

Testing Performance of Microbolometer Detector for Satellite Laser Ranging Application

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PROJECT OVERVIEW

- Assess the feasibility of using a microbolometer in an SLR as a replacement for current detectors.
- Evaluate models for atmospheric transmission.
- Assess the performance of microbolometers compared to other detectors across various metrics, such as beam divergence, atmospheric turbulence, and detector sensitivity, by utilizing an empirical Link Budget Equation.

Key Steps

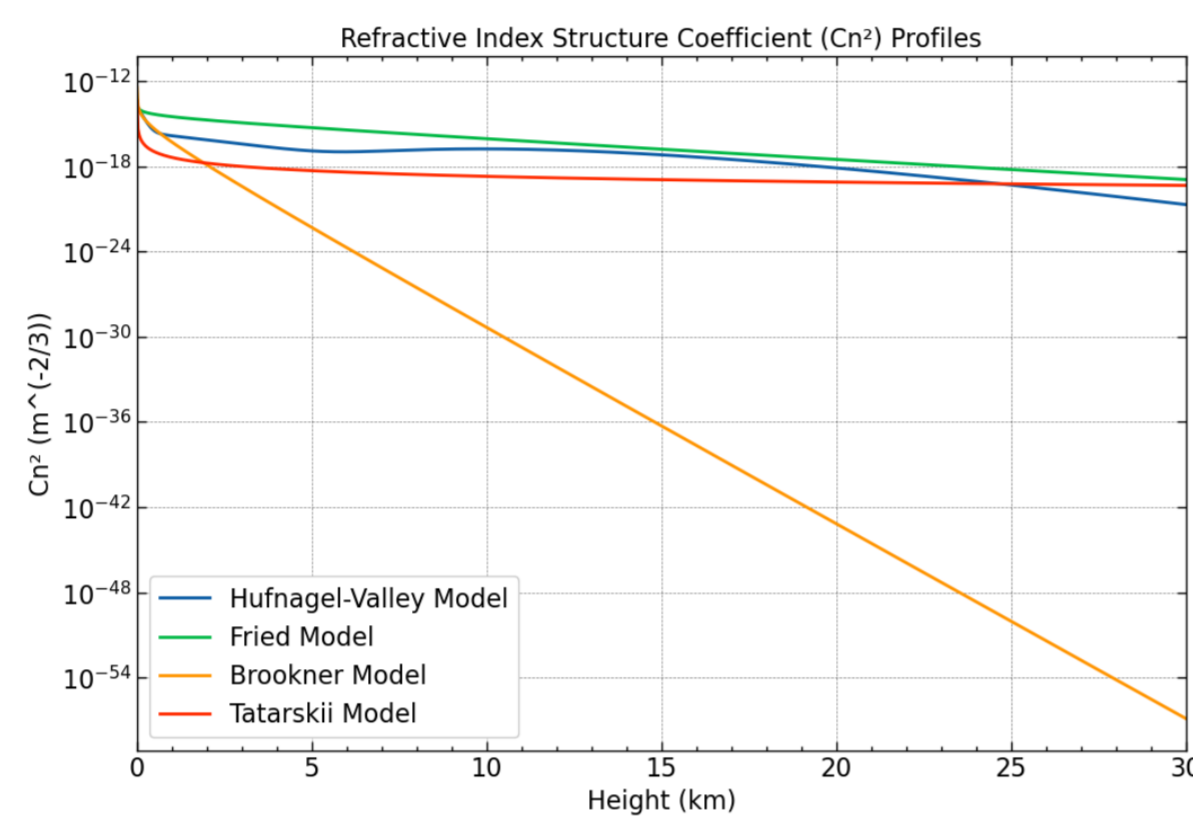
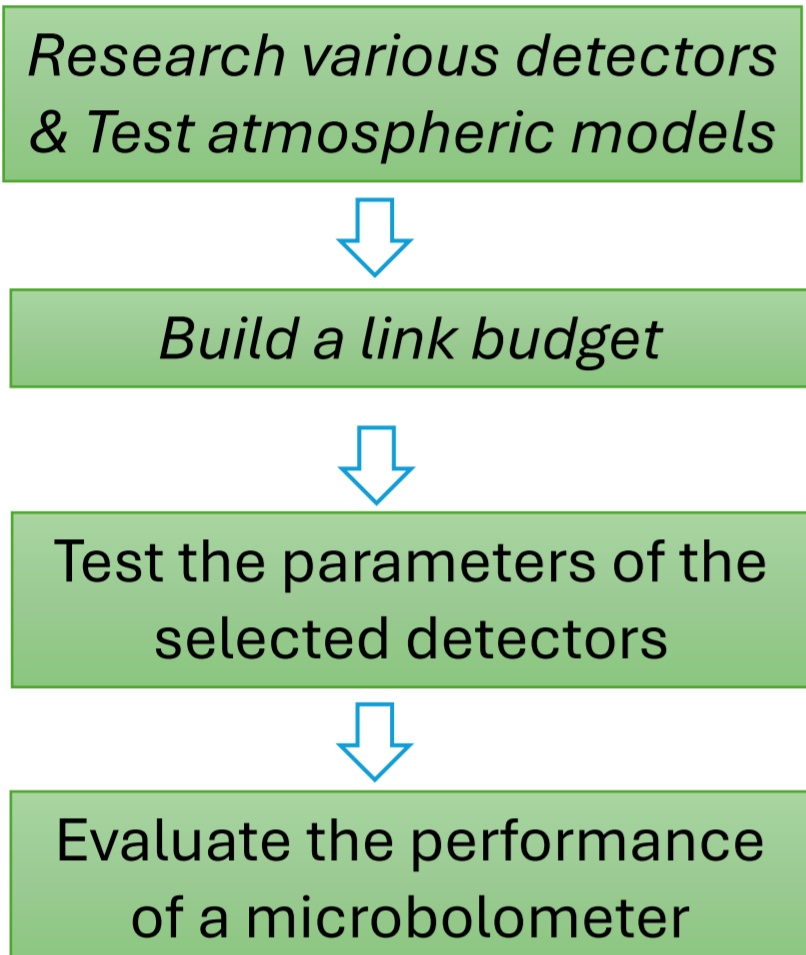


