Classical Communication To and From Space

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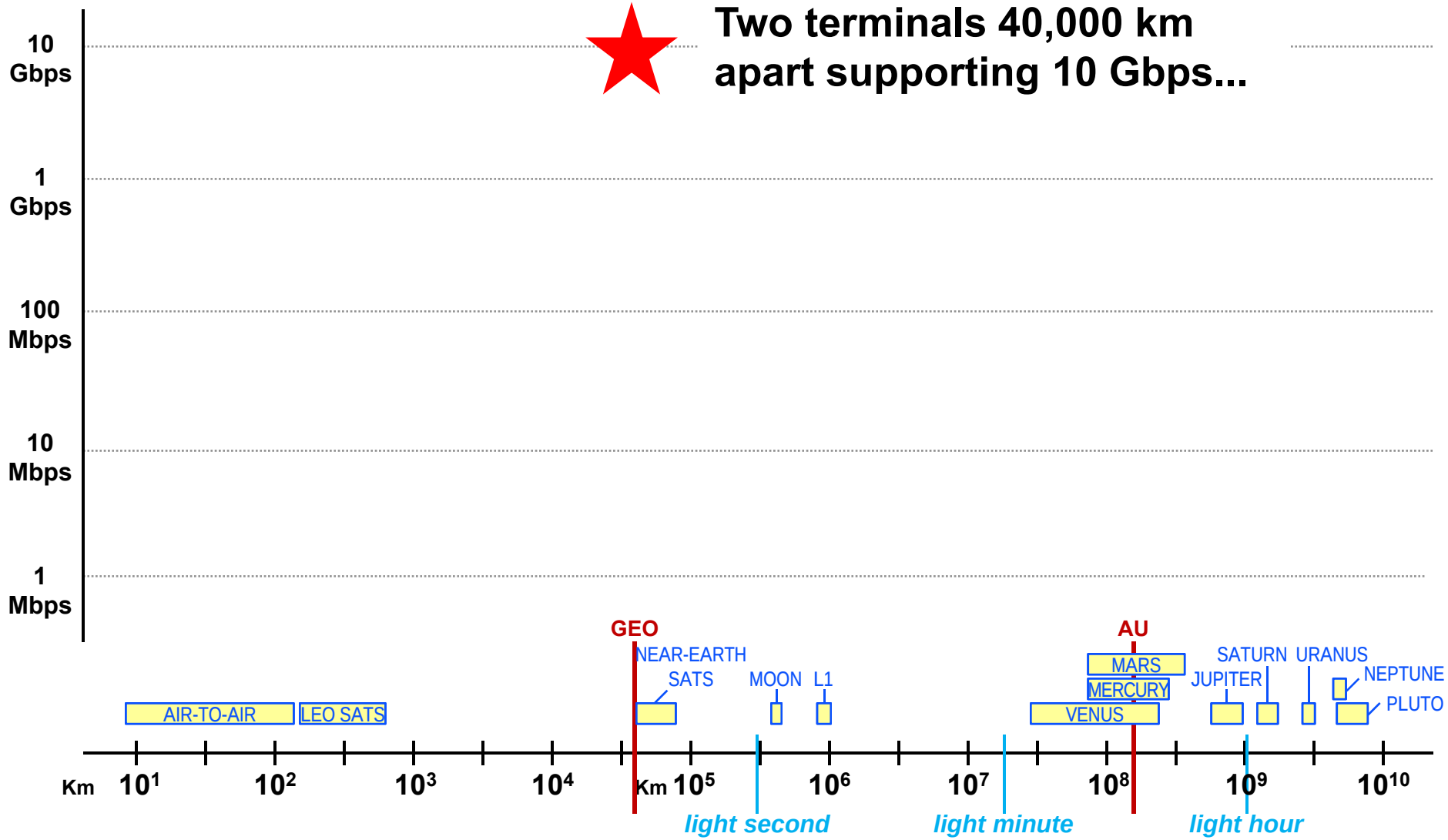
- Factoids
- Opportunities & challenges
- The technology
- An example

