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Charge management for LISA Pathfinder and beyond

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Science & Technology Facilities Council

UK SPACE AGENCY

esa

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Overview

- Introduction
- Measuring and modelling discharging
- Increasing robustness of discharge process
- LISA Pathfinder charge management hardware
- The future: Technology development for eLISA/NGO

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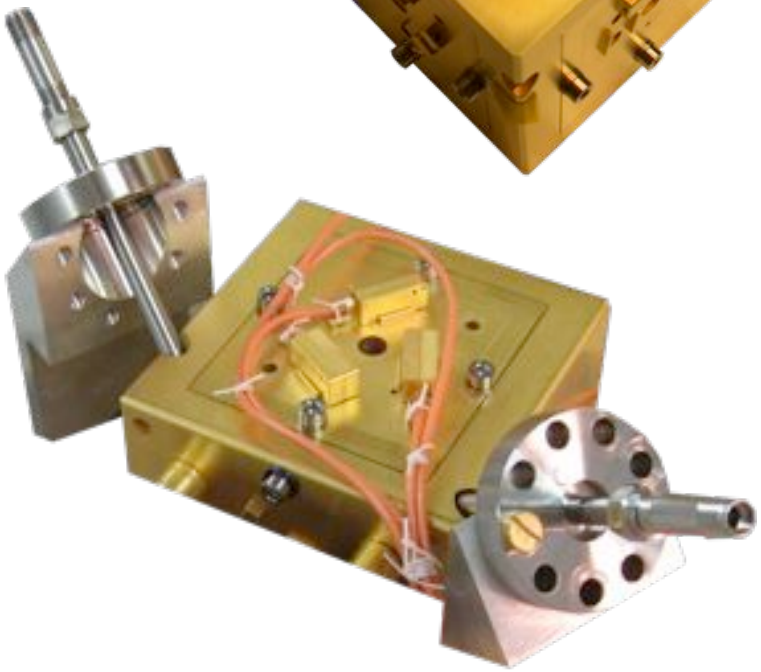
Introduction

- Sensor
  - 6-degree of freedom position sensing and actuation of free-floating test mass
- Discharging
  - Neutralise test mass by preferential illumination and photoemission from test mass or electrode housing
- Light injection
  - UV fibre optic feed at vertex of sensor
- Applied voltages
  - DC
  - Sensing bias constant at 100kHz
  - Actuation voltages, variable AC at 60-270 Hz



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Testing discharging

- Test mass negative charge

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Testing discharging

- Test mass positive charge

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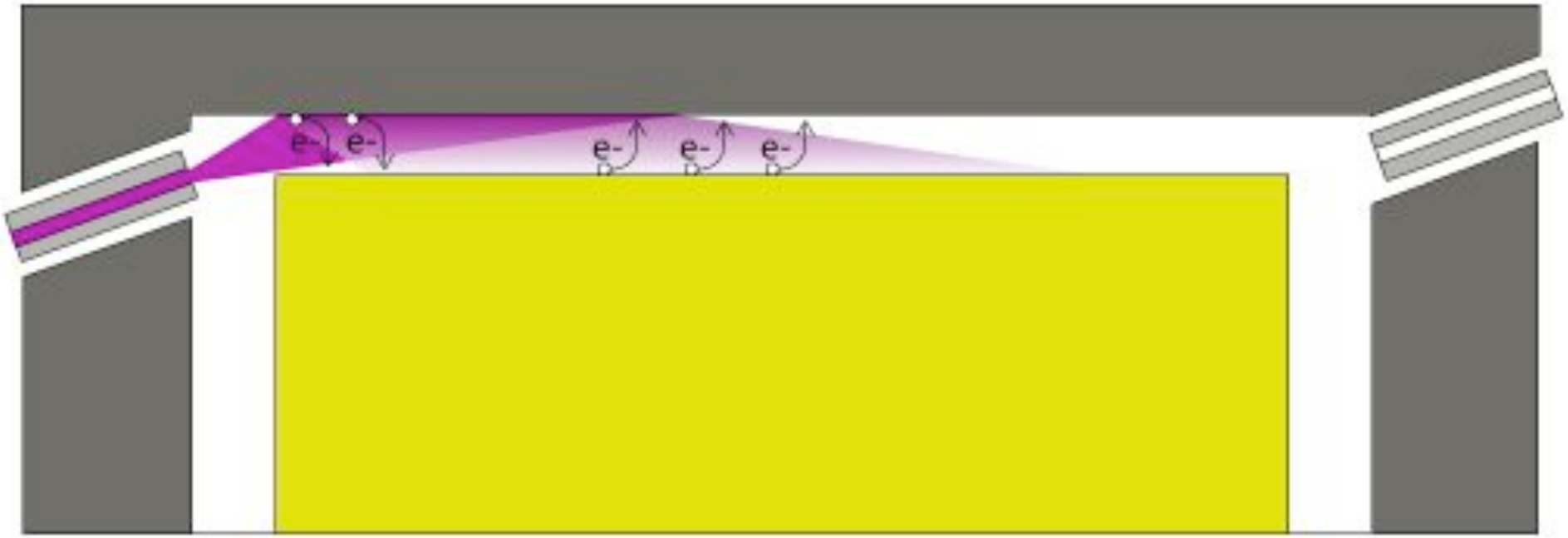
Testing discharging