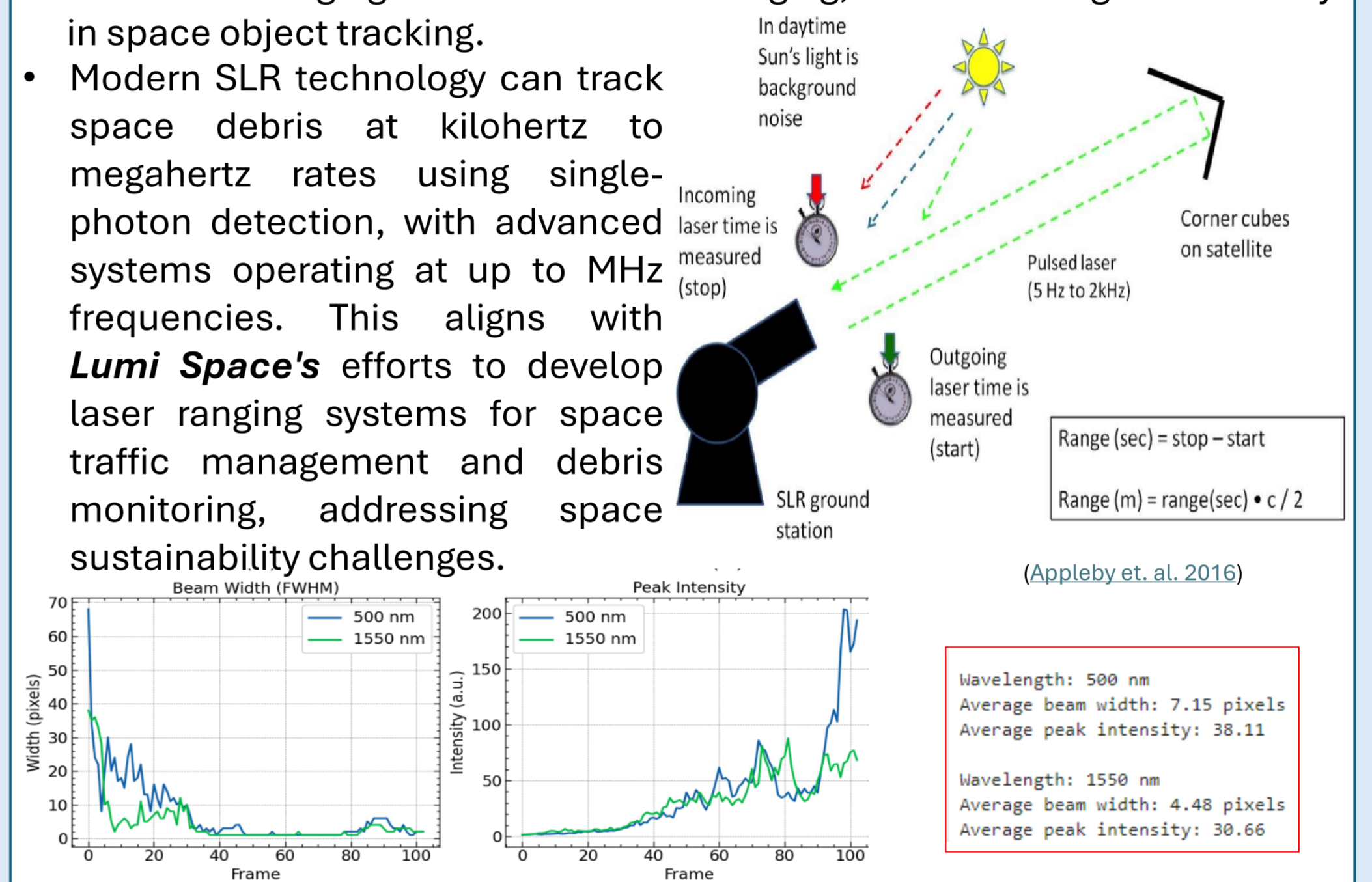
Table 8. Typical refractive index structure coefficient values for turbulence adapted from [47].

