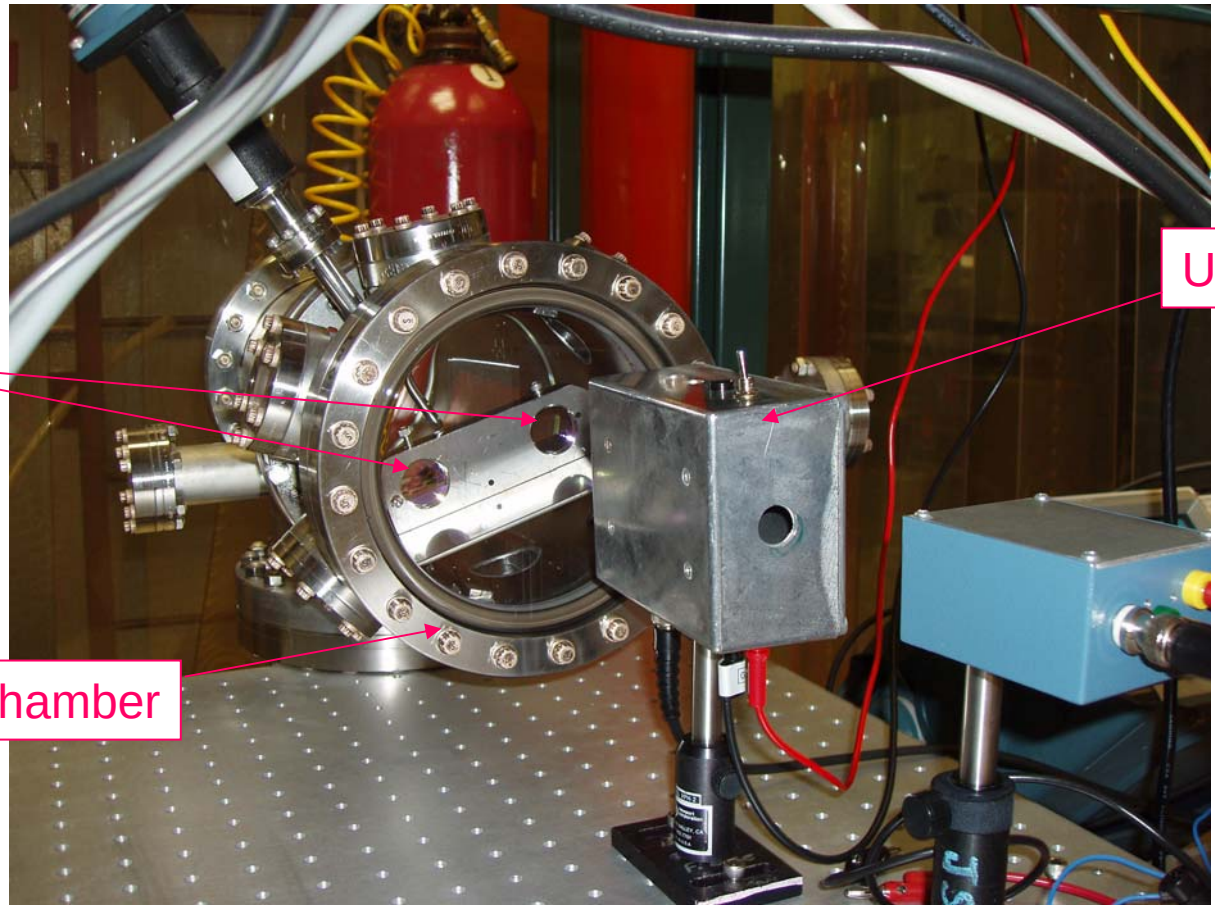
UV LED Irradiation Conditions

- Started UV irradiation 3/9/2007
- UV LED peak power <10 μW
- Power modulated at 10 kHz
- Using ball lens for directionality
- LIGO 1” optics with HR/AR coating
- Receiving UV power ~0.2-0.5 μW
- Mirror and coating losses measured before and after UV irradiation