- Surfaces are reflective
- Emissivity of surfaces needs to be balanced



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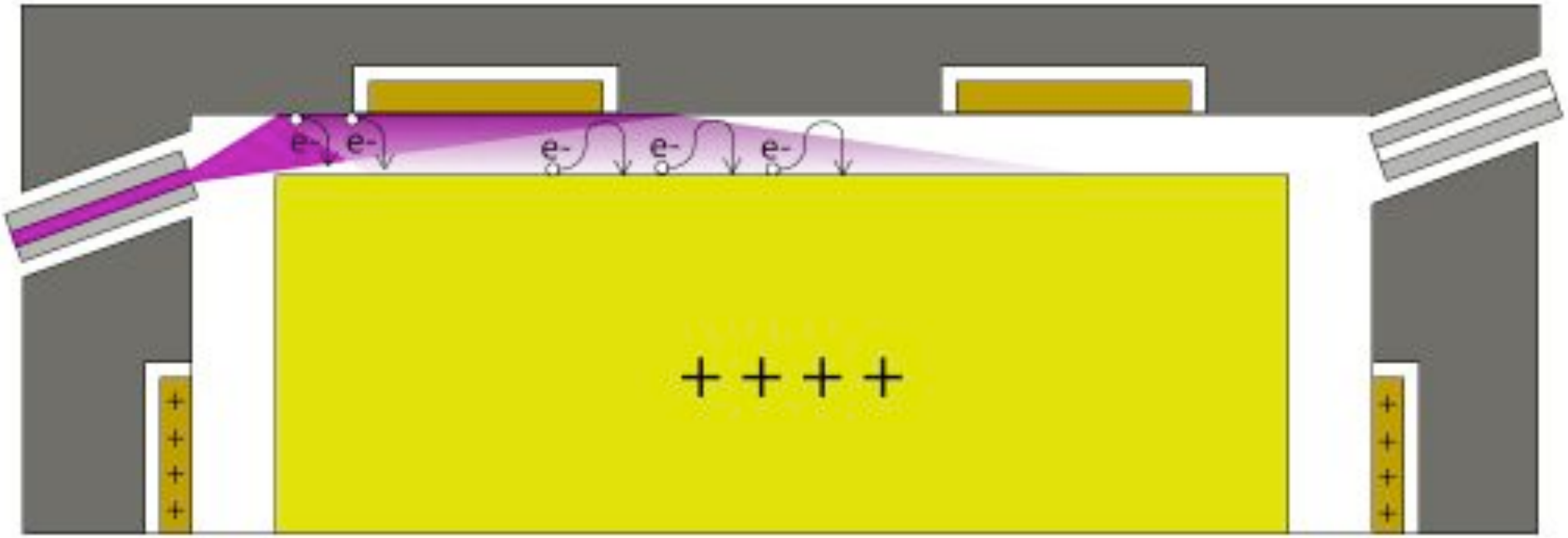
Testing discharging

- Voltages can help discharging



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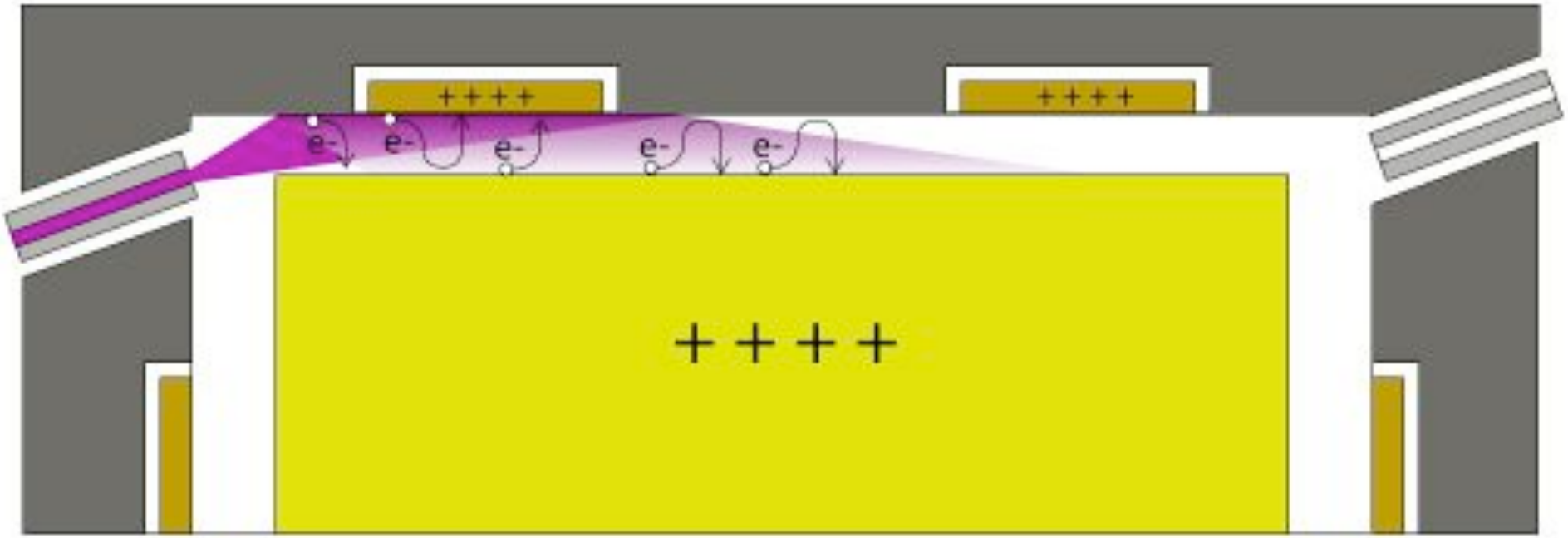
Testing discharging