Turbulence Strength	Refractive Index Structure Coefficient, C_n^2
Strong	$C_n^2 = 5 \times 10^{-14} \text{ [m}^{-2/3}\text{]}$
Intermediate	$C_n^2 = 4 \times 10^{-16} \text{ [m}^{-2/3}\text{]}$
Weak	$C_n^2 = 8 \times 10^{-18} \text{ [m}^{-2/3}\text{]}$

(T.Fahey et al., 2021)

SATELLITE LASER RANGING STATION

- SLR stations use ultra-short laser pulses to measure the round-trip time to satellites with retroreflectors, providing millimeter-level precision for orbits up to 42,000 km altitude. This technology has been extended to lunar laser ranging and even asteroid ranging, demonstrating its versatility in space object tracking.
- Modern SLR technology can track space debris at kilohertz to megahertz rates using single-photon detection, with advanced systems operating at up to MHz frequencies. This aligns with **Lumi Space's** efforts to develop laser ranging systems for space traffic management and debris monitoring, addressing space sustainability challenges.



(Appleby et al., 2016)

Wavelength: 500 nm
Average beam width: 7.15 pixels
Average peak intensity: 38.11

Wavelength: 1550 nm
Average beam width: 4.48 pixels
Average peak intensity: 30.66

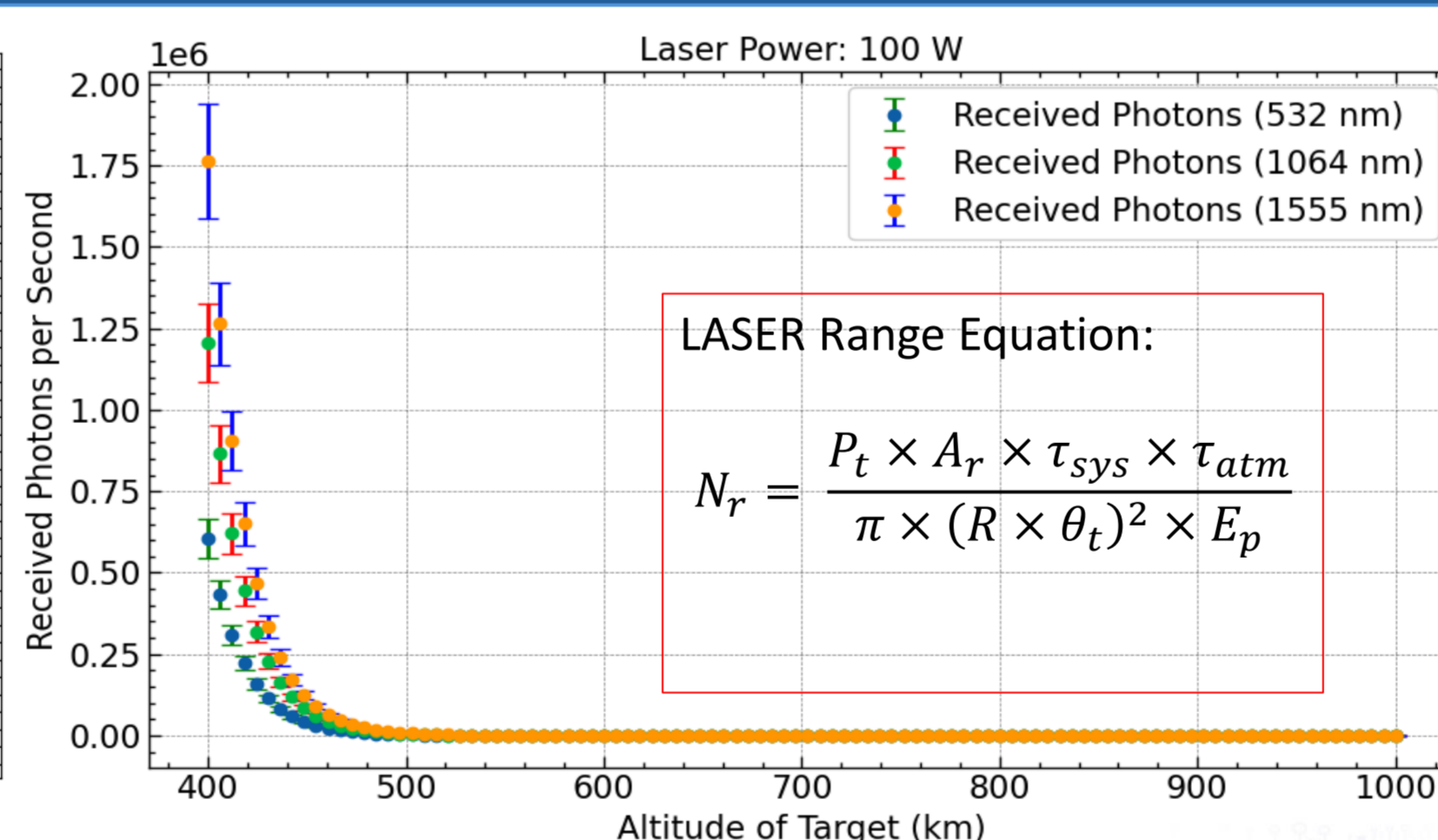
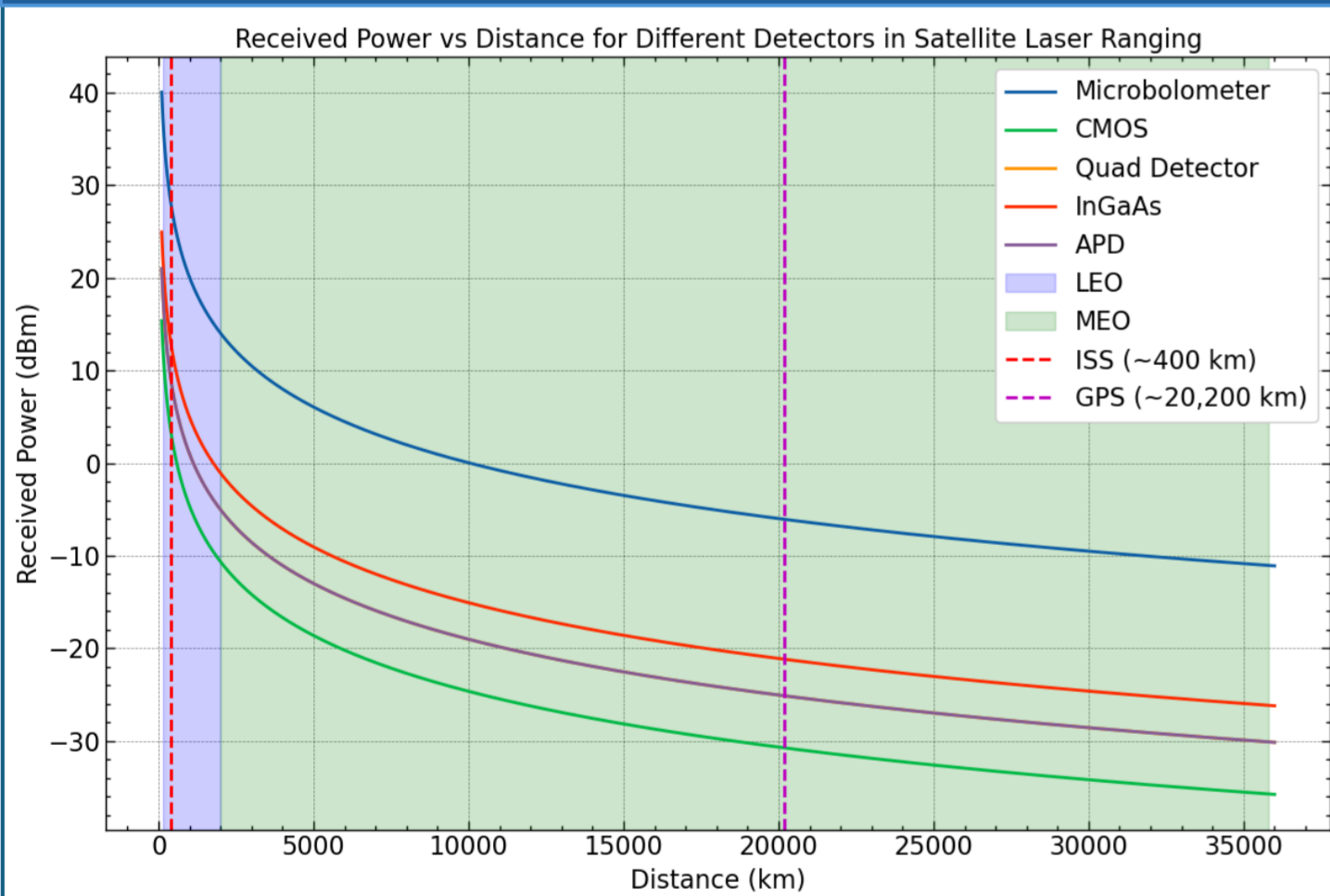
LINK BUDGET