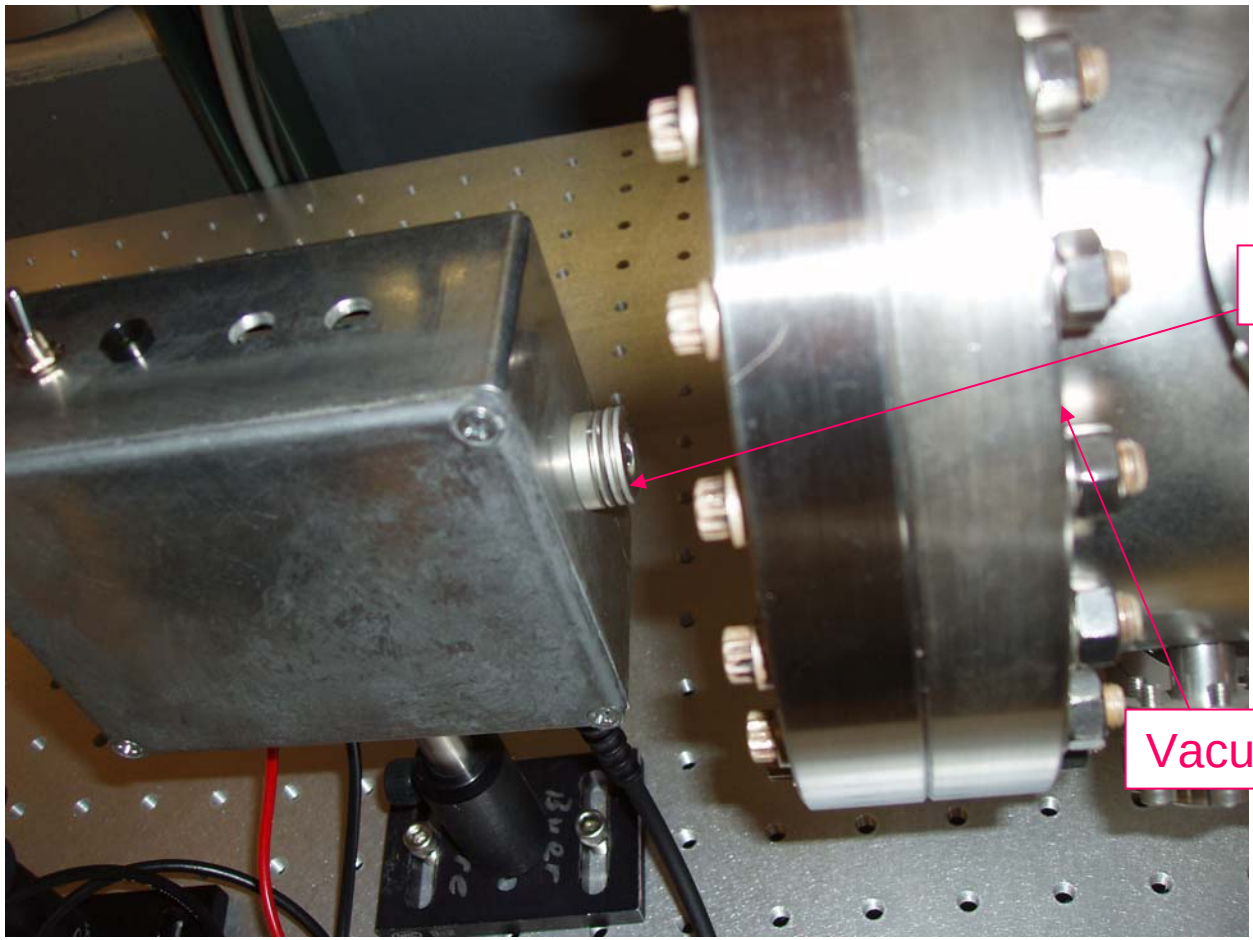
UV LED Irradiation Experiment



The Experimental Setup (I)



The Experimental Setup (II)