- Voltages can help discharging
- …not always



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Testing discharging

- Discharging tests using a torsion pendulum at University of Trento with different TM/EH combinations
  - In some cases unassisted bipolar discharge was possible
  - In others UV illumination always results in a positive test mass
  - However, discharging is possible by applying selective voltages. **(Nominal operation for LISA Pathfinder)**
  - Worst case requires a reduction in capacitive sensitivity only while discharging: still compatible with Science operations
  - Qualitatively understood by imbalance in photoemissivity
  - Variability of surfaces underestimated
  - Robustness: ratio of yields that will allow discharging

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Modelling system

- Two models have been developed to explain/predict discharging results quantitatively
  - EADS Astrium: LPF flight model, ICL: UTN results
  - Ray-tracing of UV light propagation in sensor
  - Assumption of photoelectric yields (from measurements + ray-tracing)
  - Calculation of electric fields at discrete time steps
  - Propagation of electrons between housing and test mass
  - See posters: Hollington and Ziegler
- Models developed independently conclude that pendulum yields are 10:1 (TM:EH)

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Increasing robustness

- Extensive period of investigation by EADS Astrium and others
- Many options to increase robustness of discharging studied
  - Understanding surface physics and controlling yield
  - Many measurements on sample surfaces
  - Selective enhancement 'Hot-spots'
  - Selective suppression
  - Light redirection

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Outcomes

- Robustness for baseline
  - No bias: +ve: 3.0 –ve: 2.7
  - With voltage assistance: +ve: 3.6 –ve: 9.7
  - Reduced injection: +ve: 3.7 –ve: 15
- Robustness for redirected light
  - No bias: +ve: 3.5 –ve: 17
  - With voltage assistance: +ve: 4.2 –ve: 36
- Surface preparation and handling reduces variation in yield
  - Plasma cleaning + bakeout in vacuum
- Final test go/no-go on integrated flight hardware

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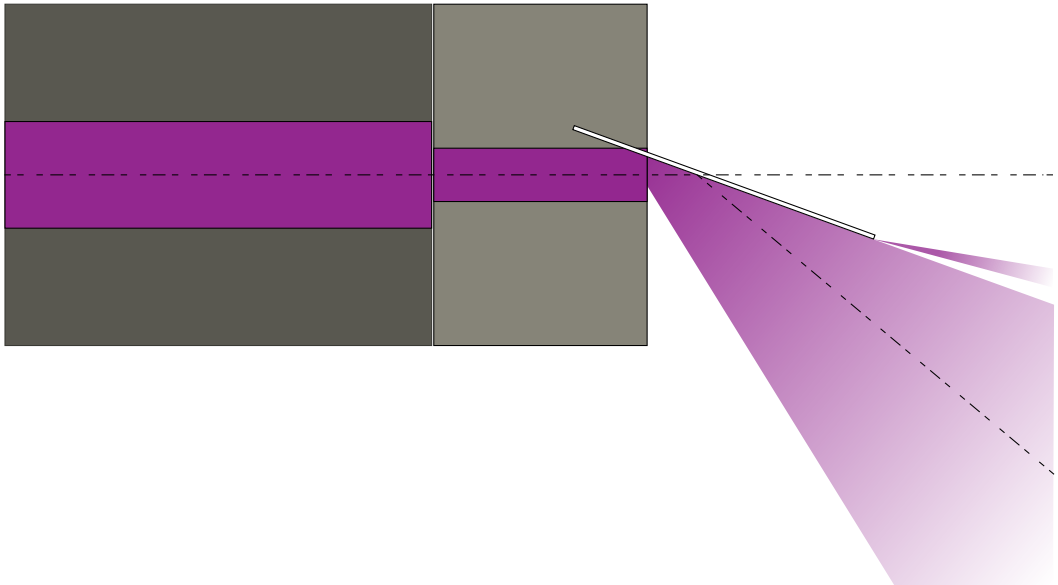
Light redirection

- Adapt ISUK tip with mirror
- Beam spread: 12-degrees
- Desired deflection angle: 40-degrees
- Simple mirror results in a lot of light missing mirror, big spot
- Narrow aperture to increase fraction of light on mirror



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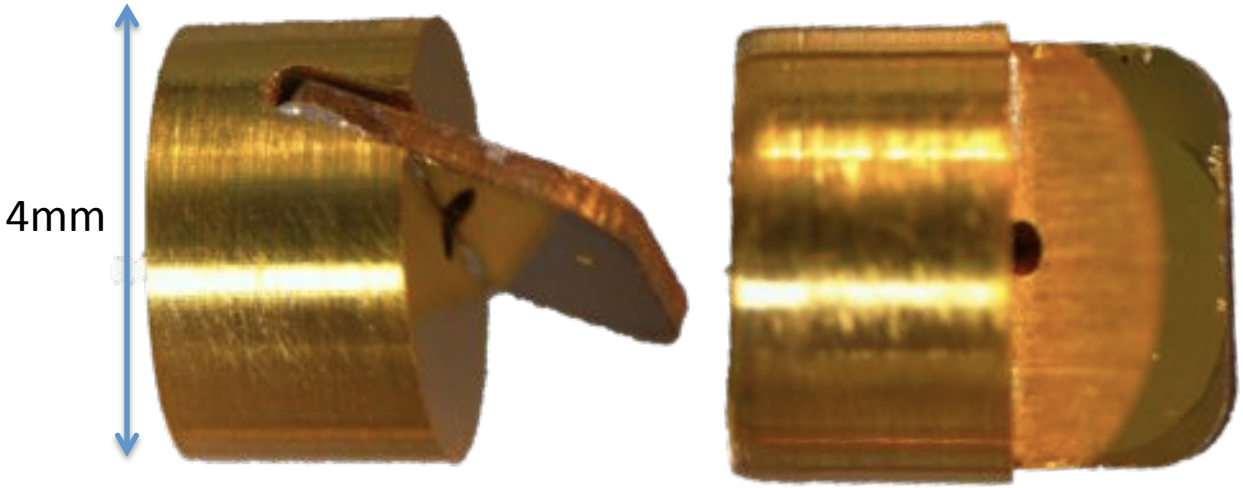
Light redirection

