



NASA SBIR 2016 Phase I Solicitation

H9.01 Long Range Optical Telecommunications

Lead Center: JPL

Participating Center(s): GRC, GSFC

The Long Range Optical Communications subtopic seeks innovative technologies in free-space optical communications for increased data volume returns from space missions in multiple domains [1]:

- >100 gigabit/s cis-lunar (Earth or lunar orbit to ground).
- >10 gigabit/s Earth-sun L1 and L2.
- >1 gigabit/s per A.U.-squared deep space.
- >100 megabit/s planetary lander to orbiter.

Proposals are sought in the following specific areas (TRL3 Phase I to mature to TRL4 to 5 in Phase II):

- *Low-mass large apertures for high-EIRP laser transceivers [2]* - 30 to 100 cm diameter laser communications telescopes massing less than 65 kg/square-meter with wavefront errors less than 1/25th of a wavelength at 1550 nm and a cumulative wavefront error and transmission loss of <3dB in the far field that can survive direct sun-pointing. Operational range of -20°C to +50°C without active thermal control is desired.
- *High-gigabit/s laser transmitter and receiver optical-electronic subsystems* - space qualifiable 1550 nm laser transmitter and receiver optoelectronic modulator, detection, and Forward-Error-Correction assemblies for data rates from 1 gigabits/s to >200 gigabits/s with power efficiencies better than 10W per gigabit/s and mass efficiencies better than 100 g per gigabit/s. Radiation tolerance better than 100 Krad is required. Technologies for efficient waveform modulation, detection, and synchronization and on-board low-gap-to-capacity forward-error-correction decoding are of interest; also of interest are hybrid RF-optical technologies. Integrated photonic circuit solutions are strongly desired. Highly efficient (>20% DC-to-optical, including support electronics) and space qualifiable (including resilience to photo-darkening) multi-watt Erbium Doped Fiber Amplifier with high gain bandwidth (> 30nm, 0.5 dB flatness) concepts will also be considered. Detailed description of approaches to achieve the stated efficiency is a must.
- *Waveform signal processing technologies [3]* - **CCSDS White Book, "High Photon Efficiency Optical Communications -- Coding & Modulation," March 2015,** <http://www.nasa.gov/directorates/heo/scan/engineering/datastandards/index.html> - 100 Mb/s and higher hardware/firmware implementation of the coding and synchronization layer of the proposed Consultative Committee for Space Data Systems (CCSDS) high-photon-efficiency optical signaling waveform, including transmitter and receiver functions. Supported features are to include CCSDS Transfer Frame ingestion and slicing; attached frame sync markers; CRC; serially concatenated convolutional coding with accumulate pulse position modulation (SCPPM), including a constraint length 3 convolutional code of rates 1/3, 1/2, and 2/3, code interleaver, accumulator, and PPM of orders 4, 8, ..., 256; randomizer; 1 s channel interleaver;

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- codeblock sync marker repeat/spreader, and guard slot insertion.
- *Large aperture ground receiver subsystem technologies [4]* - Demonstrate innovative subsystem technologies for >10 m diameter ground receiver capable of operating to within 3 degrees of solar limb with a better than 10 microradian spot size (excluding atmospheric seeing contribution). Desire demonstration of low-cost primary mirror segment fabrication to meet a cost goal of less than \$35K per square meter and low-cost techniques for segment alignment and control, including daytime operations. Also desired are cryogenic optical filters for operation at 40K with noise equivalent bandwidths of a few nm in the 1550 nm spectral region, transmission losses < 0.25 dB, clear aperture >35 mm, and acceptance angle >40 milliradians with out-of-band rejection of >65 dB from 0.4 to 5 microns.
 - *Superconducting magnesium diboride (MgB₂) thin films for ground receiver detectors [5]* - 5 to 20 nm thick MgB₂ films with critical temperature T_c > 35 K and critical current density J_c > 5 MA / cm² at 20 K The preferred substrates are SiC, Sapphire or MgO. The substrate size should be at least 4 in². There is also strong interest in MgB₂ films deposited on buffered Si wafers. The MgB₂ films should be passivated with SiO₂ or Au.
 - *Cryogenic read-out electronics for large format superconducting nanowire arrays [6]* - 64 to 1024 channel DC coupled amplifier arrays for mounting onto a 40K cryocooler stage with 50 to 110 Ohm input impedance, <0.5 dB noise figure, DC to >4 GHz bandwidth, >40 dB gain, <1 dB compression with -47 dBm input, < 5 ps additive jitter, and less than 20 mW per channel power dissipation; strongly desired is an integrated per-channel leading-edge detect discriminator with LVDS-compatible output signal levels. Also of great interest is development of an read-out integrated circuit for direct bump-bonding to superconducting nanowire arrays operating in the 1 to 3 K range, with <0.5 dB noise figure, DC to >4 GHz bandwidth, >20 dB gain, <1 dB compression with -47 dBm input, < 5 ps additive jitter, and less than 1 mW per channel power dissipation.
 - *Beaconless pointing subsystems for operations beyond 3 A.U.* - Point 20 to 100 cm lasercomm transmitter aperture to an Earth-based receiver with a 1-sigma accuracy of better than 100 nanoradians with an assumed integrated spacecraft micro-vibration angular disturbance of 150 micro-radians (<0.1 Hz to ~500 Hz) without requiring a dedicated laser beacon transmission from Earth; lowest subsystem mass and power is a primary selection factor.
 - *Low mass / low power / cold survivable optical transceivers for planetary lander to orbiter links [7]* - Bi-directional optical terminals with data rates from >100 megabit/second at a nominal link range of 1000 km, with an individual terminal mass <5 kg and operational power < 25W, including a pointing system for at least full hemisphere coverage. Terminals shall be capable of operationally surviving >500 cycles of unpowered temperature cycling from -40°C to +40°C and a 100 krad TID. Discussion of acquisition and tracking con-ops and requirements is a must.

Research must convincingly prove technical feasibility (proof-of-concept) during Phase I, ideally with hardware deliverables that can be tested to validate performance claims, with a clear path to demonstrating and delivering functional hardware meeting all objectives and specifications in Phase II.

References:

- [1] - (<http://ssed.gsfc.nasa.gov/IPM/PDF/1010.pdf>).
- [2] - W. Farr, W, et al. Overview and Design of the DOT Flight Laser Transceiver; IPN Progress Report 42-185, (2011).
- [3] - CCSDS White Book, "High Photon Efficiency Optical Communications -- Coding & Modulation," March 2015.
- [4] - Birnbaum, K., et al. DOT Ground Laser Receiver: Overview and Major Trades; IPN Progress Report 42-182, (2010).
- [5] - Wolak, M. A. et al., IEEE Trans. Appl. Supercond. 25, 1-5 (2015).
- [6] - Dauler, E., et al., Review of Superconducting Nanowire Single-Photon Detector System Design Options and Demonstrated Performance; Opt. Eng 53 (2014).
- [7] - Biswas, A., et al., Future Planetary Optical Access Links; 2011 International Conference on Space Optical Systems and Applications.