

15TH LISA SYMPOSIUM
LISA INSTRUMENTATION

JULY 8 – 12, 2024



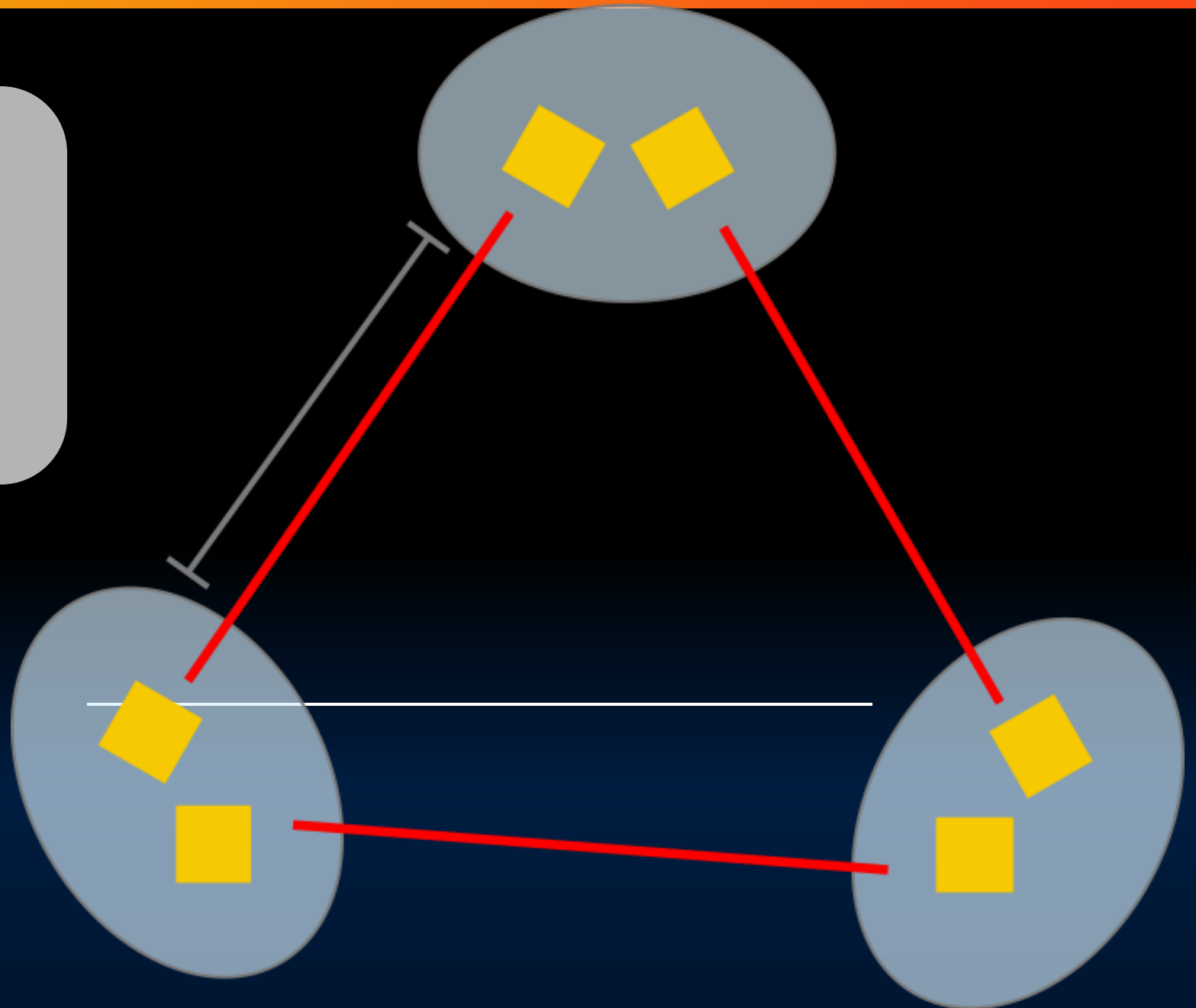
Charge Management – Verification Testing and Flight Hardware Development

Lea Bischof

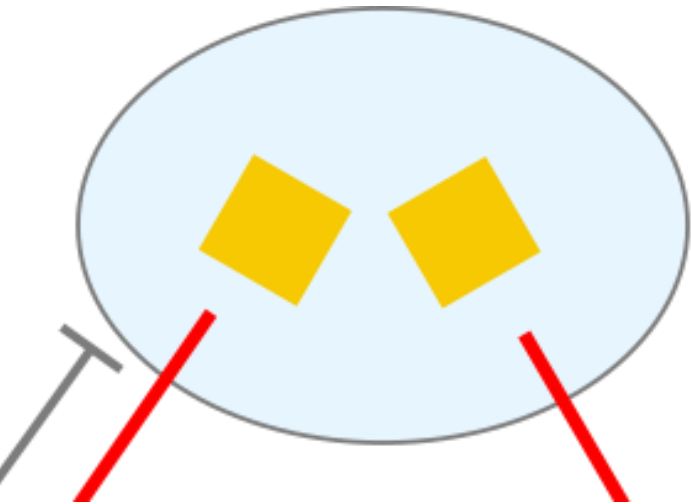
For the PSSL CMD-Team

*PRECISION SPACE SYSTEMS LABORATORY
MECHANICAL AND AEROSPACE ENGINEERING*

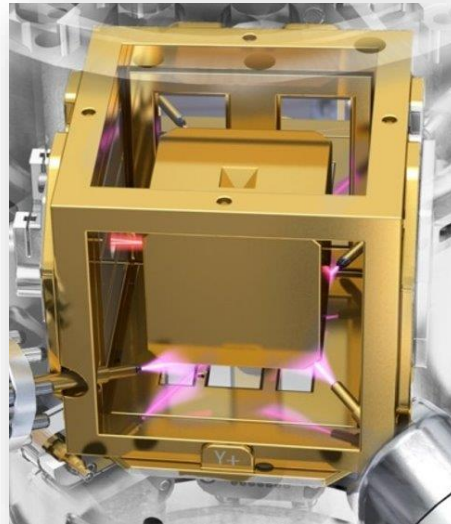
Acceleration noise
allocation
< $10 \text{ fm/s}^2/\sqrt{\text{Hz}}$
@0.1mHz



Electric charge build-up
On test masses
Requirement:
 $< 3\text{fm/s}^2/\text{sqrt}(\text{Hz})$
@0.1mHz