- Adapt ISUK tip with mirror
- Beam spread: 12-degrees
- Desired deflection angle: 40-degrees
- Narrow aperture to increase fraction of light on mirror
- Prototypes manufactured and tested
- Design being refined for flight model



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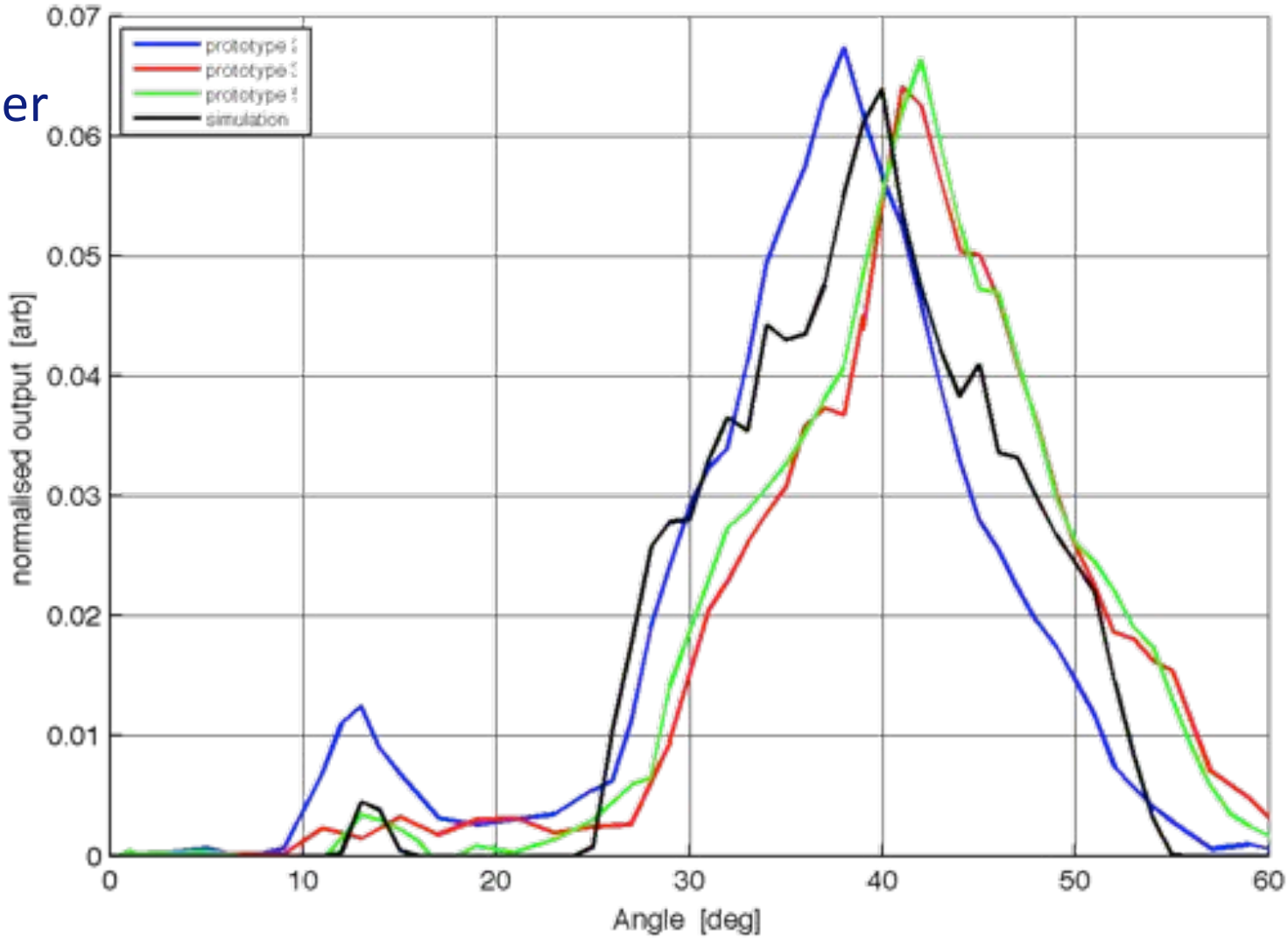
Angular output

- Output power 11% of undeflected



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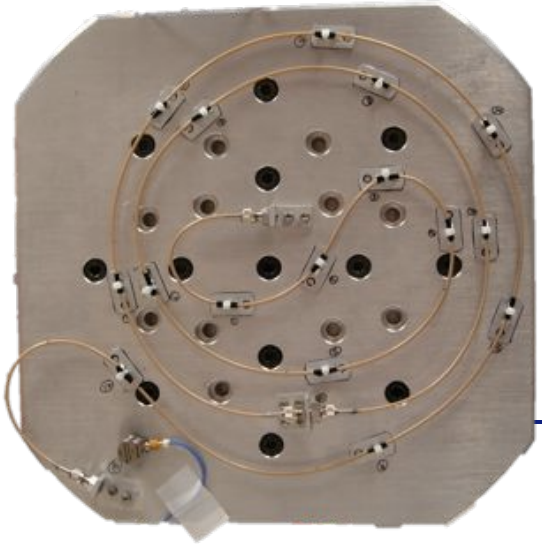
LISA Pathfinder CMD