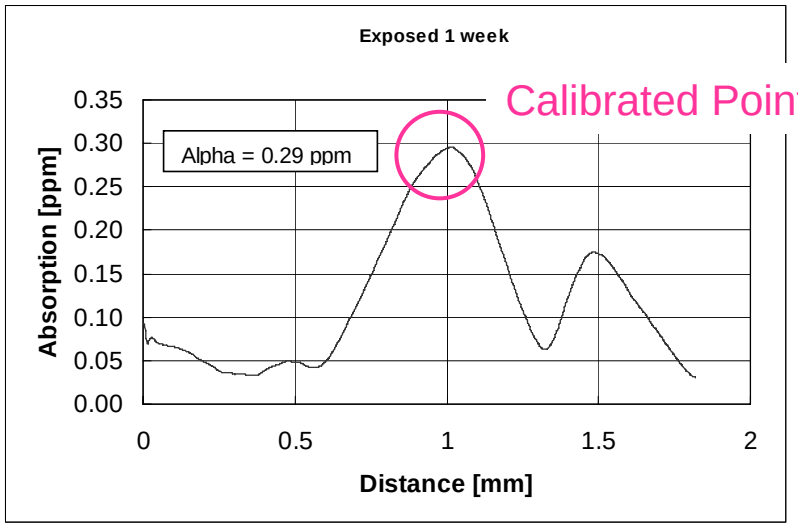


The Experimental Setup (III)

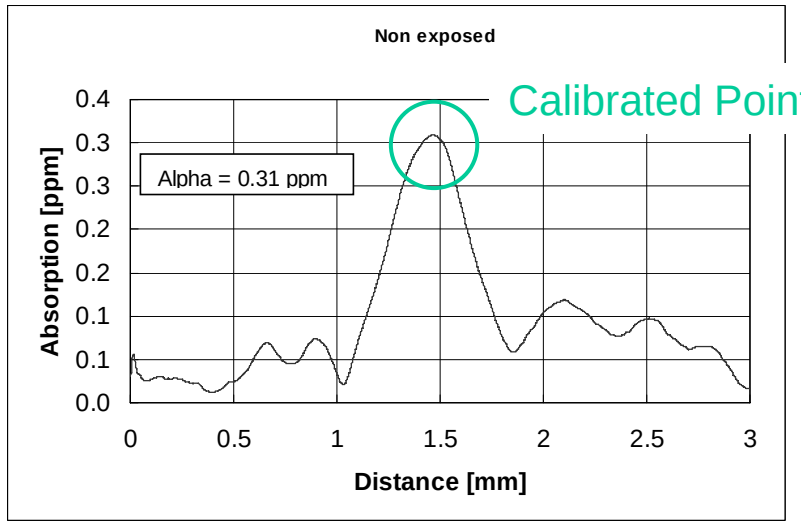
High Vacuum (4×10^{-8} torr) to Insure No Contamination

Loss Measurements after One Week UV Irradiation

Left Side Mirror, Non Exposed



Right Side Mirror, Exposed



Loss Measurement Before and After UV Irradiation	Before [ppm]	After [ppm]	Change [ppm]
Non Irradiated Mirror	0.19	0.31	+0.12
Irradiated Mirror	0.23	0.29	+0.06