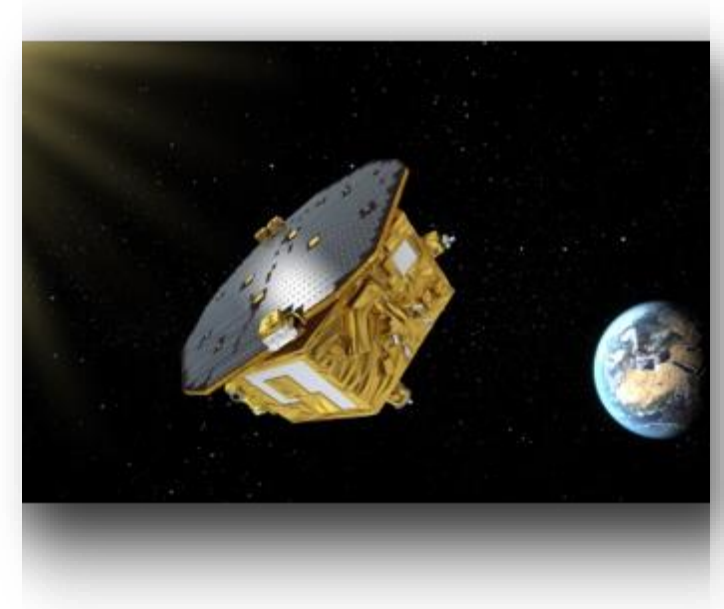
Solution:
- Photoelectric effect
- UV-light



☑ Successful in LISA Pathfinder

For LISA:
UV LEDs

- Lifetime
- Power consumption
- High bandwidth enables pulsed operation

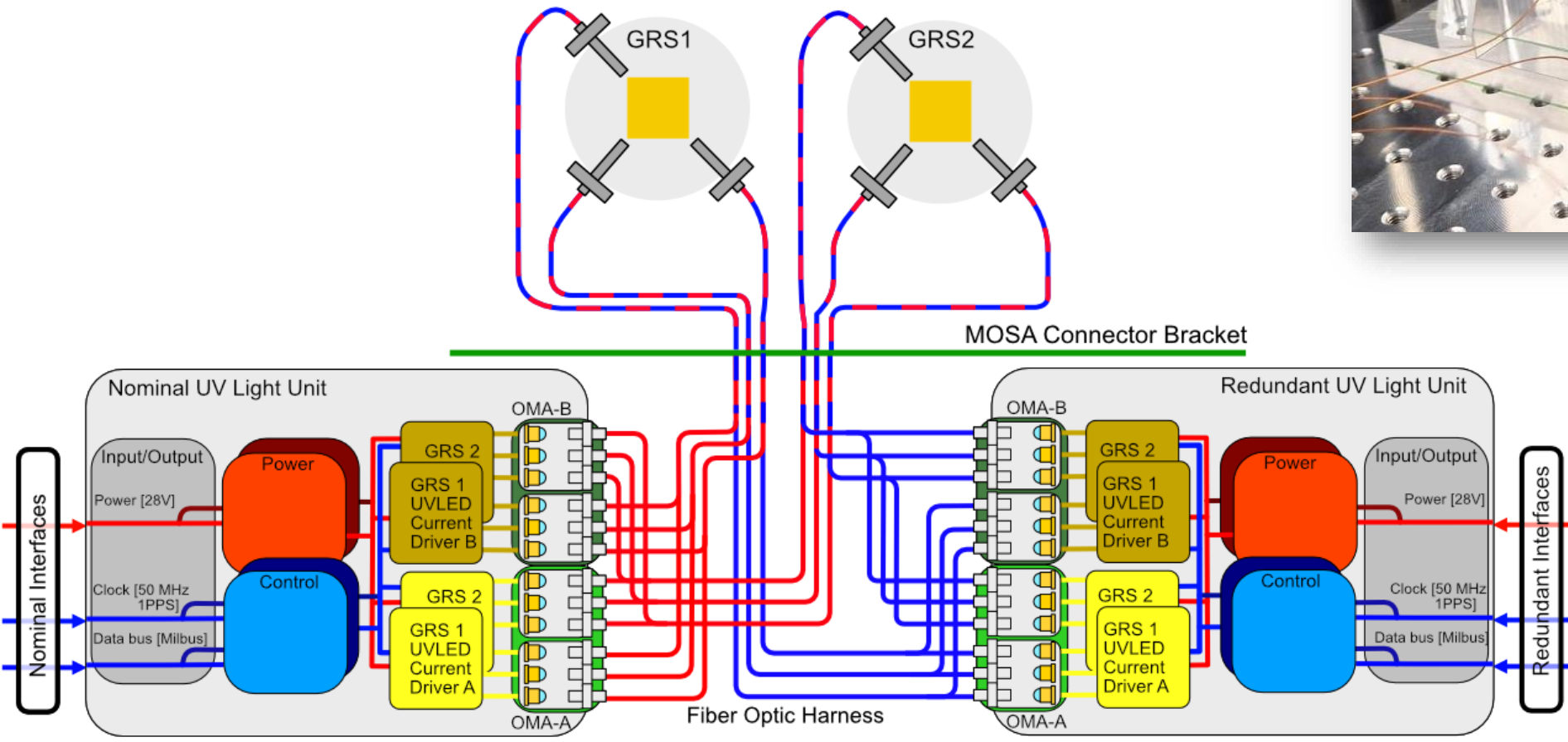
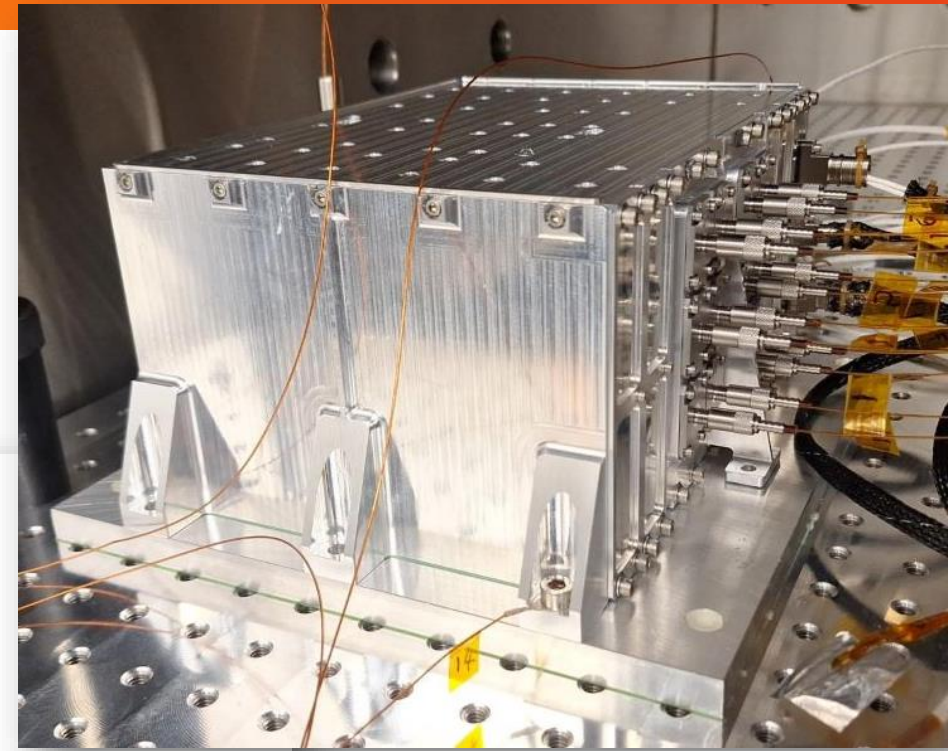