- ULU
  - Testing and calibration complete
  - Integrated on spacecraft for OSTT
  - At ICL during hibernation to resolve final qualification issues



- FOH
  - Completed manufacture and test
  - Ready for integration after hibernation
  - NEW: Attenuator prepared to adjust UV light power

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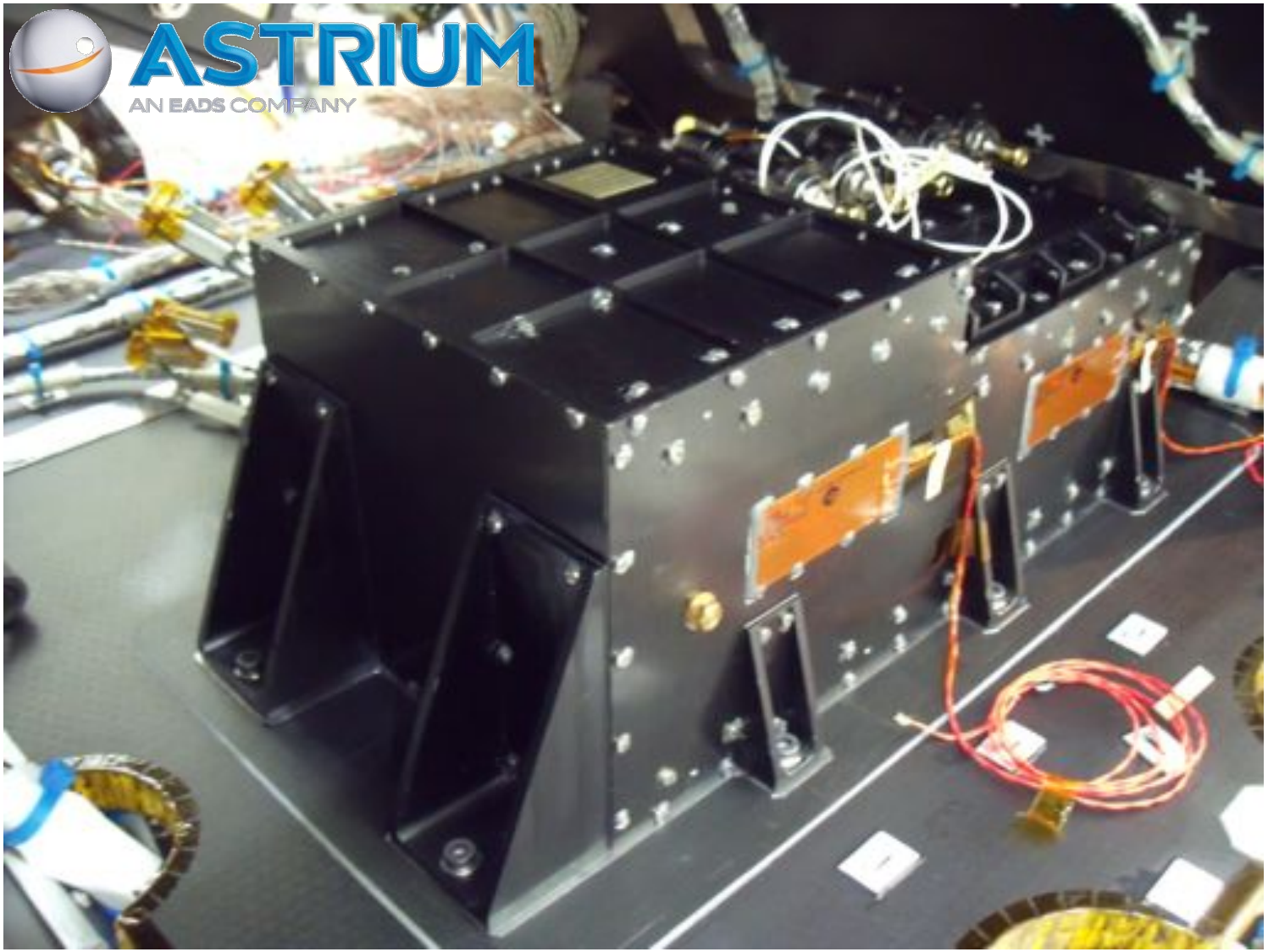
LISA Pathfinder CMD



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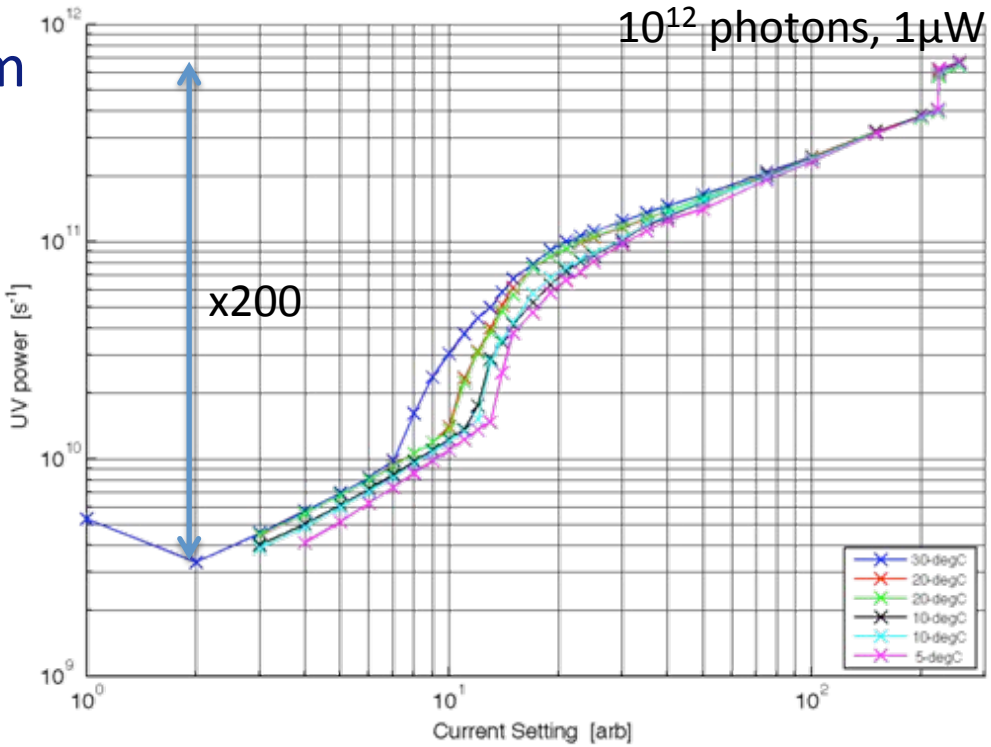
LISA Pathfinder CMD