The Diffraction Limit



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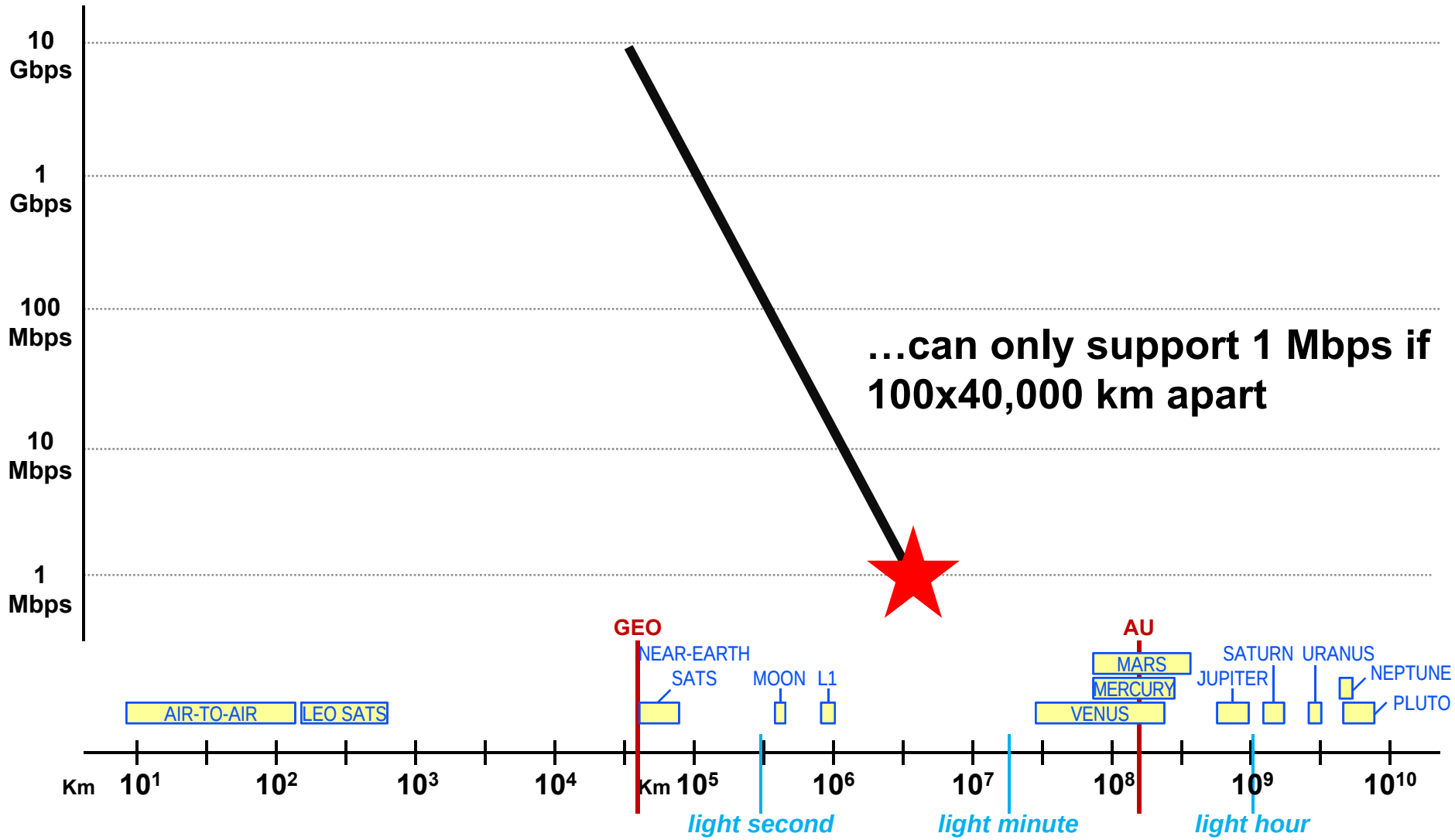
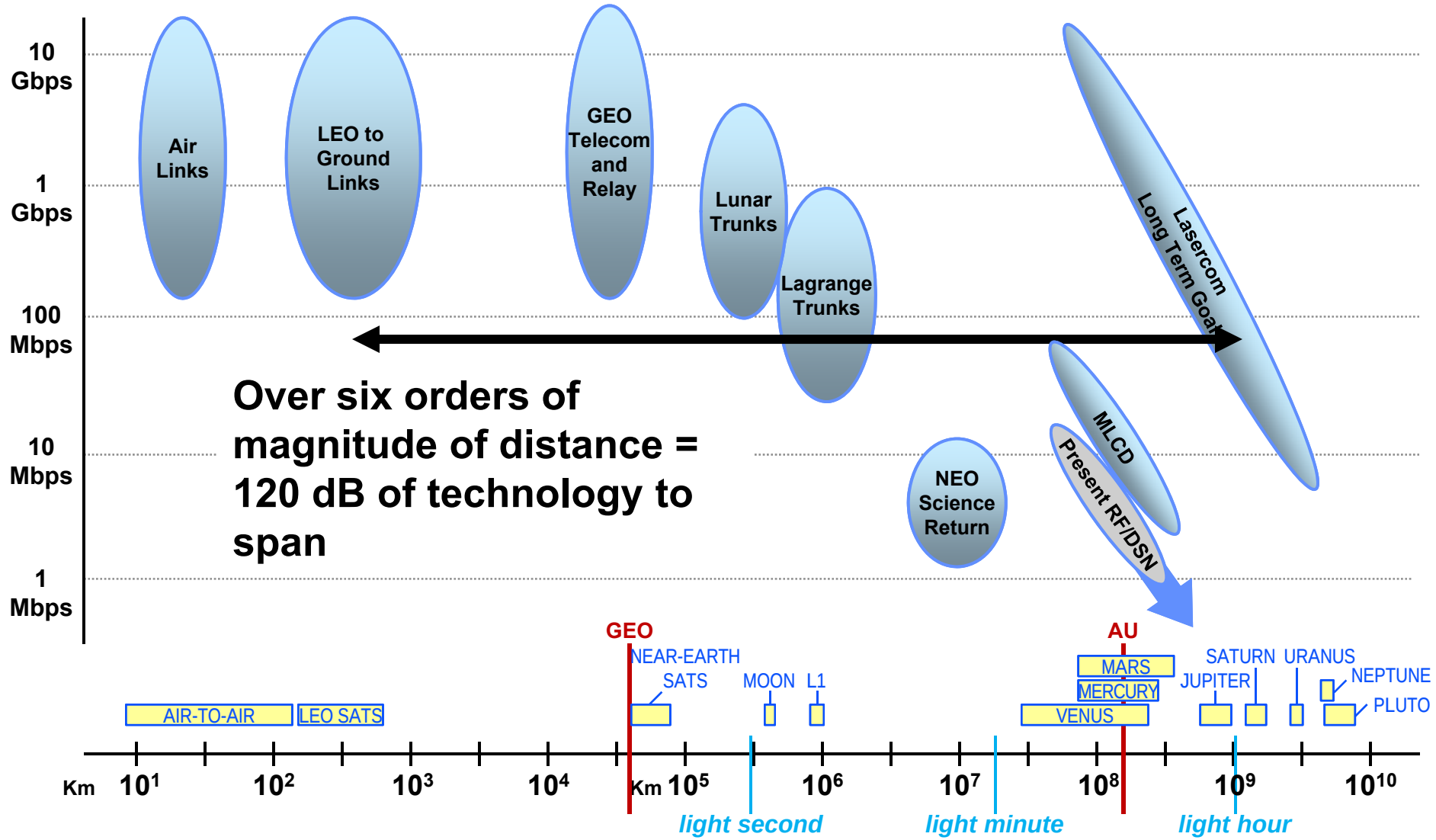


All the High-Rate Links Anyone Could Be Interested In (until we travel to the stars)