Input

$$N_{pe} = N_t \cdot G_t \cdot \left(\frac{1}{4\pi R^2}\right)^2 \cdot \sigma \cdot A_r \cdot \tau_r \cdot \tau_t \cdot n_q \cdot \tau_{filter} \cdot \tau_{atm} \cdot \tau_c^2$$

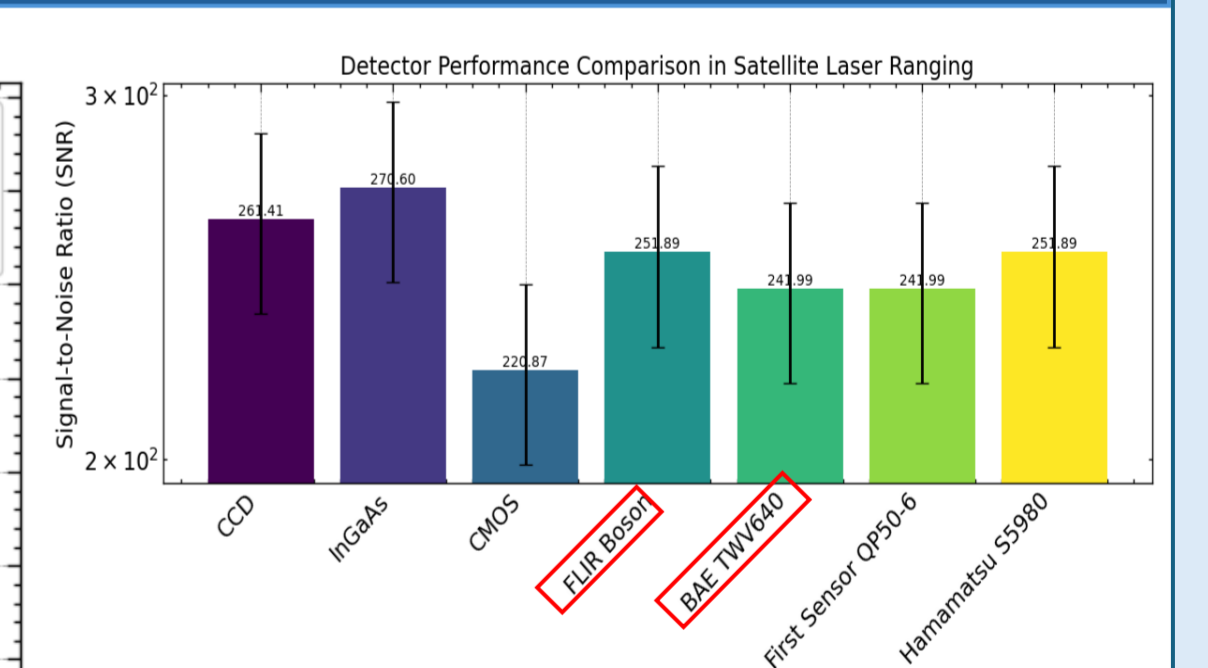
Output

RESULTS AND DISCUSSION



LASER Range Equation:

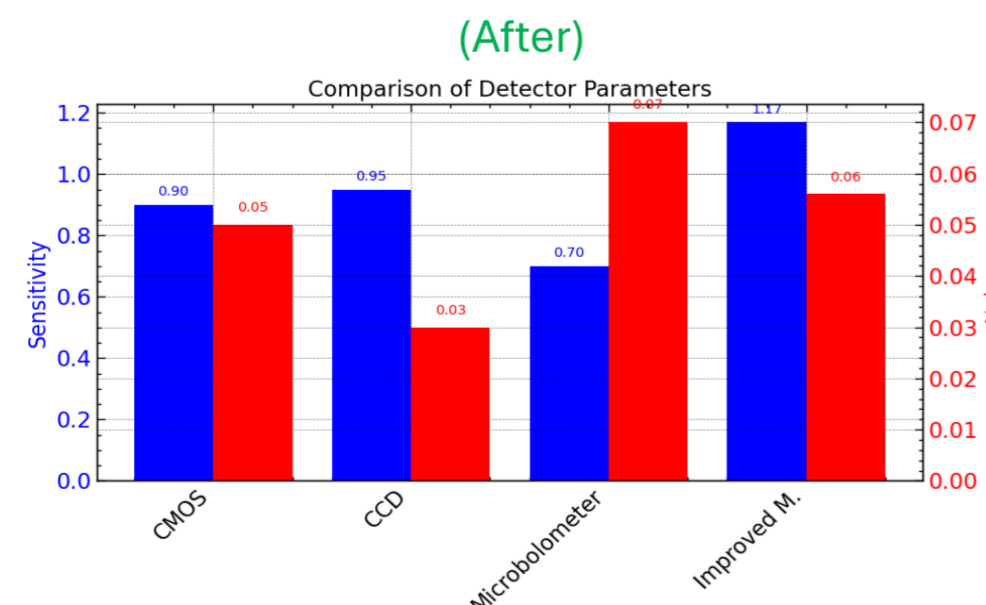
$$N_r = \frac{P_t \times A_r \times \tau_{sys} \times \tau_{atm}}{\pi \times (R \times \theta_t)^2 \times E_p}$$



Comparison with CCD and CMOS:

- CCD Detectors: High sensitivity, low noise, requires cooling.
- CMOS Detectors: Fast response, low power, noisier than CCDs.
- Microbolometers: No cooling needed, excels in IR detection, less sensitive in visible spectrum.