- UV output level and stability measured in thermal vacuum
- Calibrated for light injected into sensor
- UV attenuation
  - Typical output ~0.05-1μW (3.10^9-7.10^{12} photons/s)
  - Target discharge rate 10^2-10^4
  - Large uncertainty in absolute level of photelectron yield
  - Attenuate light up to 100x by altering FOH junction



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eLISA/NGO

- Investigating performance and suitability of new light sources for eLISA/NGO charge management device
- Motivation for changing technology:
  - Mission lifetime longer: years rather than months
  - Can a different technology provide a more robust discharging solution
- New solid-state technologies have become available that can rival lamps in UV emission
  - Blue laser diodes doubled to deep UV wavelengths (~200nm)
  - UV LED 240-255nm
- Currently UV LEDs are most promising

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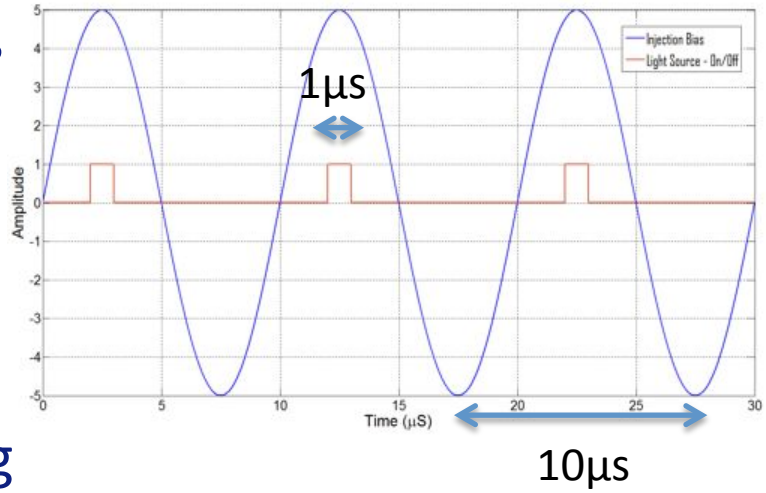
eLISA/NGO

- UV LED devices have many advantages vs mercury lamps
  - more compact
  - no high voltage power supply
  - low power consumption
  - faster modulation
  - Long-life

- Synchronisation with sensor voltages improves robustness
- Lower wavelength may also increase robustness
- High dynamic-range by high-frequency sigma-delta switching