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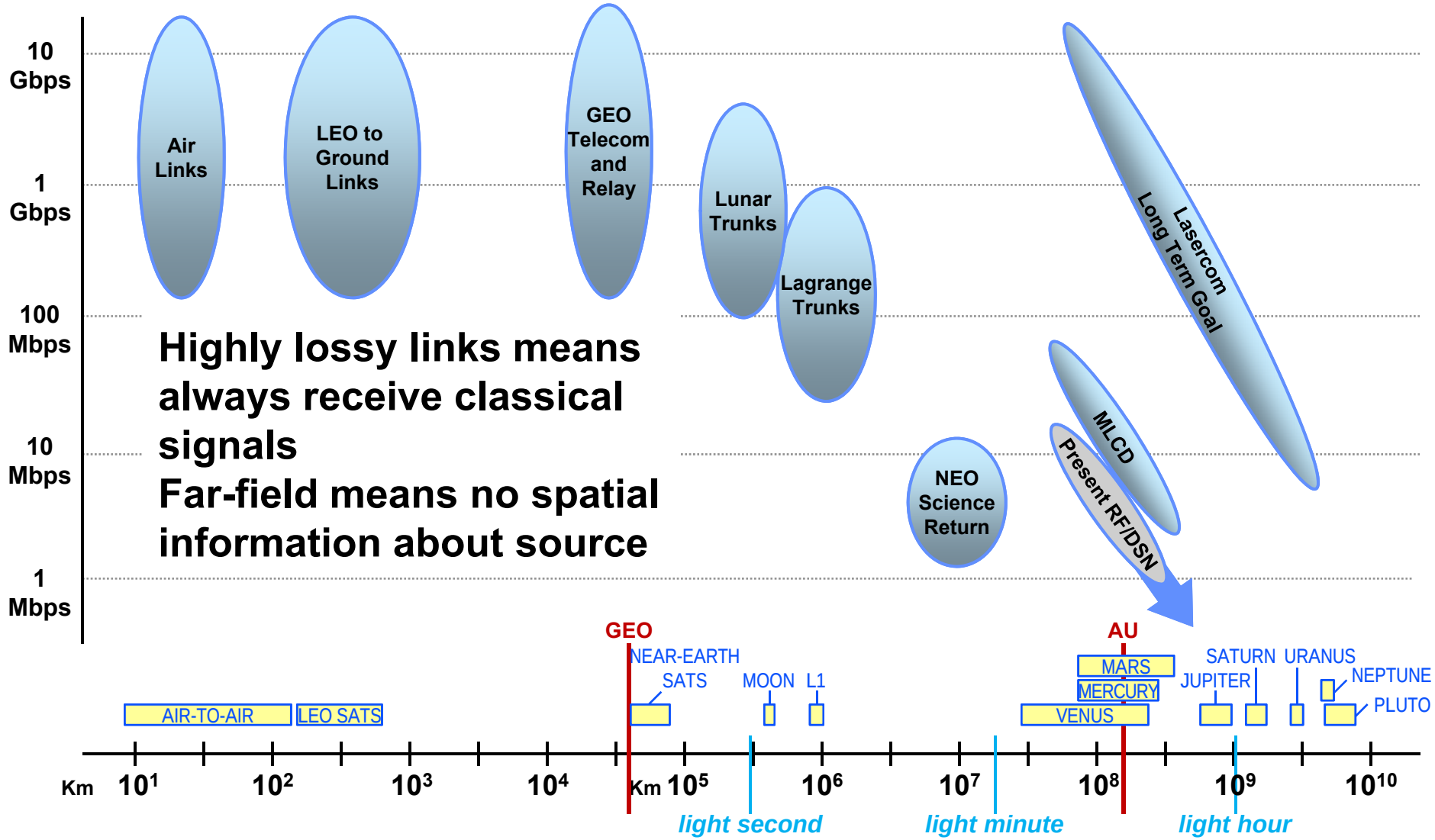
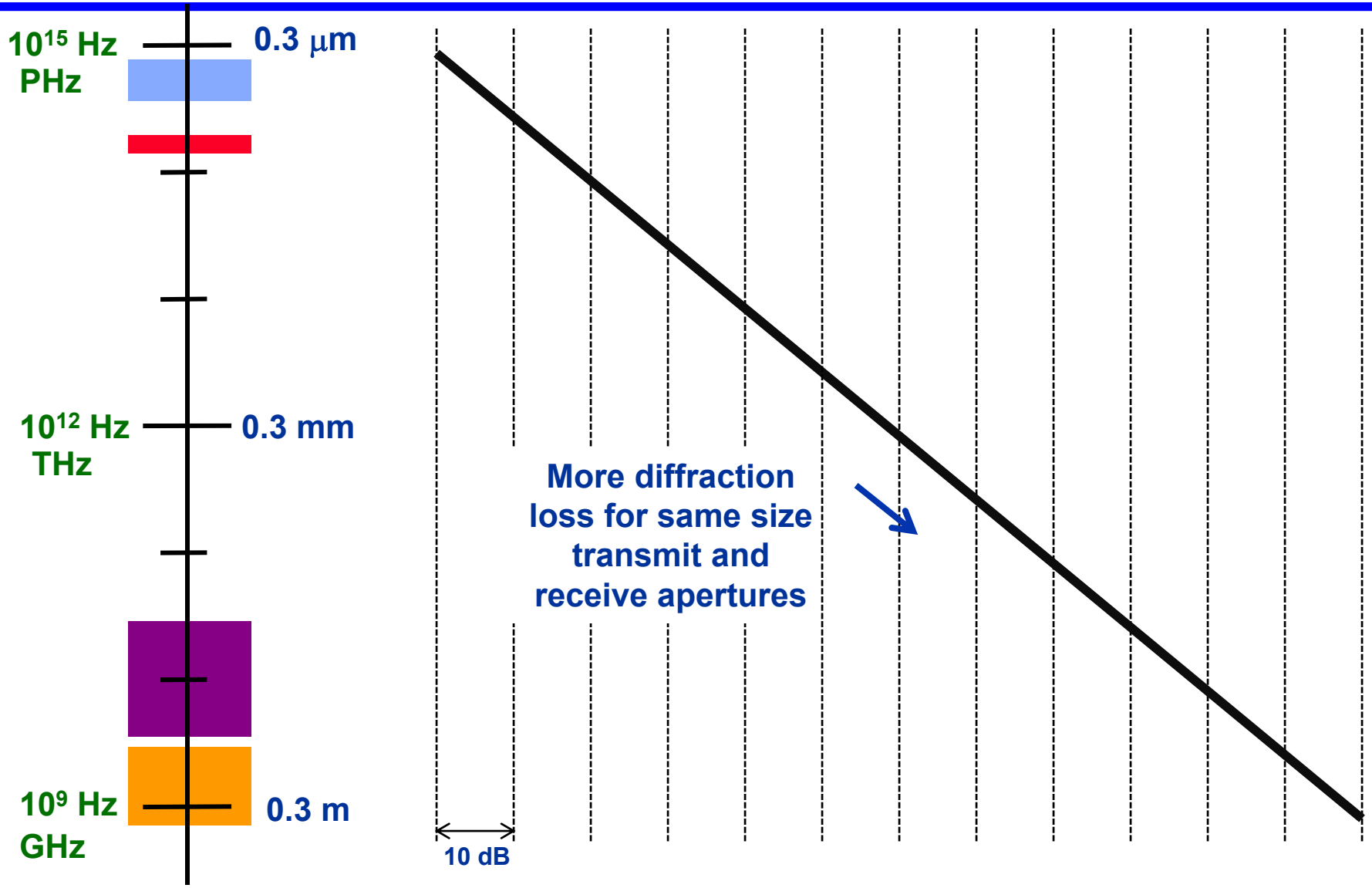


Radio Frequency (RF) vs Optical



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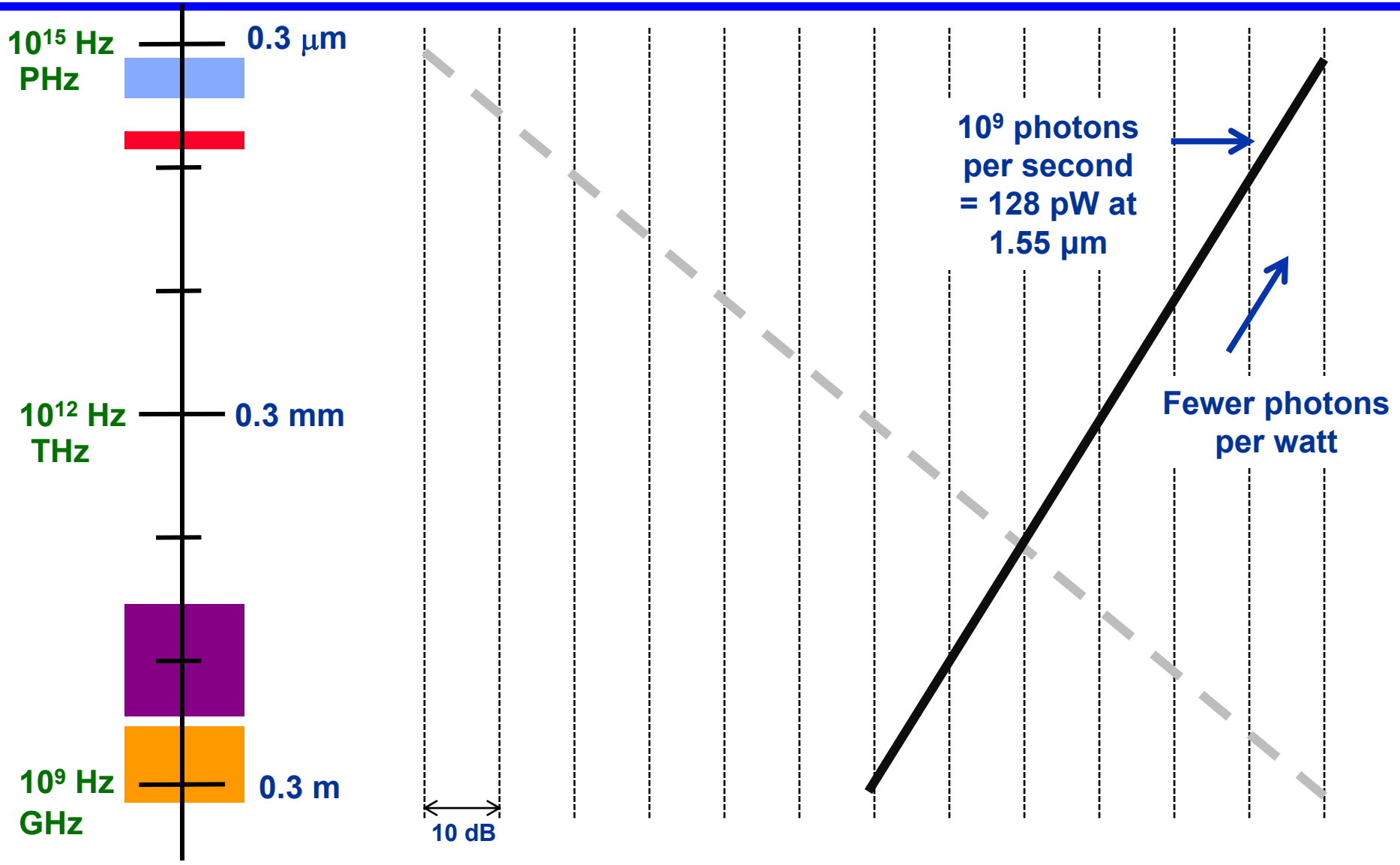