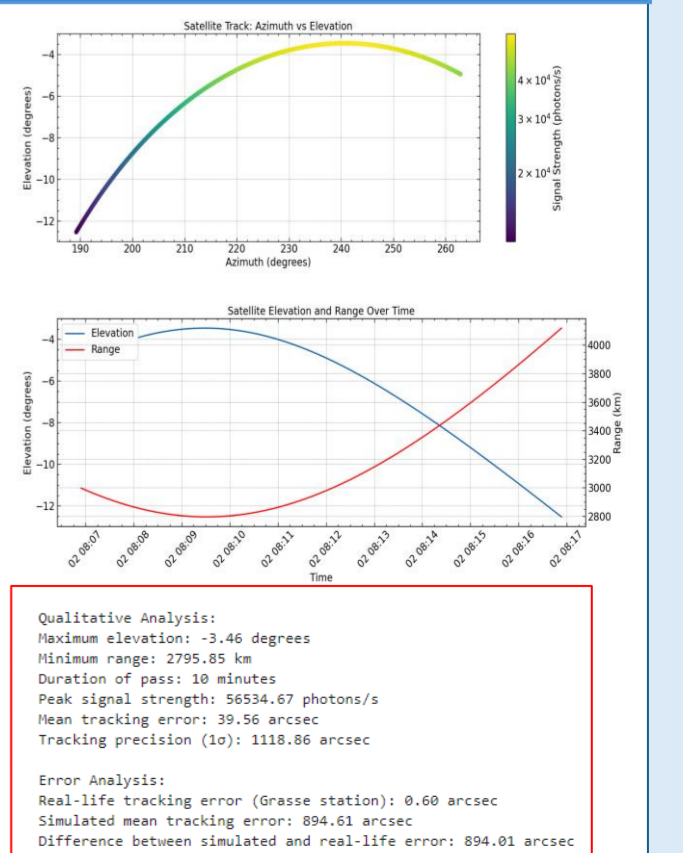
Detector Type	Received Power (dBm)	Carrier-to-Noise Ratio (C/N) (dB)
CMOS Detector:	-7.37	101.63
CCD Detector:	-7.13	103.87
Microbolometer Detector:	-8.46	98.54



- Optimize Operating Temperature:** Reduces radiated heat loss, enhancing performance.
- Material Selection:** High TCR materials like VOx and a-Si improve IR sensitivity.
- Infrared Optical Antennae:** Enhances detection by focusing IR radiation.
- Reduce Pixel Size:** Increases resolution but may affect NETD.
- Thermal Isolation:** Reduces thermal noise, improving SNR.
- Dynamic NUC Mapping:** Compensates for drift, improving stability.

CONCLUSION AND FUTURE WORK

- SLR systems track objects at various distances, including lunar ranges. Advanced models accounting for atmospheric effects are crucial for improving accuracy across all tracking distances.
- Microbolometers with **infrared optical antennas** and **high TCR materials** may potentially enhance SLR detection and IR sensitivity.
- Current tracking models require real-time improvements to achieve 1m accuracy for over 150,000 space debris objects as small as 1cm.



Qualitative Analysis:
Maximum elevation: -3.46 degrees
Minimum range: 2795.85 km
Duration of pass: 38 minutes
Peak signal strength: 56534.67 photons/s
Peak tracking error: 39.56 arcsec
Tracking precision (1σ): 1138.86 arcsec

Error Analysis:
Real-life tracking error (Grasse station): 0.60 arcsec
Simulated mean tracking error: 394.63 arcsec
Difference between simulated and real-life error: 894.01 arcsec