Charge Management Device (CMD)

UV Light Unit (ULU)

And

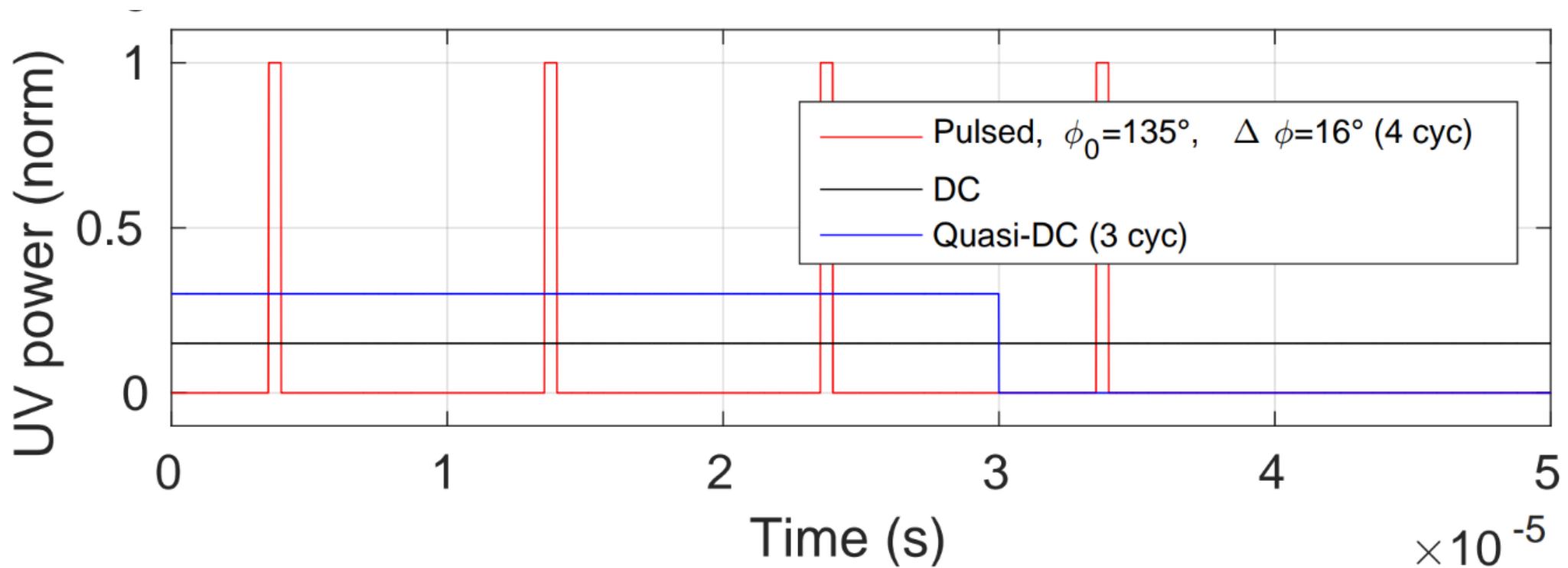
Fiber Optic Harness (FOH)



Requirement:

Control pulse parameters vs DC-mode

- Pulse width
- Amplitude
- Phase delay
- Number of pulses



Discharge Modes

Continuous

- No interruption in science mode

Requirements:

- Effective charging rate

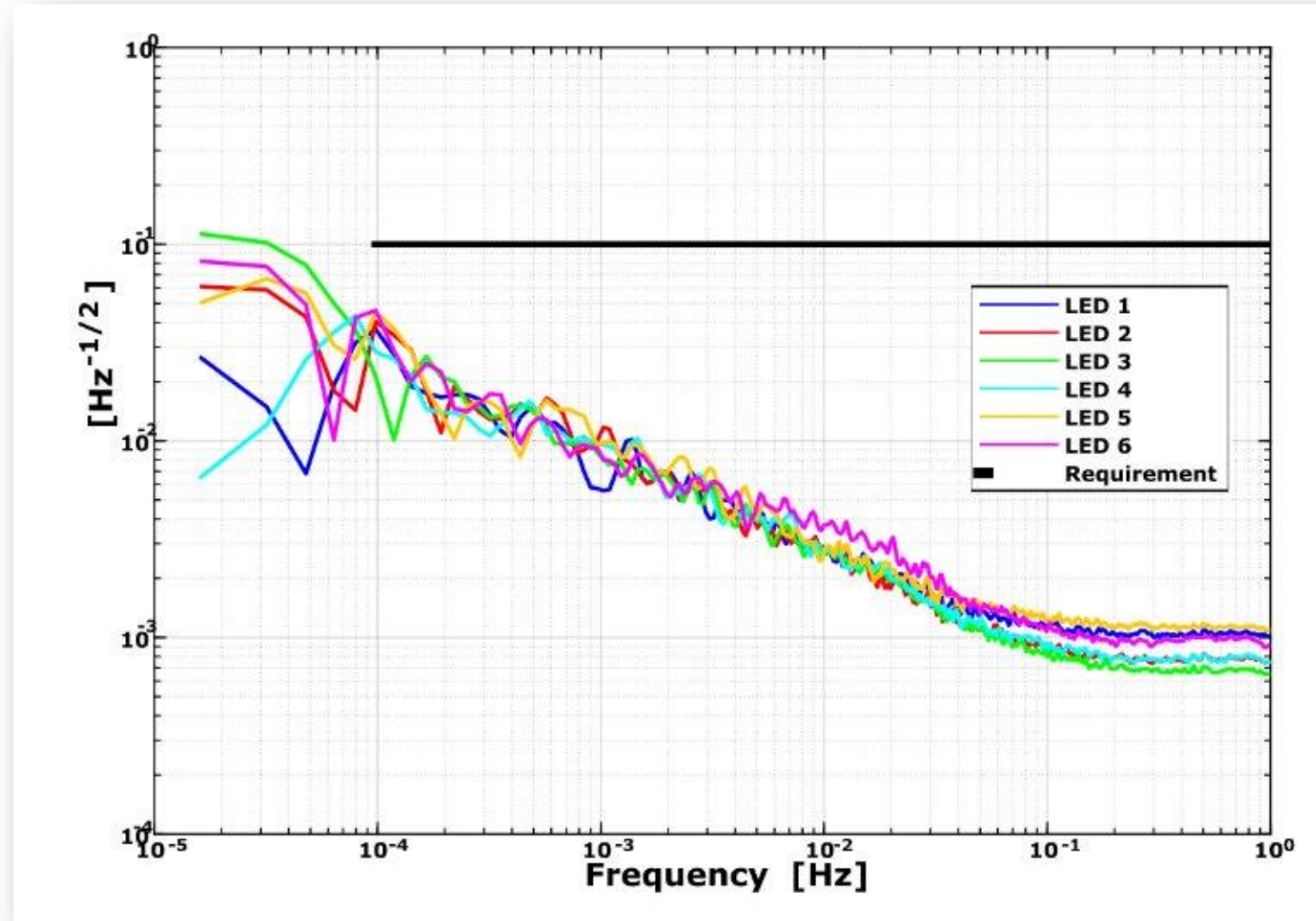
$$\lambda_{EFF}^{TOT} \equiv \lambda_{EFF} + \Delta\lambda_{EFF}^{UV} < 5000 \text{ e/s}$$