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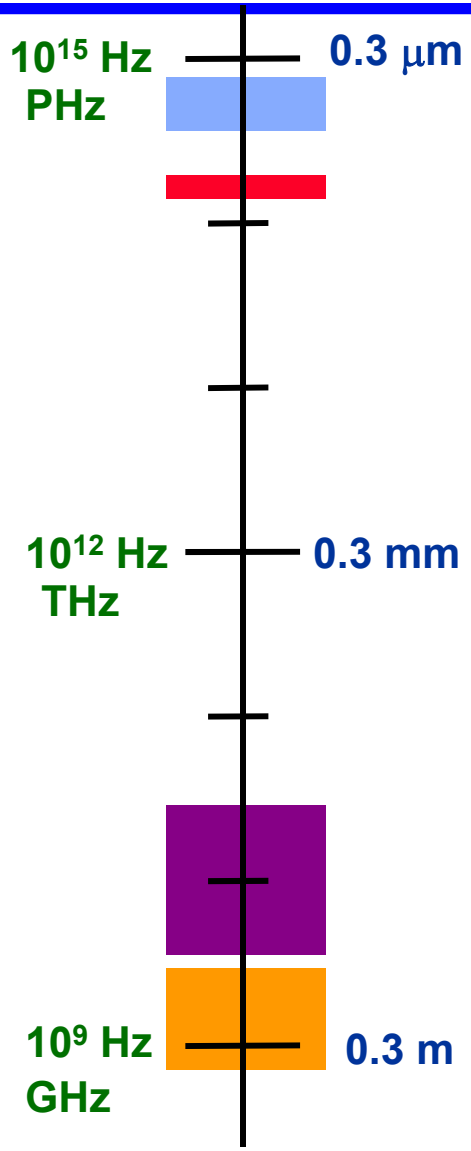
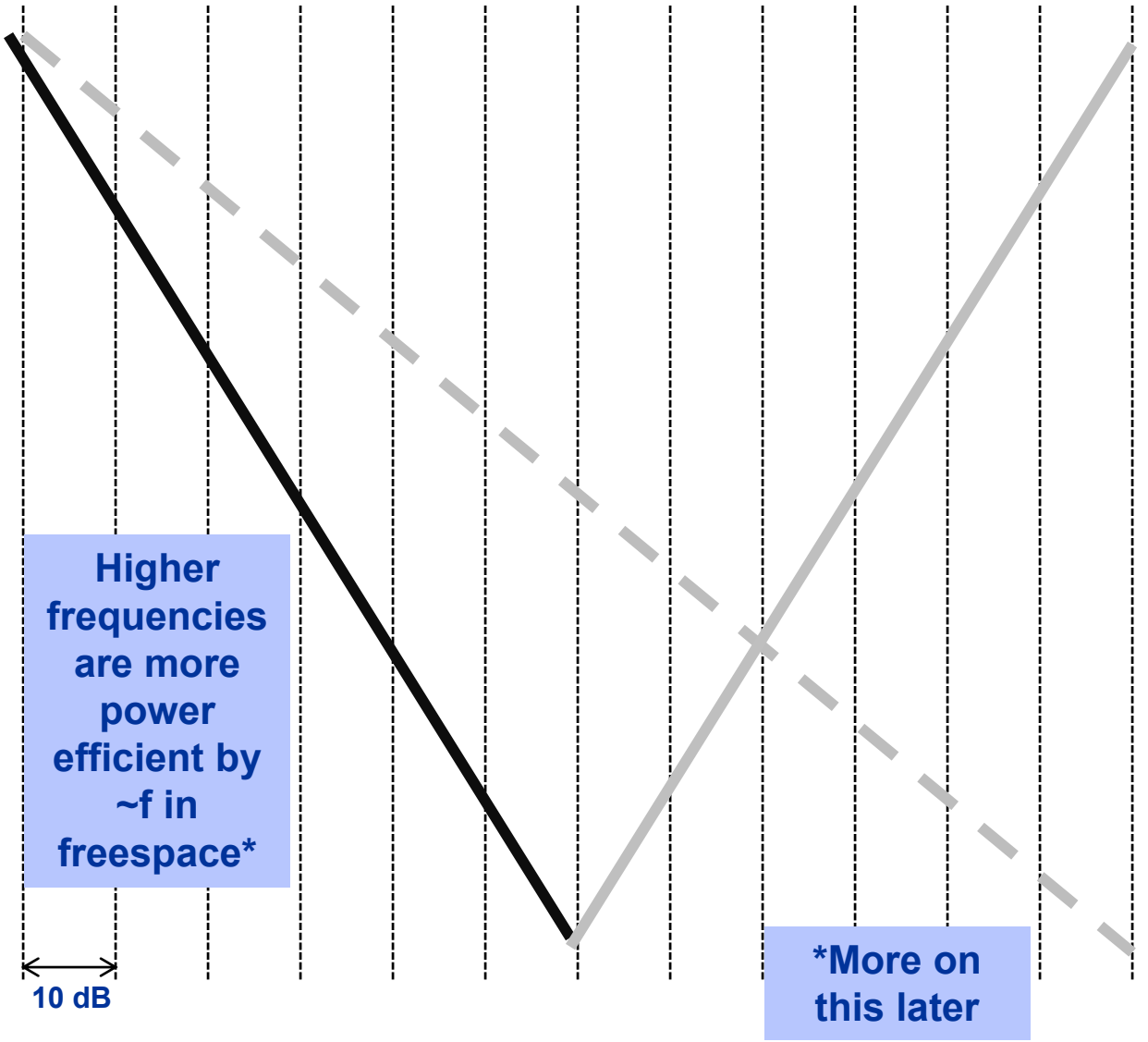
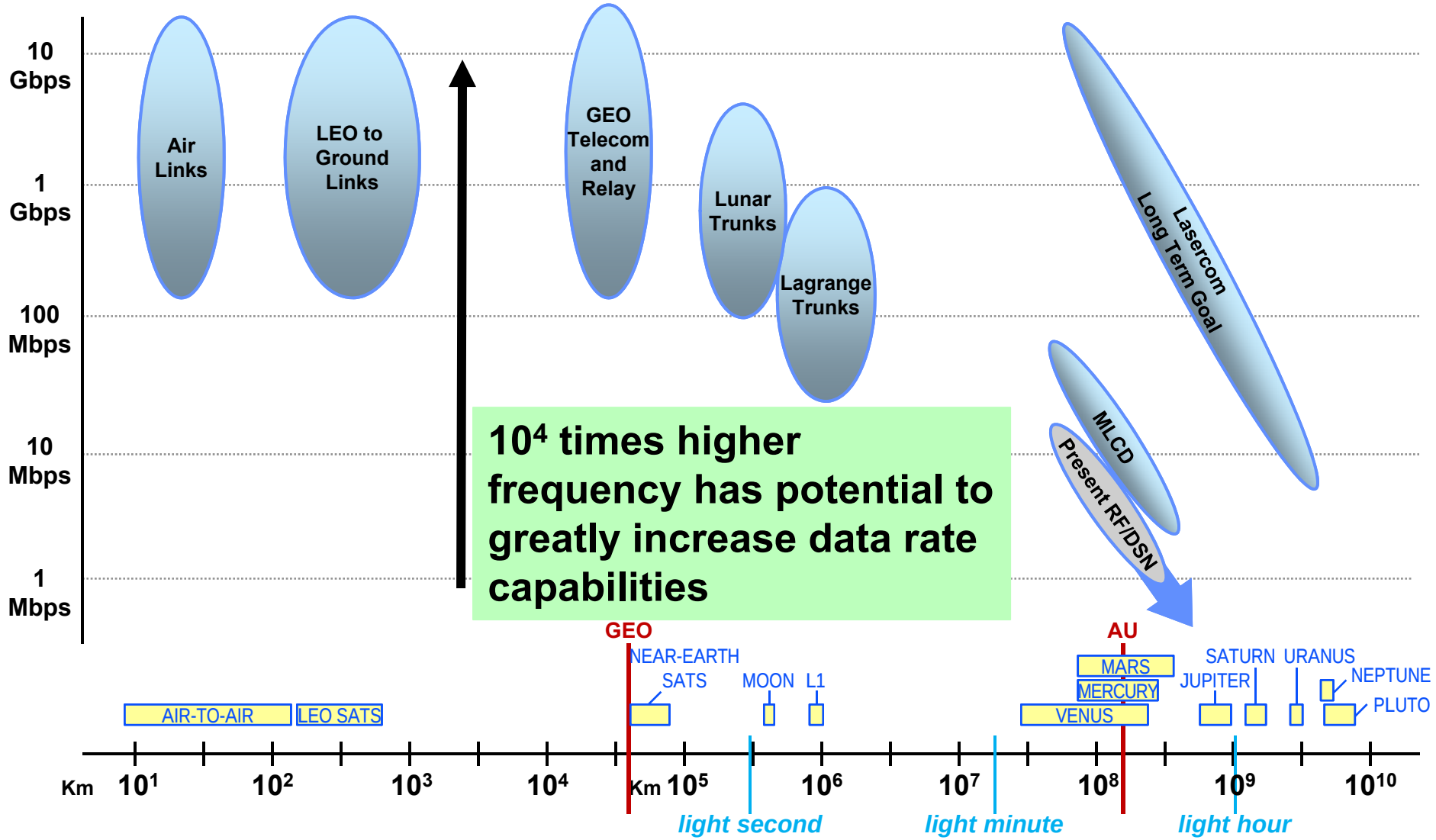