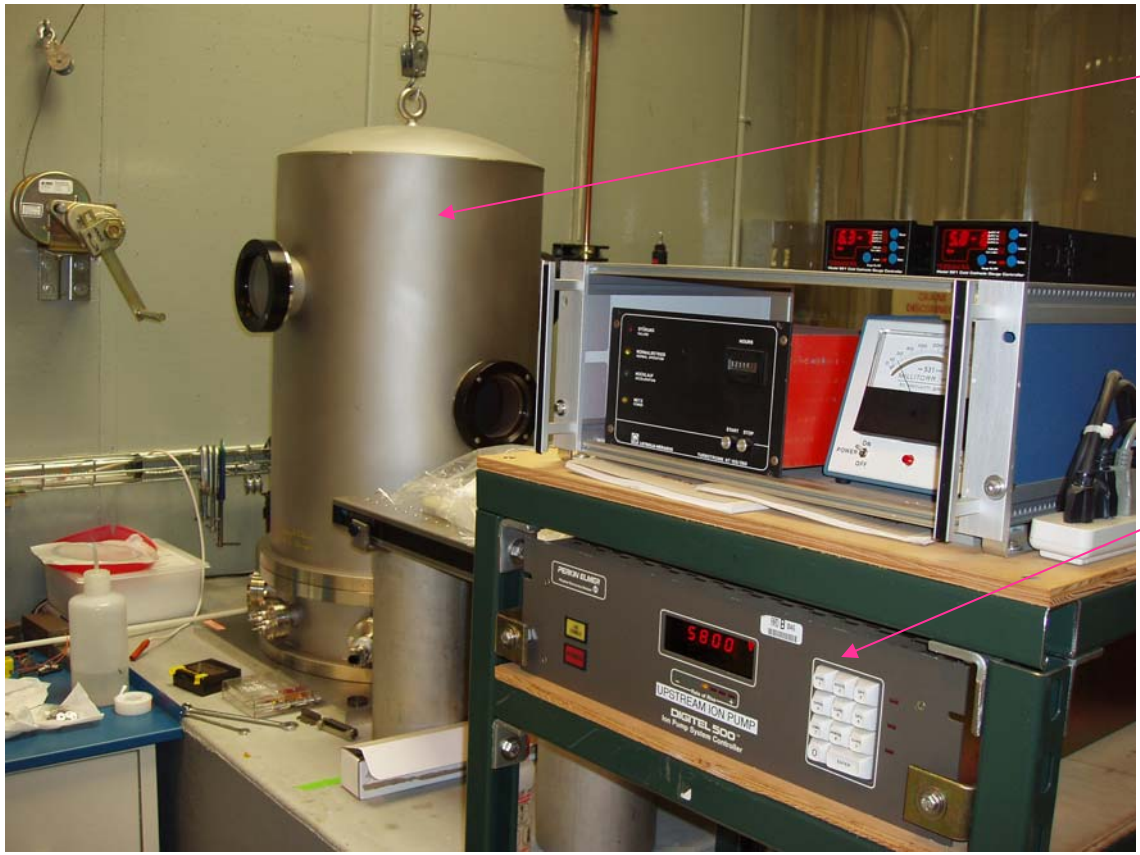
Next Step (I)

- UV charge management works
  - The good news --- UV worked for GEO, easily
  - UV is *the* non-contact charge management tool
- Development LIGO-targeted UV system
  - More sophisticate UV LED system rivaling that for what we did for LISA
    - UV LED sources with flexibility
    - Modulation optimization
    - Wavelength selections beyond 253.7 nm Hg line
    - Full spectrum LED available from 248 nm and longer wavelength
  - Customization for eLIGO and advLIGO
  - UV optics for targeted illumination

Next Steps (II)

- UV Irradiation Tests:
  - Continued UV irradiation tests on LIGO mirrors AND coatings
    - The doubt from coaters --- increased absorption loss by UV illumination
    - Are there any damaging effects on oxide coatings?
    - What is the UV power threshold beyond safe charging management?
    - What is the wavelength dependence/threshold?
    - What is the modulation dependence?
  - Alternative UV scheme
    - Wavelengths that fill in the gap between effectiveness and damage (such as 355 nm etc)
    - Hidden UV source as an electron control device