- 2000e/s environmental charging
- 3000e/s discharging
 - 50e/s power fluctuations
 - 300e/s phase fluctuations
 - Rest: photoelectron current shot noise

- LED light power stability:
relative: 0.1/sqrt(Hz)
- LED light phase stability:
7mrad/sqrt(Hz)
- Low power: down to 2nW

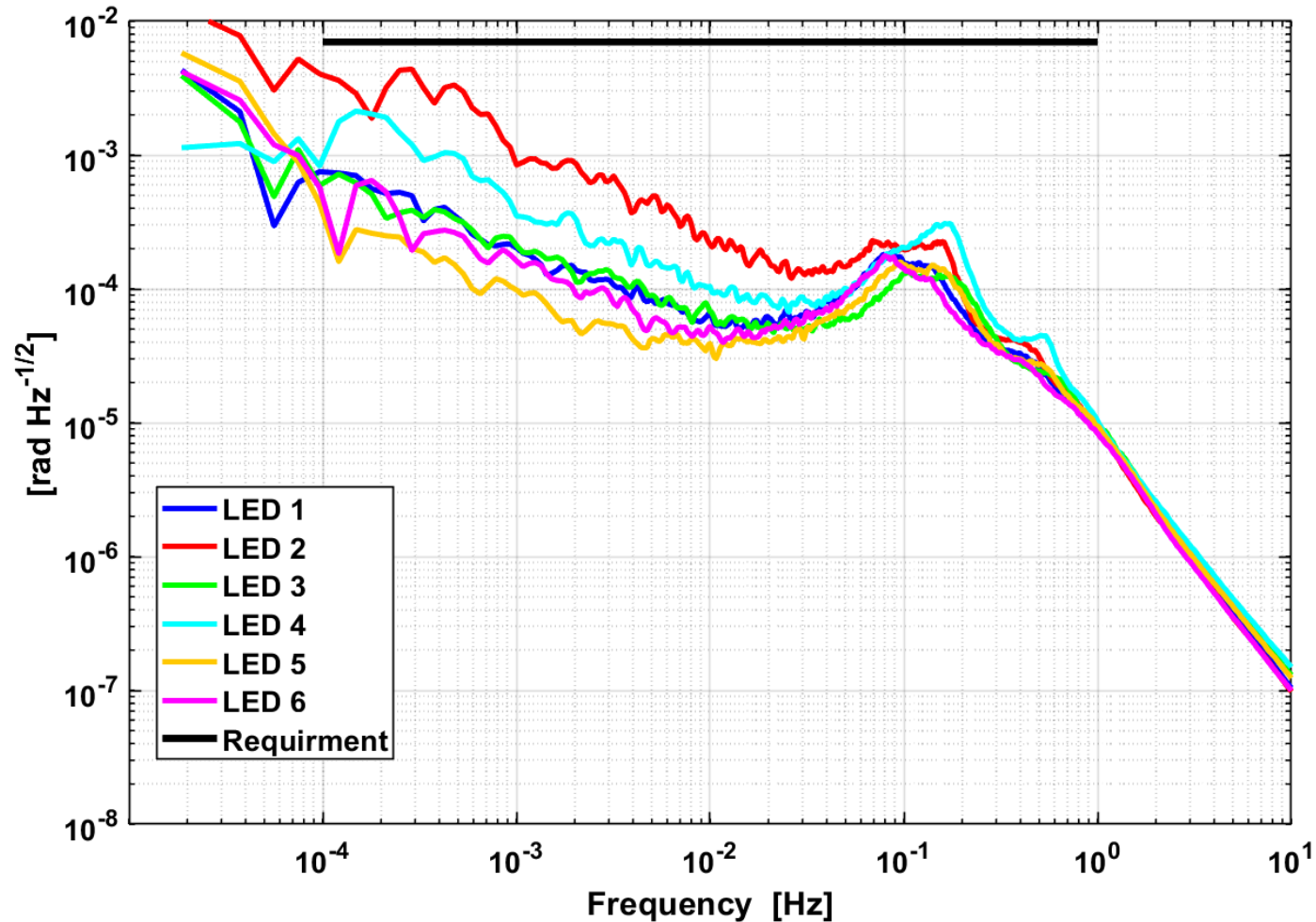
Performance Test – Pulsed Light Power Stability

- Relative stability of UV light power
- **Requirement: $0.1/\sqrt{\text{Hz}}$**
- Power Spectral Density (PSD) Recipe
ESA-LISA-EST-MIS-TN-0004
 - Blackman-Harris
 - 50% overlap
 - Lpsd-algorithm



Operation temperature 20°C

Performance Test – Pulsed Light Phase Stability



LTPDA 3.0.14.dev (R2023a), 2023-12-21 14:37:27.517 UTC, ltpda: 2423e80, Input_5

- Stability of UV light phase
- **Requirement:**
7mrad/sqrt(Hz)