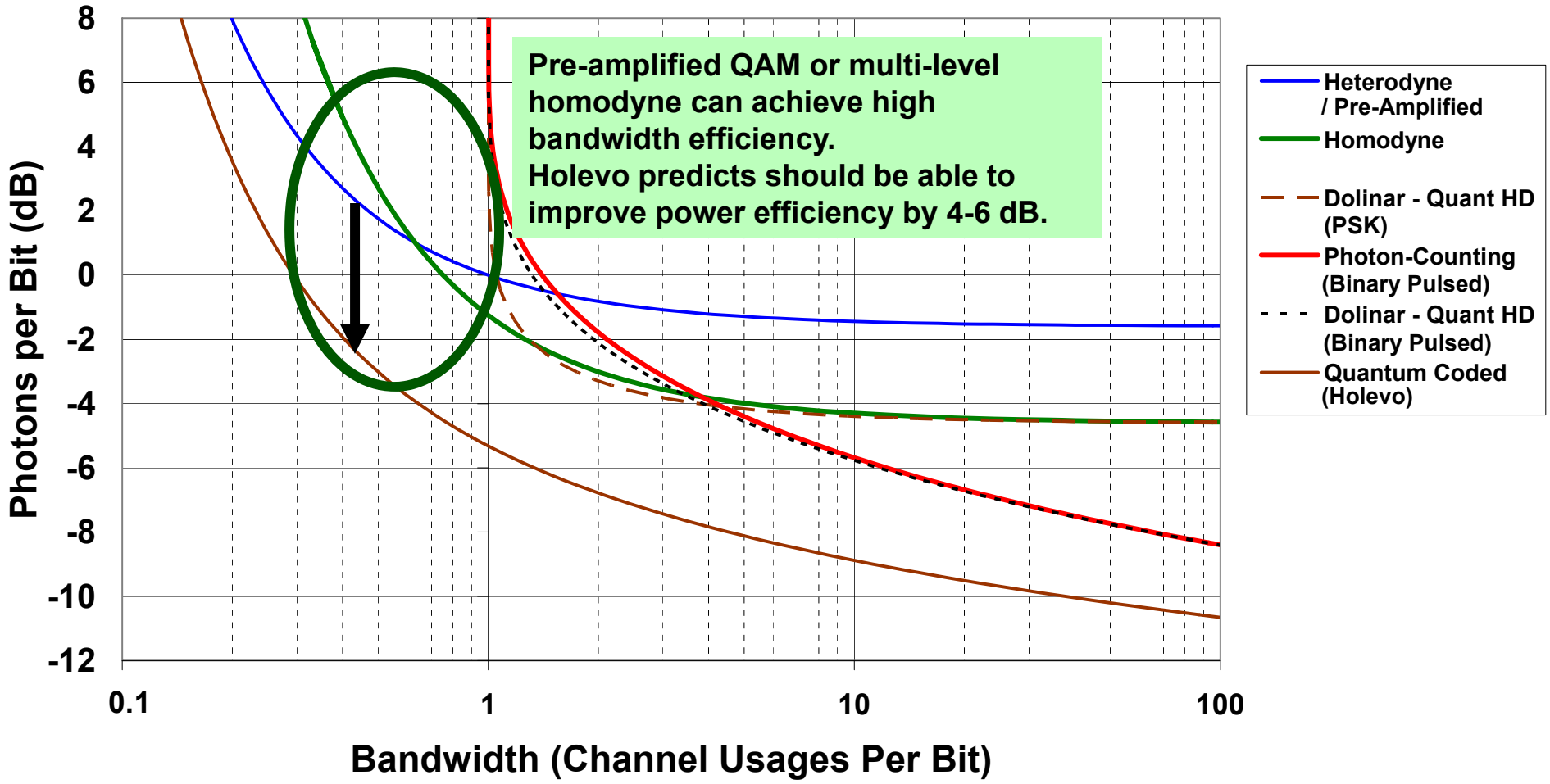


Opportunity/Challenge –
Achieve Narrow-Beam Benefits of Optical



Challenge –
Achieve Optimum Coded Efficiency

*Channel/noise-limited capacities
Arbitrary modulations



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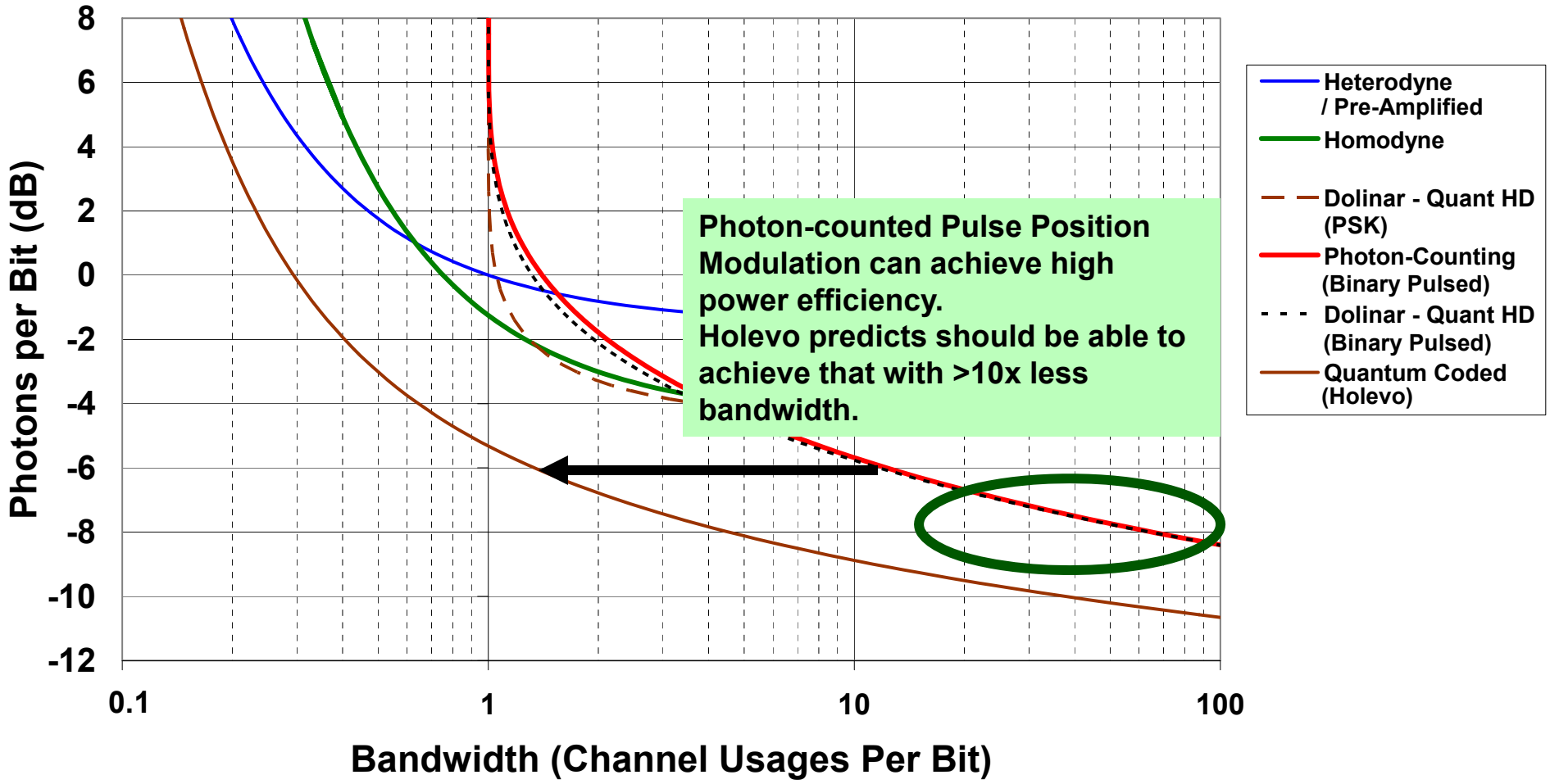