Experimental Setup (IV)
Two Chambers for LIGO Charging Mitigation Work

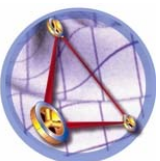


Mid Vac Chamber Probe and Charge Management Experiment

High Vac System UV Irradiation Effect Assessment

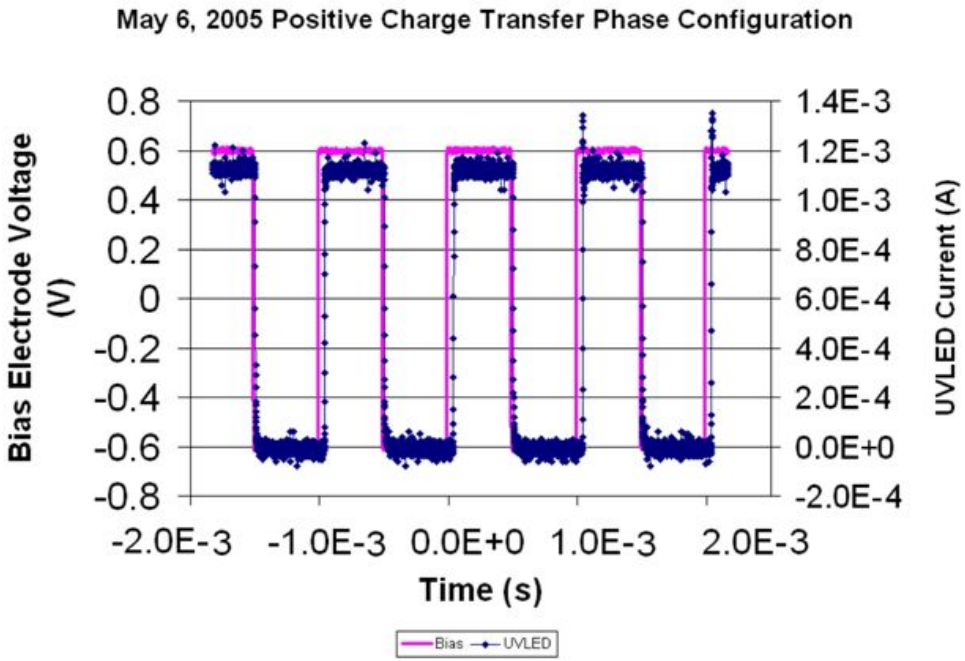
Next Steps (III)

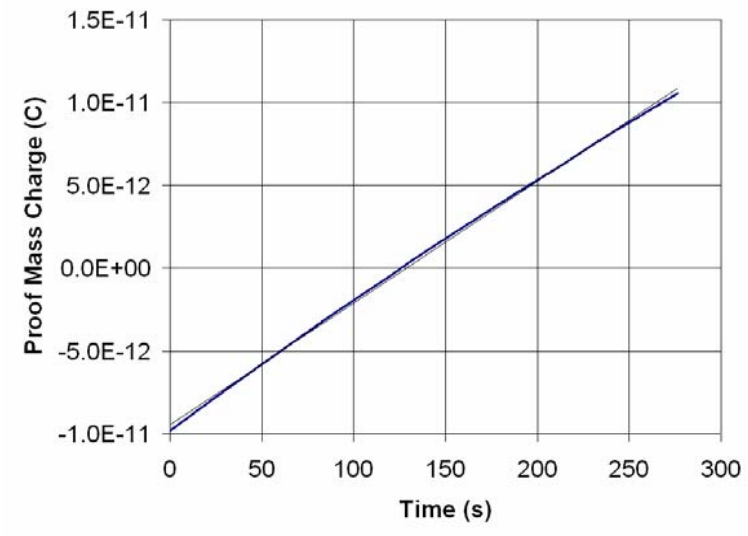
- Voltage probe development
  - GSFC Kelvin probe will be commissioned after accelerated moving request. (It is a PZT driven buzzer)
  - LIGO needs an independent, vibration-less voltage probe for test mass charging concerns
  - Some possible schemes
    - Differential electrometer
    - Lower the cost using commercial alterations
    - EO crystals
  - Will use a second chamber for technology development