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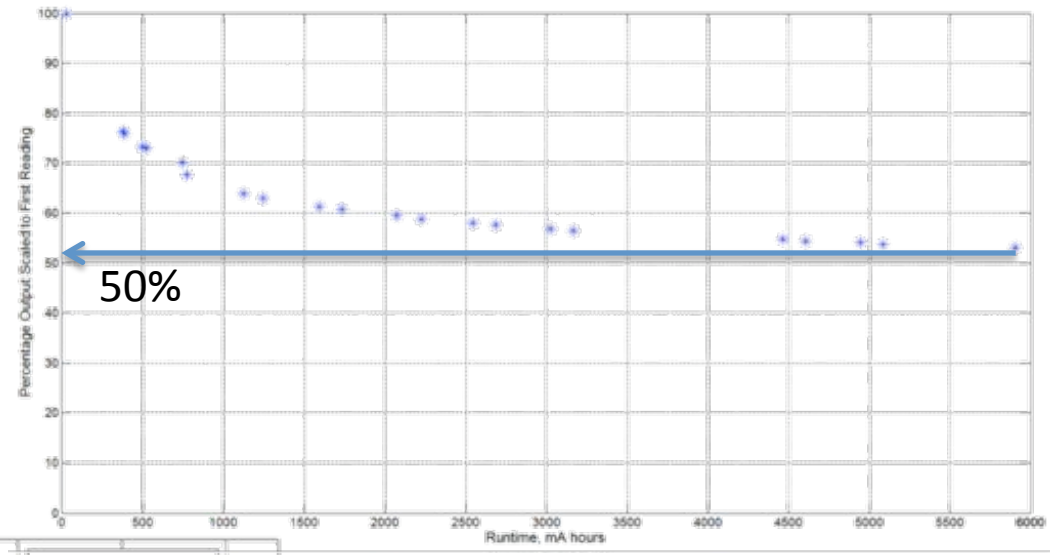
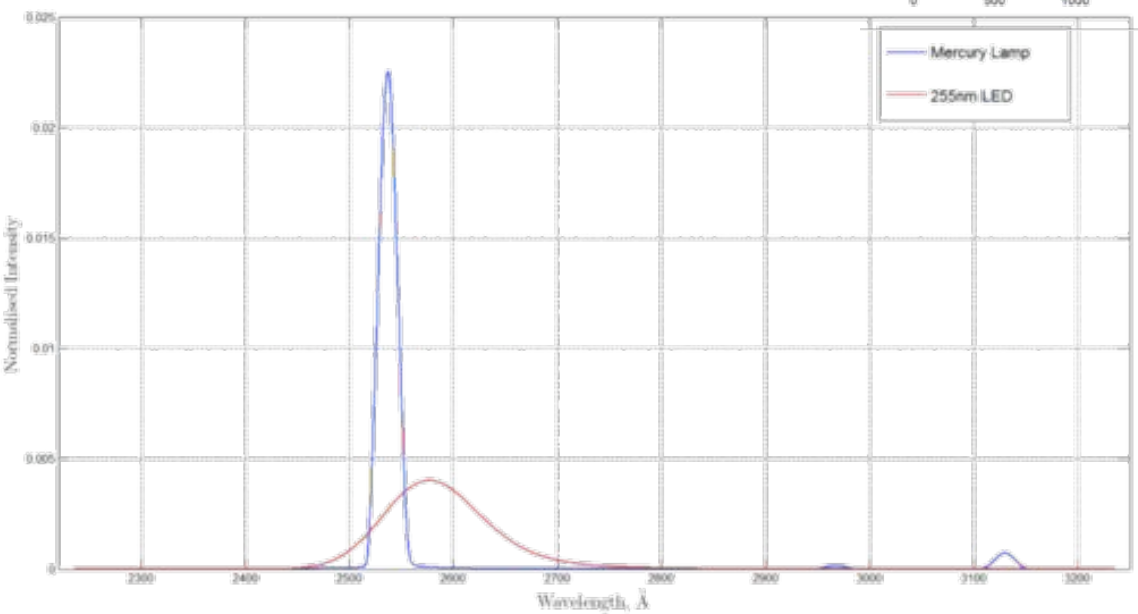
Testing UV LEDs

- Previous tests…
- 255nm LED
- DC operation
- Lifetime 1000s mA-hrs





- Relatively broad spectrum
- Not all light may contribute to discharging
- Lower wavelengths may be advantageous

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Testing UV LEDs

- Three commercially UV LED devices have been selected for detailed testing.
- Component testing underway
  - Spectral output
  - Power consumption
  - Temperature dependencies
  - Thermal vacuum
  - Vibration
  - Radiation
  - Lifetime

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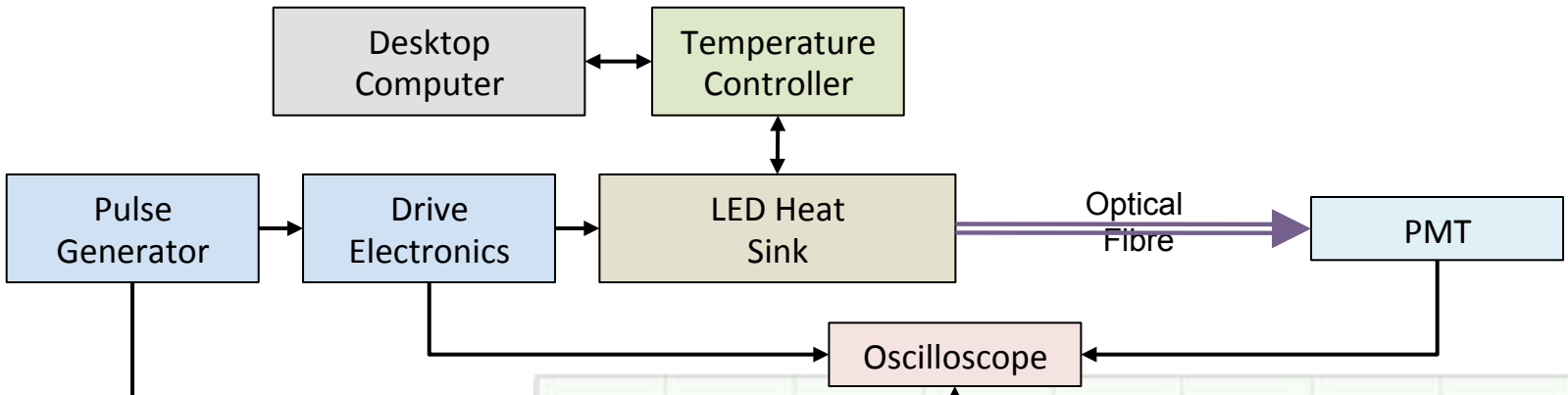
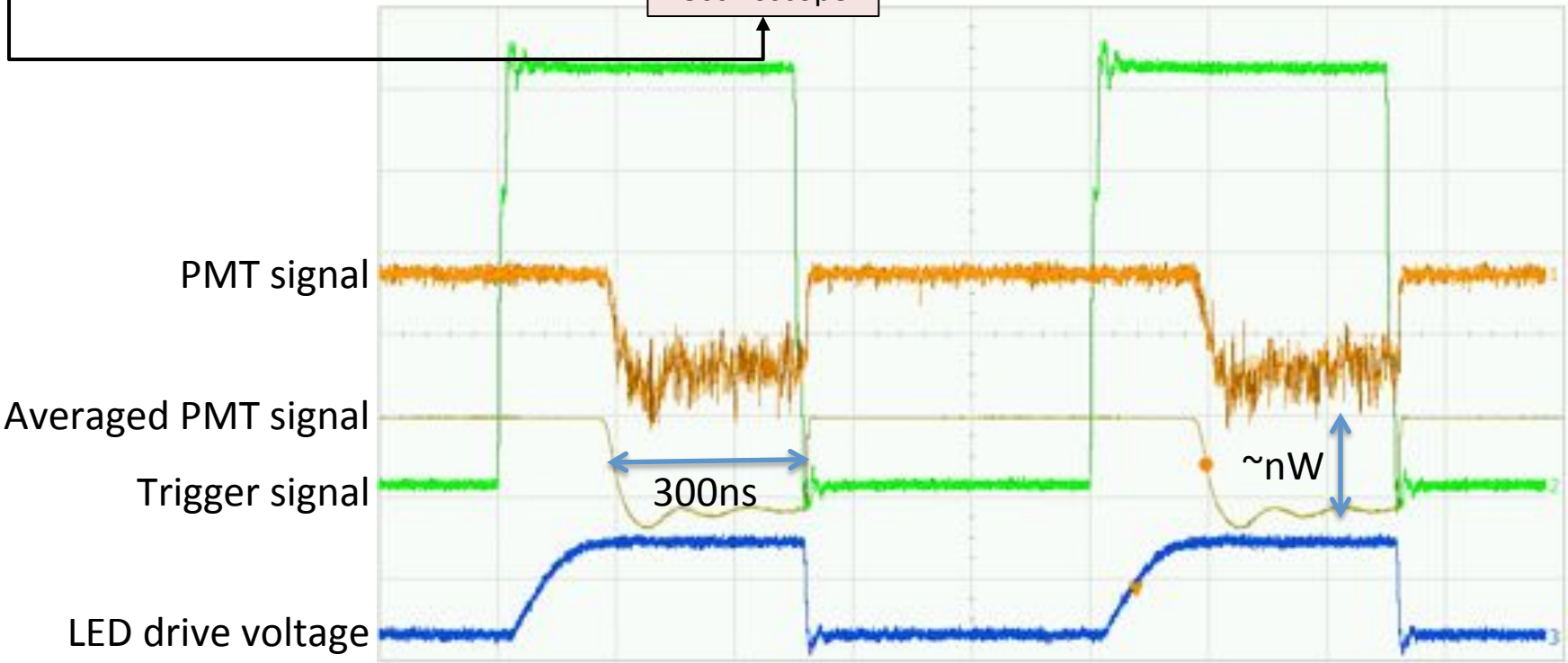
Testing UV LEDs