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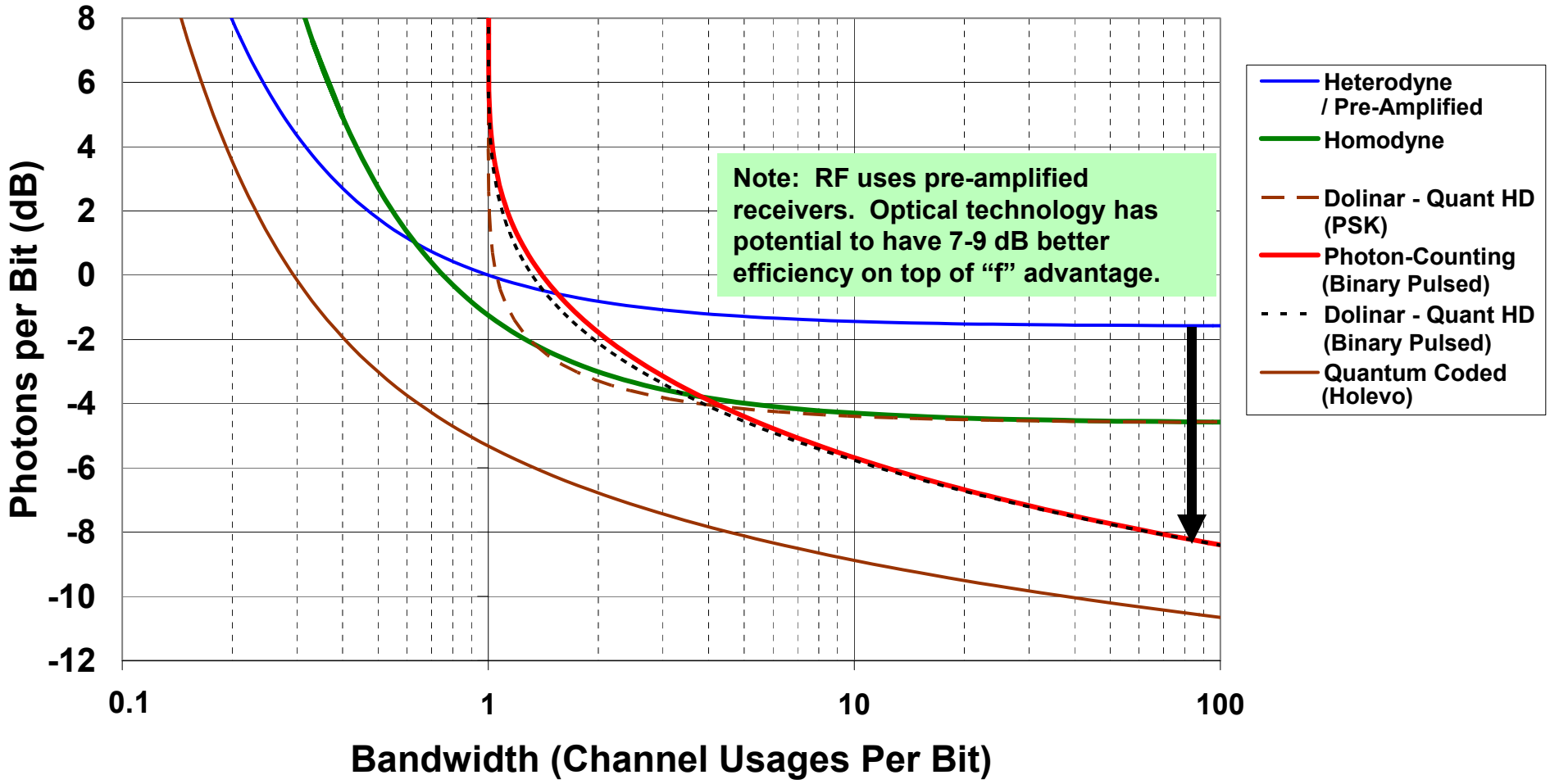

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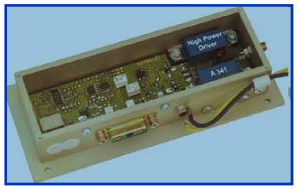
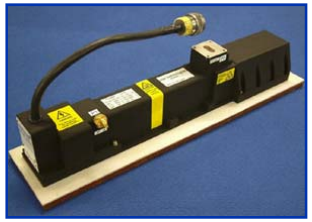
Parts of a Free-Space Communications System – RF



RF Osc



Antenna 1'-50'