Discharge Modes

Continuous

- No interruption in science mode

Intermittent

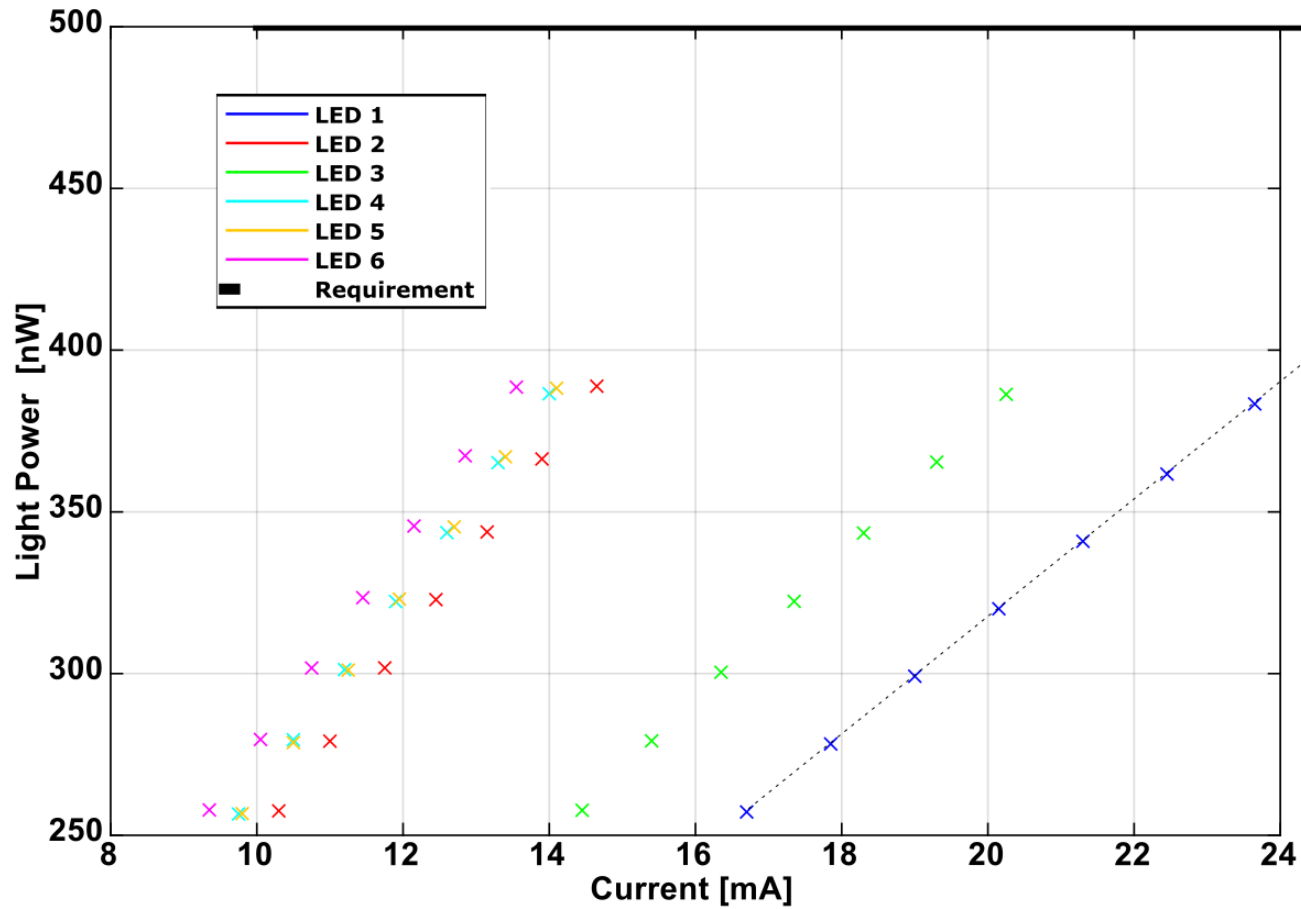
- Short interruptions and performance degradation
- Discharge from +1.5Me to -1.5Me in 600s

Requirements:

- High power: up to 500nW (quasi DC)
- High power: up to 125 nW (pulsed @ 10%)