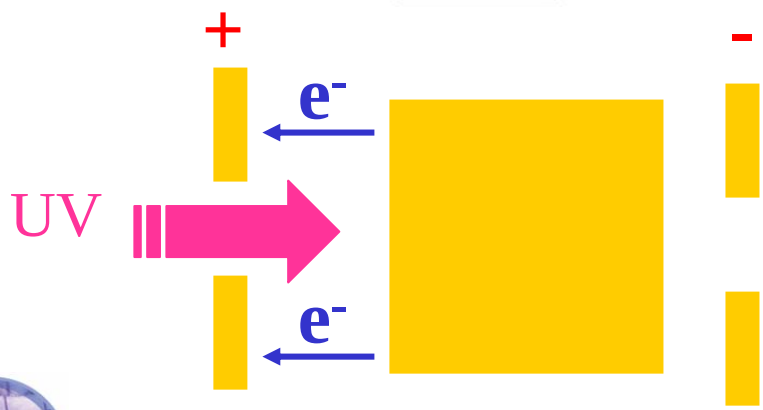


Positive Charge Transfer

UV LED and bias voltage modulated at 1 kHz







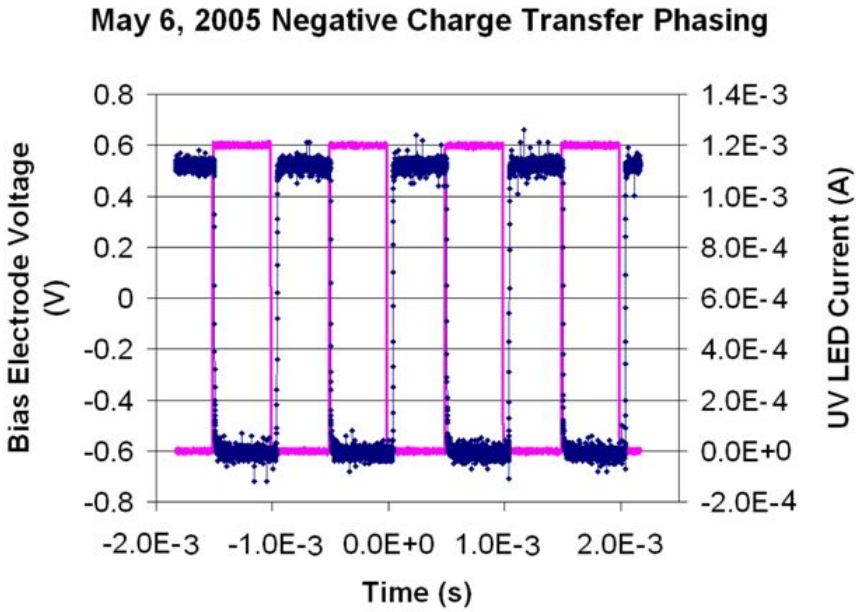
UV phased to positive AC ½ cycle

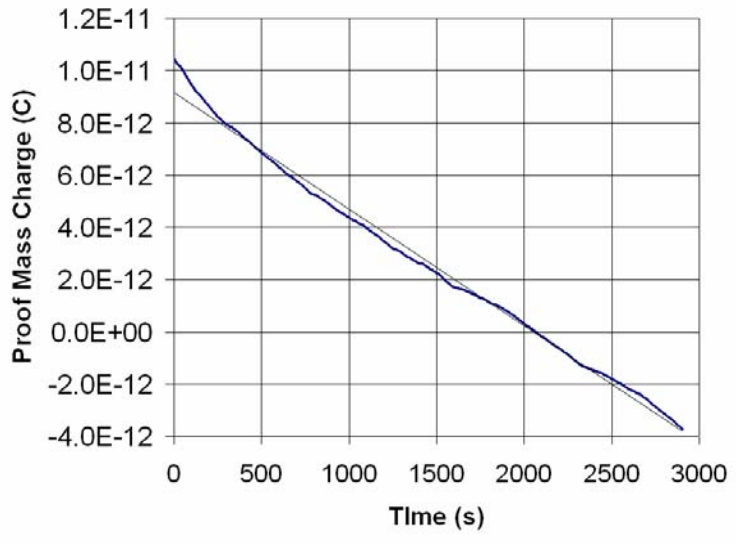
Electrons fly to housing electrode

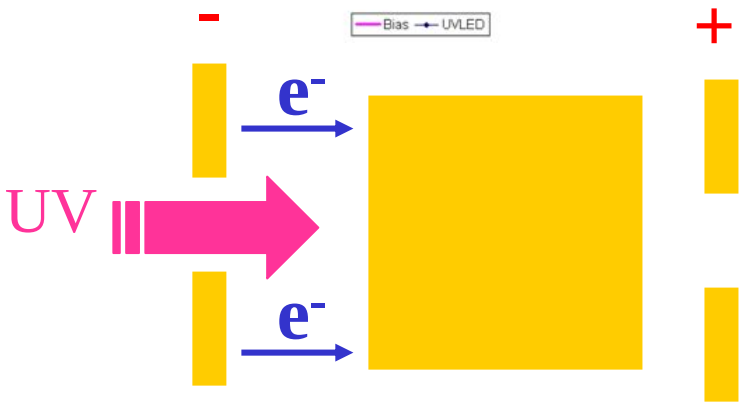
Proof mass potential increase

Negative Charge Transfer

UV LED and bias voltage modulated at 1 kHz







UV phased to negative AC ½ cycle

Electrons fly to proof mass

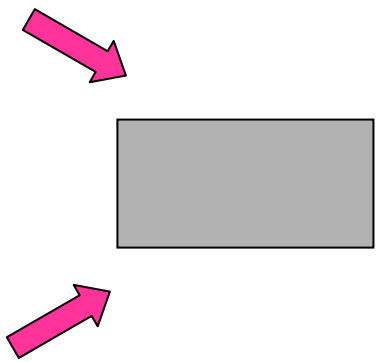
Proof mass potential decreases

Next Steps (IV)