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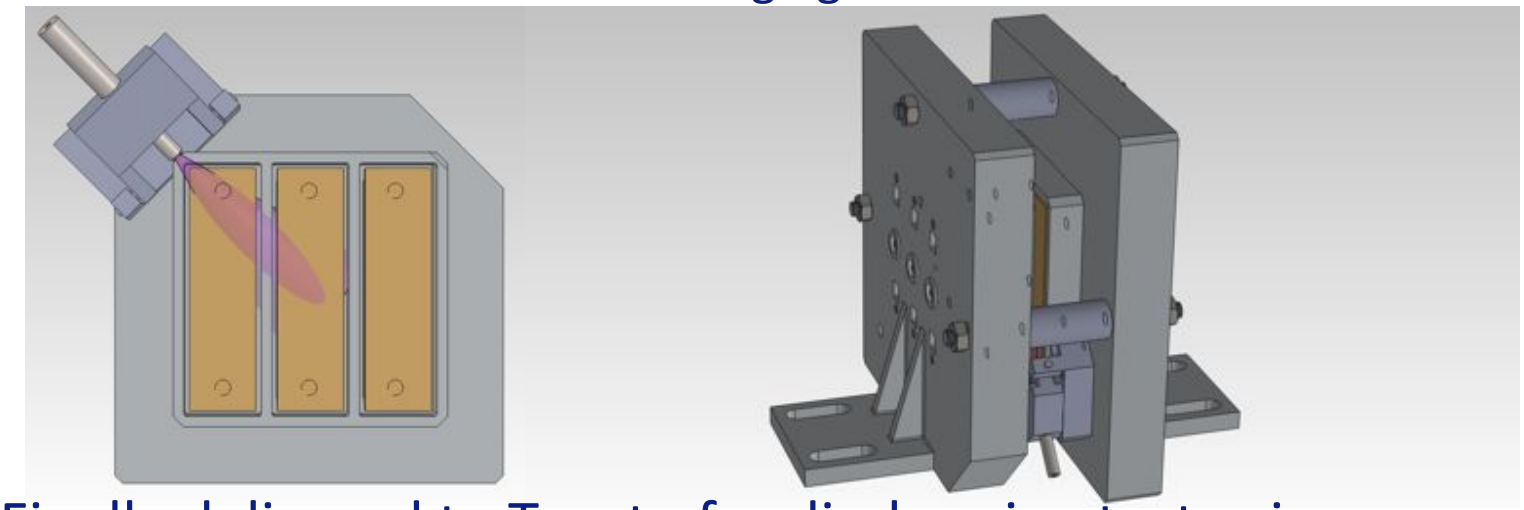
eLISA/NGO

- Breadboard electronics unit will be used with a sensor mockup to test discharging strategies
  - Synchronisation with AC voltages
  - Investigate surface cleaning/contamination effects
  - Test software model of discharging



- Finally delivered to Trento for discharging test using a representative TM and sensor

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Summary

- Understanding of the discharge process has improved
- Strategies have been defined to increase robustness
- Implementation is underway
- LISA pathfinder hardware ready for flight
- New technology for eLISA/NGO looks promising