Performance

maximal power in DC mode



- Required current unproblematic

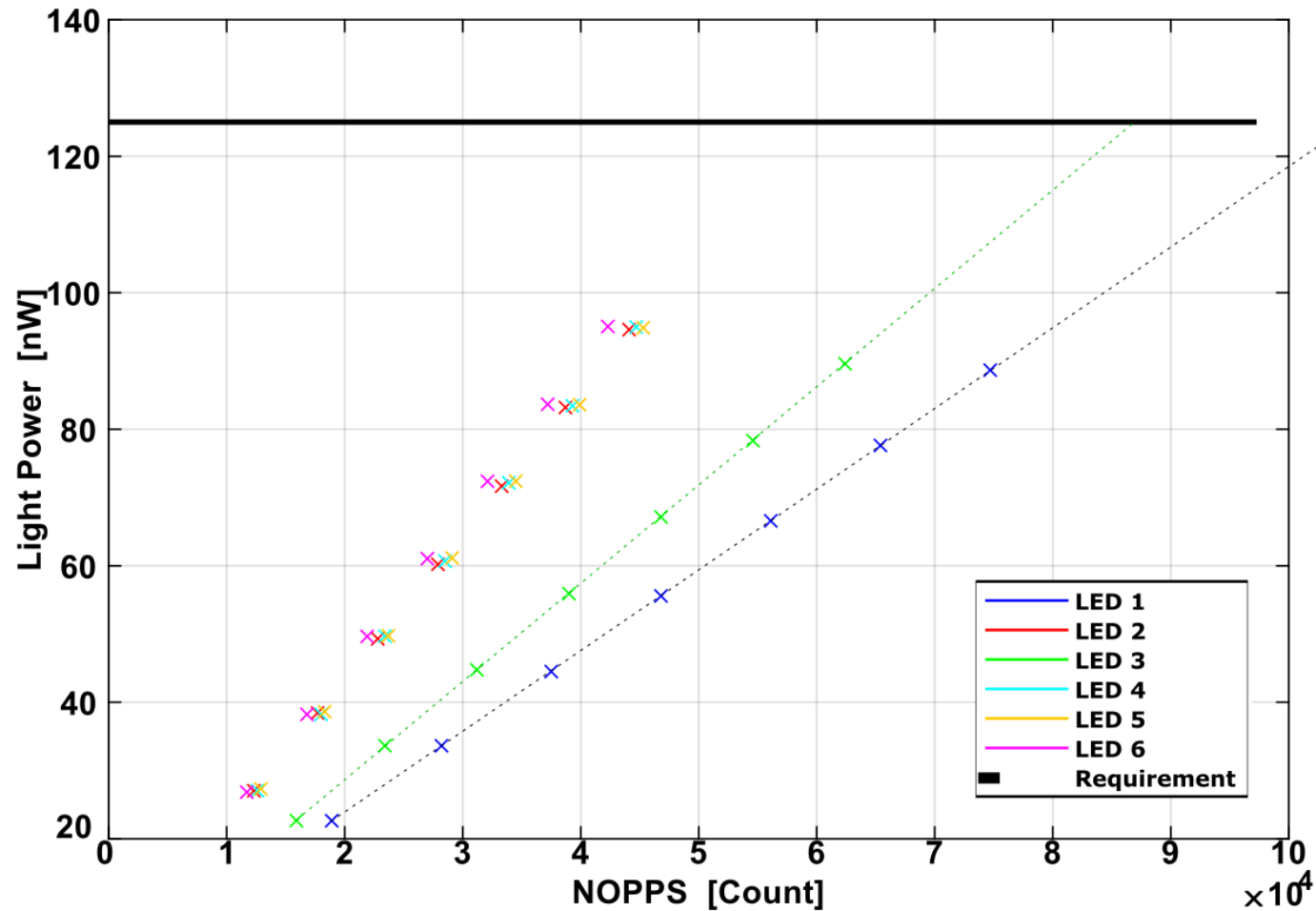
|
~30mA

LTPDA 3.0.14.dev (R2023b), 2024-06-28 13:23:25.264 UTC, ltpda: 2423e80, main

Operation temperature +20°C

Performance

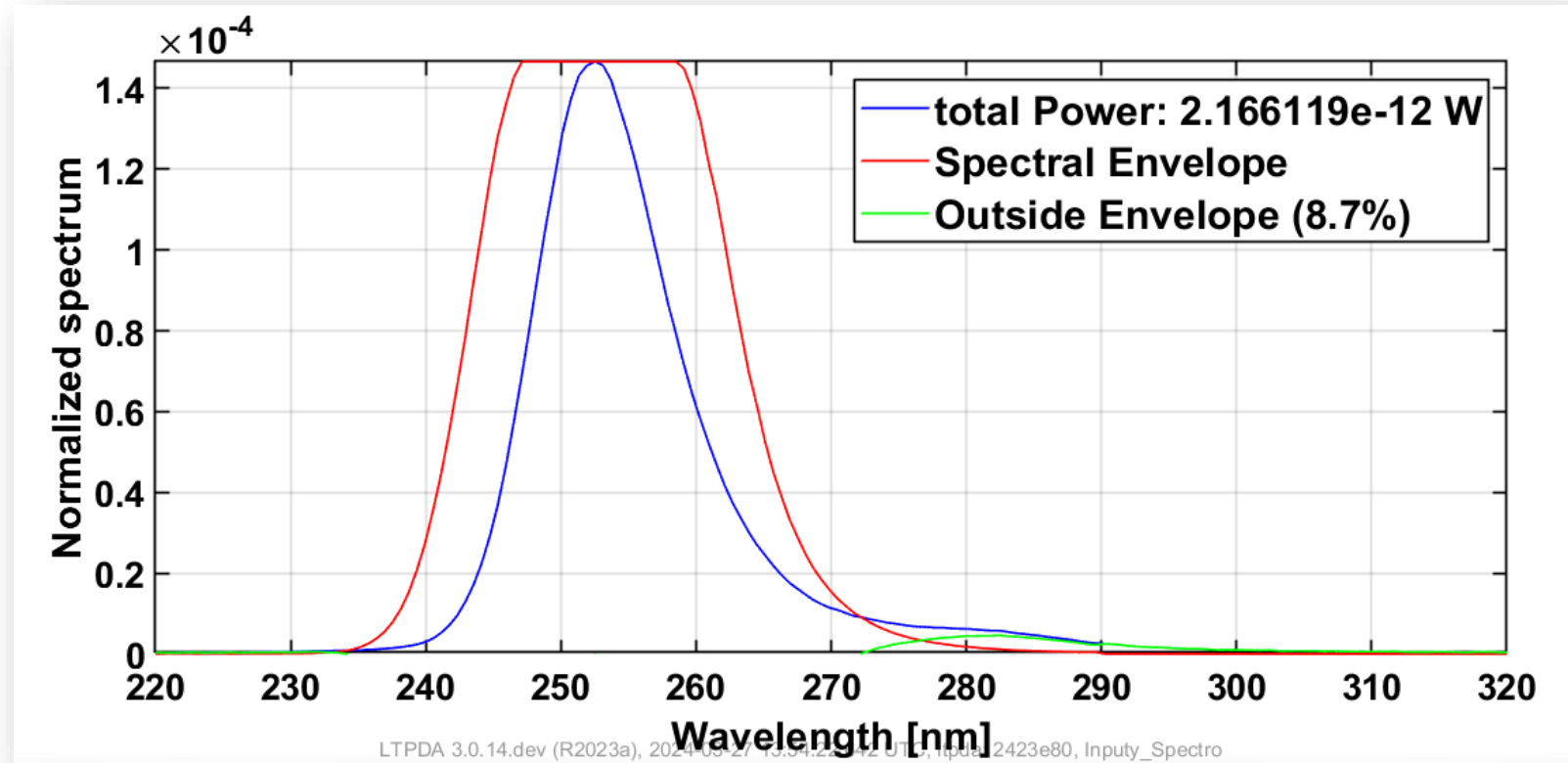
maximal power in pulsed mode



- Maximal Number of Pulses: 98304
- Pre-screening and careful selection of LEDs necessary!

Operation temperature +40°C

LED light spectrum



Air
Room Temperature

Charge management development

University of Florida

- UV Light Unit
 - TRL4 and TRL5
 - Fiber Optical Harness

Industrial partner Fibertek

- UV Light Unit TRL6

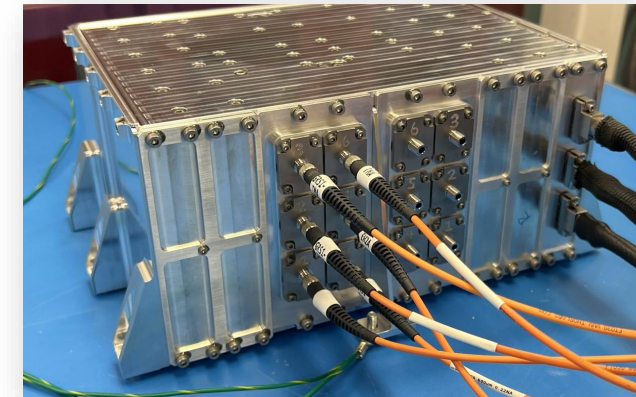


TRL5 Unit



B. Letson, PhD 2022

TRL6 Unit



Current activities

Technology Readiness Level 6 (TRL 6):

‘System[...] demonstration in a relevant environment (ground or space)’

<https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/>

- Launch environment: Vibration
- Mission environment: Temperature environment

- Thermal environment
 - min temperature -30°C
 - max temperature $+60^{\circ}\text{C}$