Digital Processor

Modulator

TWTA

2 slightly frequency-offset RF carriers

RF Waveguide

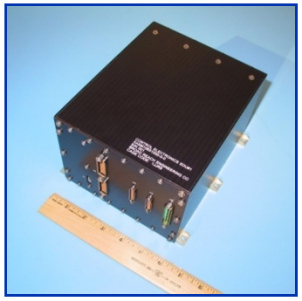
Diplexer

Digital Back End

Demod

Receiver Front End

RF (Local) Osc



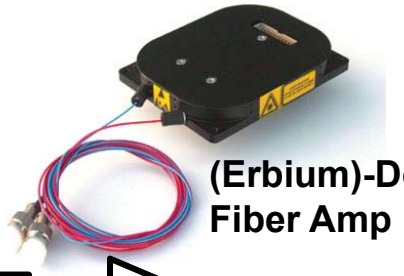
Steering Actuator

Steering Control

Parts of a Free-Space Communications System - Optical

Diode Laser

Opt Osc



(Erbium)-Doped Fiber Amp

Telescope 3" – 36"

Digital Processor

Modulator

EDFA

Offset (Point-Ahead) Steering

Diplexer

2 slightly wavelength-offset optical carriers

Single Mode Fiber

Digital Back End

Demod

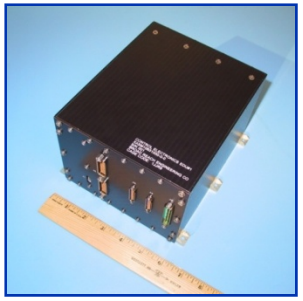
Receiver Front End

Opt (Local) Osc

Pt/Trk Actuator

Other Stabilization Devices

PAT Control



Various types of receiver/demods

What's Hard About Optical?
In Both Vacuum and Atmospheric Links

- Finding (acquiring) where to point
- Stabilizing (tracking) very narrow beam in face of platform micro-vibrations
- Subsystems must withstand vibrations of launch, wild temperature swings, and radiation

What's Hard About Optical?
In Atmospheric Links

- Transmitting beam up through atmosphere and preserving high gain in face of turbulence
- Receiving low-power signal via large aperture and coupling light into single-mode (or other small) receiver in face of turbulence
- Extremely narrow-band filtering of received light when pointed near sun
- Dealing with wide power fluctuations
- *Clouds, fog, trees…..*

What's Hard About Optical?
Technologies

- High-optical-power, low-electrical-power transmitters that can achieve high speed, high peak powers, high optical quality, etc
- Receiver components and architectures that can achieve near-optimum performance at desired rates and desired aperture sizes
- Present-day photon-counting technologies not simply suitable for space environment

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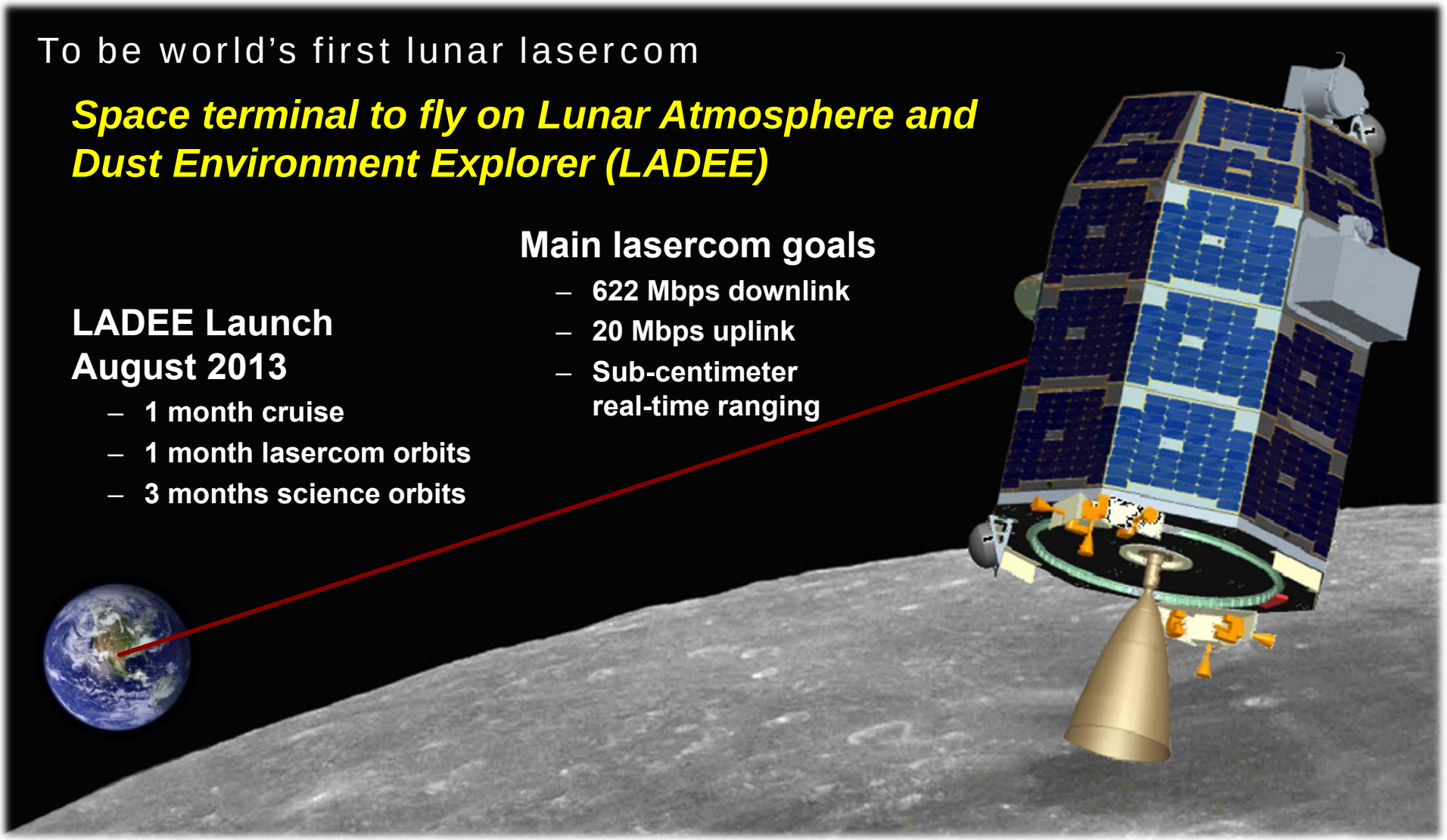
Lunar Laser Communication Demonstration Program