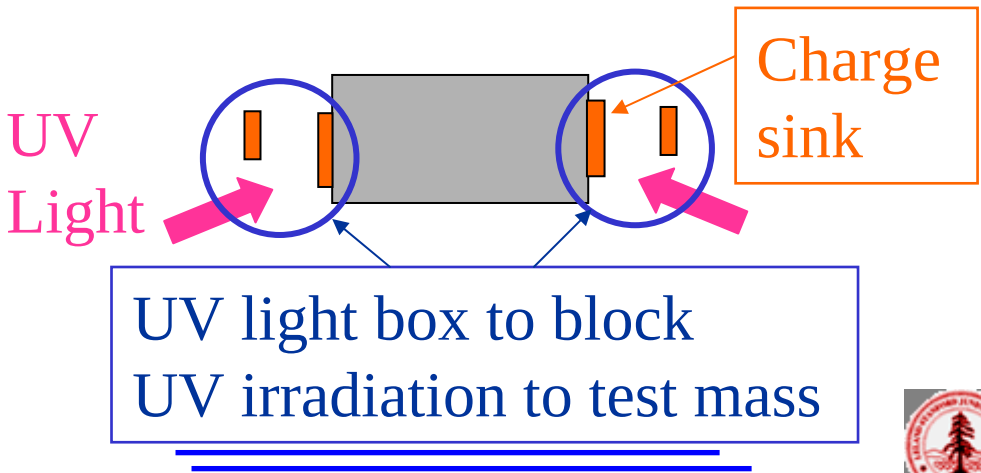
- Modified UV scheme to mitigate additional risks
  - UV illumination from side or the back of the mirrors
  - UV light box to contain UV radiation
  - Other wavelengths
- Alternative charge management schemes
  - Sharp pin discharge
  - No UV or combined with UV: Whatever is good for LIGO
  - Fluoride coating (CaF_2 etc.)
- Collaboration with other LIGO efforts
  - In-situ UV illumination for cavity ring down
  - In-situ UV illumination for *Q*-measurement
  - Etc…

UV Illumination Schemes

- Direct illumination
  - UV mercury lamp is routinely used for attachment removal
  - UV LED has sufficient power for cw direct illumination
  - Possibly works
  - But UV effect on coating?

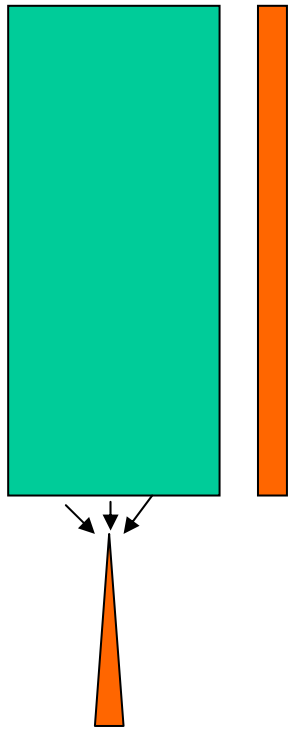


- Illumination on coatings
  - Au coating on non-critical portions of test mass and suspension structure
  - Photoelectric effect on Au surface has been utilized in GP-B and ST-7
  - Higher throughput in charge control
  - UV light dump to contain light



The Alternative Schemes: Sharp Pin Discharge

- Field concentration around a sharp pin
- Discharge at the sharp tip
- Good for high voltage objects like that in LIGO test mass
- Bidirectional charge/discharge possible



Conclusions

- Under LIGO coordination, we have actually started work on LIGO charging problems
- Laboratory setup in progress
- UV irradiations test result for more testing
- Future development plans for LIGO-specific charge management system
- Work will be under LIGO coordination, participating a range of collaborations