Verification

TRL6 for Fiber Optic Harness

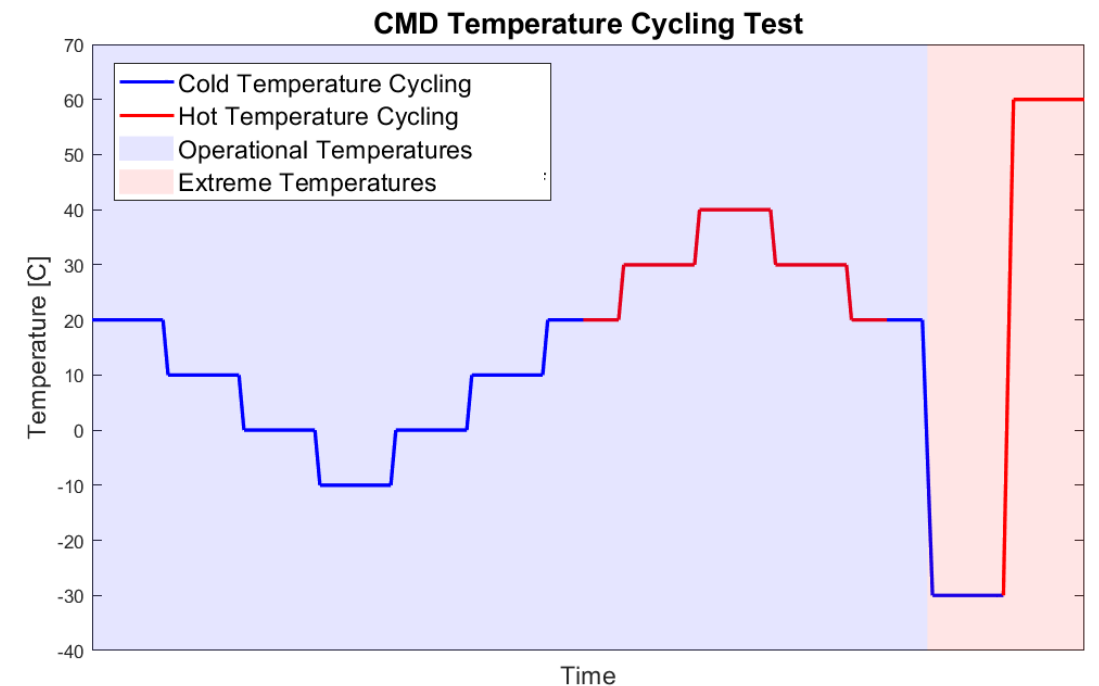
Vibration

- No significant transmission change



Temperature environment

- Extreme -30°C and +60°C
- Operational -10°C and +40°C
- No significant transmission change



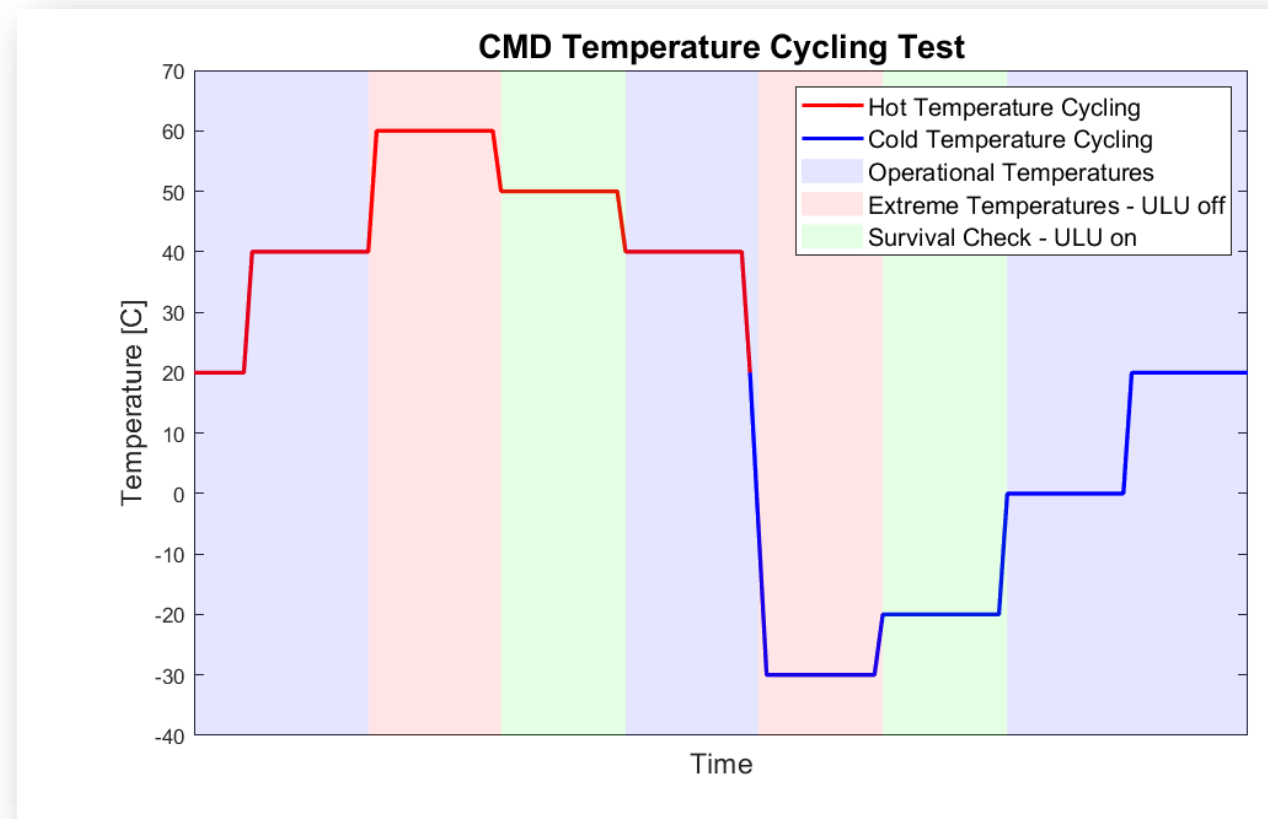
UV Light Unit

Environmental performance test - ongoing preparations

- Comprehensive Performance Tests at operational temperatures
- (+20/+40/0) [°C]
- Extreme Temperatures (+60/-30) [°C]
- Survival Check (+50/-20) [°C]



Charge Management - Lea Bischof



~10 weeks

Requirement: Environmental specifications

Radiation

LISA: dose at 3 mm Al equiv.