To be world's first lunar lasercom

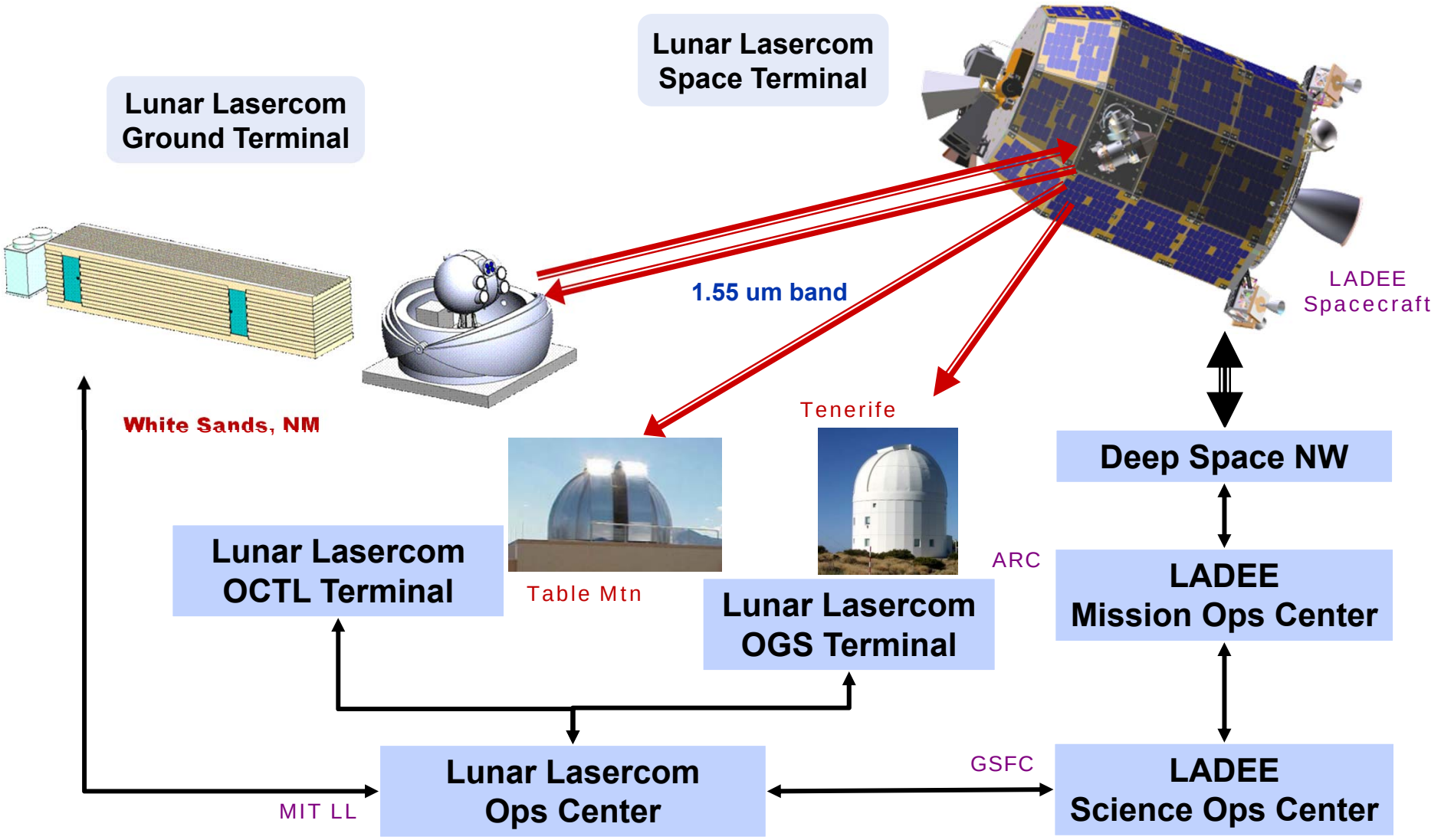
Space terminal to fly on Lunar Atmosphere and Dust Environment Explorer (LADEE)

LADEE Launch
August 2013
- 1 month cruise
- 1 month lasercom orbits
- 3 months science orbits

Main lasercom goals
- 622 Mbps downlink
- 20 Mbps uplink
- Sub-centimeter real-time ranging



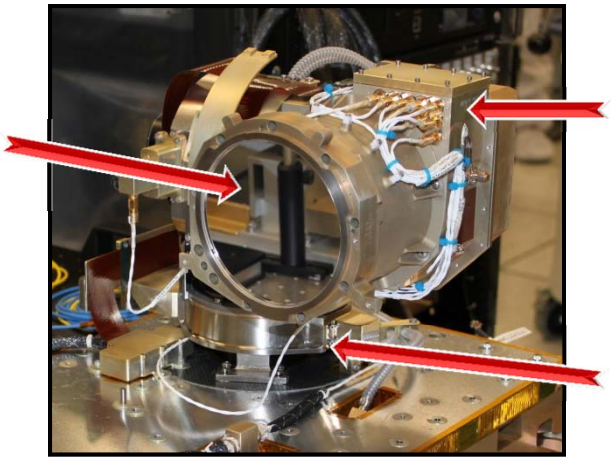
Lunar Laser Communication Demo System



Lunar Lasercom Space Terminal

Pulse Position Modulation Modem
0.5 W doped-fiber amplifier
Full coding / decoding
Mounted inside spacecraft

10-cm Beryllium Telescope Behind Solar Window

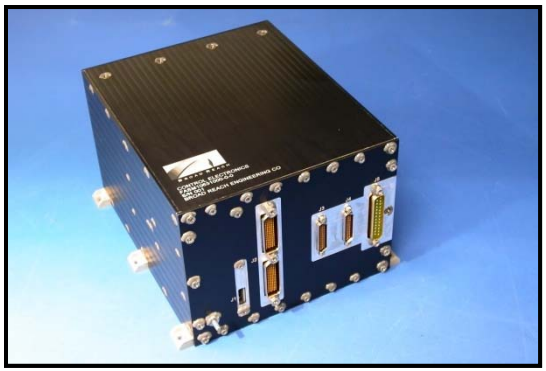


Inertial Stabilization Unit

2 Axis Gimbals

Optical Module
Fiber-coupled to Modem
Mounted on Earth-facing panel

Controller Electronics
Mounted inside spacecraft



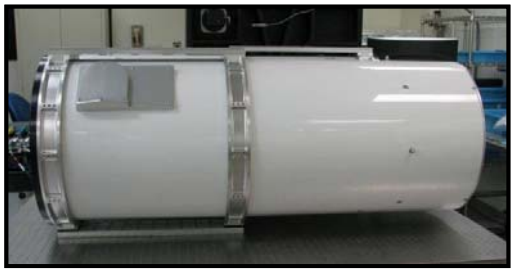
- **Space Terminal in final stages of integration**
- **To be delivered to spacecraft October**

30 kg total

Lunar Lasercom Ground Terminal

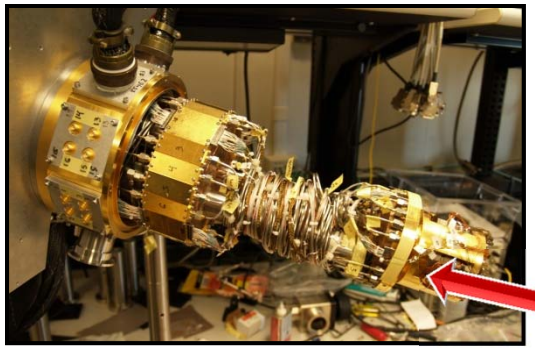
4x10-Watt uplinks

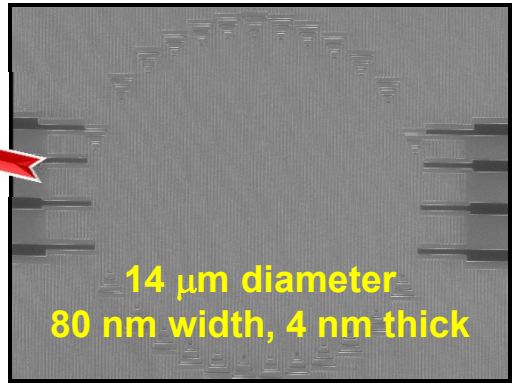
15-cm uplink telescopes



40-cm downlink telescopes

- Ground Terminal in final stages of integration
- To be operated outdoors at MIT LL for 6 months





- Superconducting nanowire single photon detector receiver system built at MIT / LL
- Coupled to receive telescopes via custom multi-mode polarization-maintaining fiber

Summary

- Present technologies adequate for achieving wide range of high-performance (optical) communications systems
- Stage is set for optical transmission and reception based on quantum properties of light