15 kRad (6.5 years)

20 kRad (12.5 years)

Tested at:

5, 10, 15, 20, 25, 50, 75, 150, 1000 kRad

Result:

Radiation hard

1/8 LEDs minor changes

7/8 LEDs no changes in spectra, power output or IV

Lifetime

LISA: Two Discharge modes

Intermittent: 21 days @ 500nW

Continuous: 10 years, low duty-cycle, @ 2nW

Tested for:

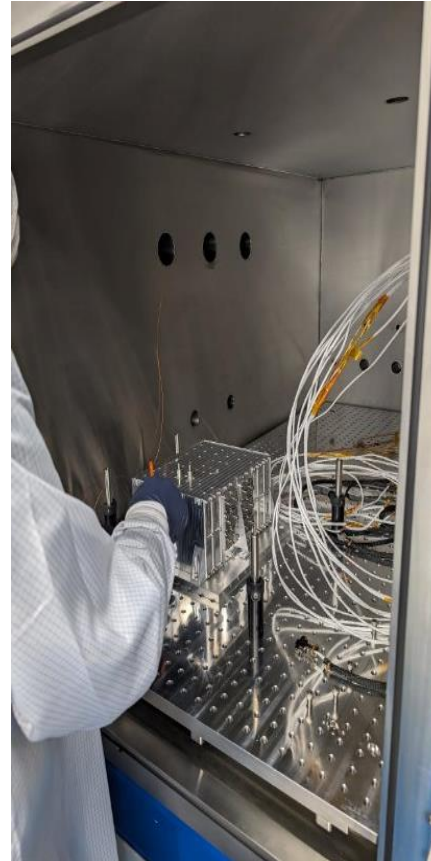
22 month

Result:

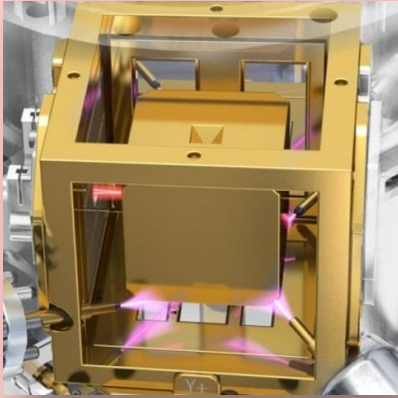
Understanding of relevant pre-screening parameters for LED selection

Test equipment at the University of Florida

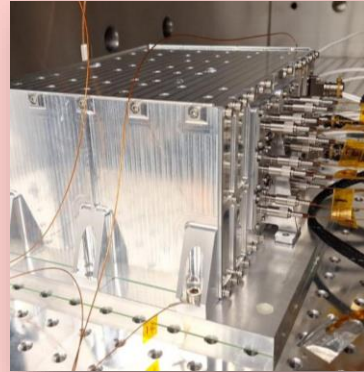
- Thermal vacuum chamber
- Cleaning facilities
 - Vacuum oven
 - Ultra-Sonic bath
- Flight-level cleaning procedure by Fibertek
- Racks provide test equipment for
 - TRL6 requirement verification
 - Flight requirement verification



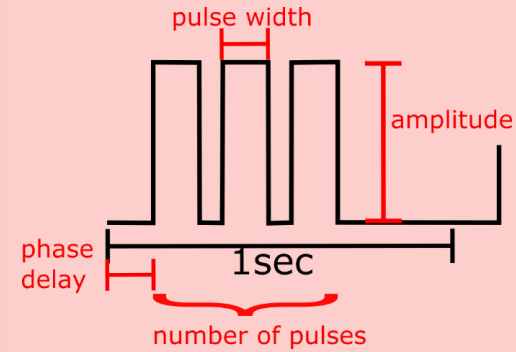
Charge Management in LISA



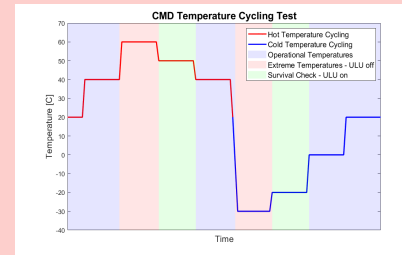
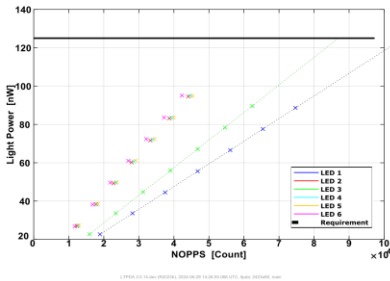
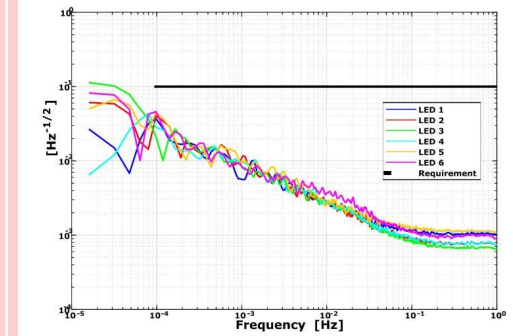
UV Light Unit



Pulsed control



Charge noise requirements

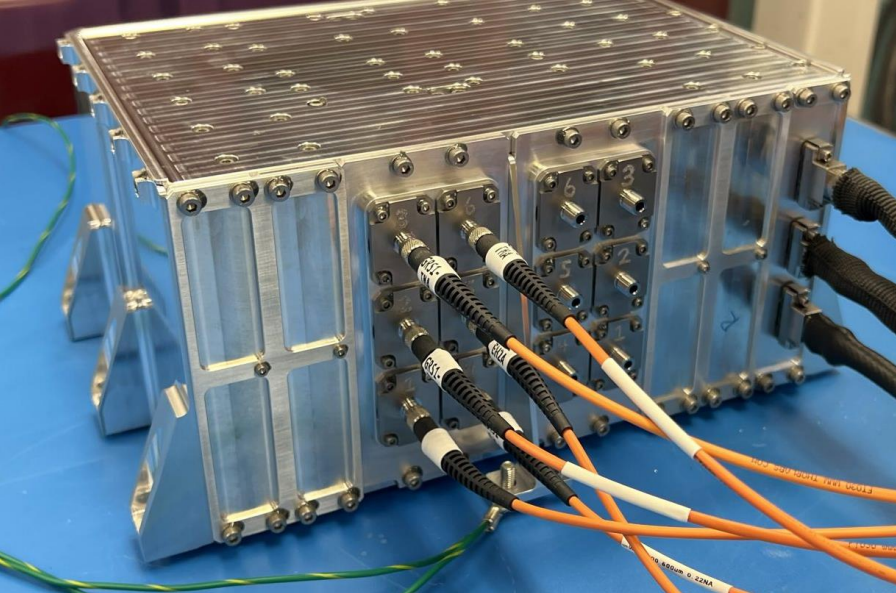


UV output power requirements

TRL6 measurements for Fiber Optic Harness

Environmental test campaigning for UV Light Unit

Test facilities at University of Florida



Thank you!

Precision Space Systems Laboratory
(PSSL)

University of Florida

CMD-Team

Lea Bischof



Related PSSL Presentations:

P147: Characterization of the LISA Fiber Optic Harness
C. Richardson

T21: Apparent Yield Measurements using a LISA-like Gravitational Reference Sensor and the University of Florida Torsion Pendulum
J. Siu

P144: End-to-end Multiphysics Simulation of the Photoelectric Charge Management for Free-falling Test Masses
B. Patel