NASA SBIR 2019 Phase I Solicitation

H9.01 Long Range Optical Telecommunications

Lead Center: JPL

Participating Center(s): GRC, GSFC

Technology Area: TA5 Communication and Navigation

Free-space optical communications technologies

Free-space Long Range Optical Communications subtopic seeks innovative technologies in free-space optical communications for pushing future data volume returns from space missions in multiple domains: >100 gigabit/s cis-lunar (Earth or lunar orbit to ground), >10 gigabit/s Earth-sun L_1 and L_2, >1 gigabit/s per AU-squared deep space, and >1 Gbit/s planetary lander to orbiter. Additionally, innovative technologies for improving efficiency, reliability, robustness, and longevity of state-of-the-art laser communication systems are also sought.

Proposals are sought in the following specific areas (TRL 2-3 Phase I for maturation to TRL 3-5 in Phase II):

Flight Laser Transceivers

Low-mass, high-effective isotropic radiated power (EIRP) laser transceivers with:

- 30 to 50 cm clear aperture diameter telescopes for laser communications.
- Targeted mass of opto-mechanical assembly per aperture area, less than 100 kg/square-meter
- Cumulative wave-front error and transmission loss not to exceed 2-dB.
- Advanced thermal designs with allowable flight temperatures of the optics and structure, at least -20° C to 50° C operational range
- Stray light design for 3-degrees from edge of sun operations and surviving direct sun-pointing of

Transceivers fitting above characteristics should support robust link acquisition tracking and pointing characteristics, including point-ahead implementation from space, for beacon assisted and/or beaconless architectures:

- Pointing loss allocations not to exceed 1 dB (pointing errors associated loss of irradiance at target less than 20%)
- Receive field-of-view of at least 1 milliradian radius, for beacon assisted operations
- Beaconless pointing subsystems for operations beyond 3 A.U.
- Assume integrated spacecraft micro-vibration angular disturbance of 150 micro-radians (<0.1 Hz to ~500 Hz)
- Low complexity small footprint laser transceivers for bi-directional optical links, >1 -10 Gbit/second, at a nominal link range of 1000-5000 km, for planetary lander/rover to orbiter and/or space-to-space cross links

Flight Laser Transmitters, Receivers and Sensors

High-gigabit/s laser transmitters:

- 1550 nm wavelength
- Space qualifiable laser and optical components
- High rate 10-100 Gb/s for cis-lunar
- 1 Gb/s for deep-space
- Integrated hardware with embedded software/firmware for innovative coding/modulation/interleaving schemes

High peak-to-average power laser transmitters for regular or augmented M-ary PPM modulation with M=4, 8, 16, 32, 64, 128, 256 operating at NIR wavelengths, preferably 1550 nm with average powers from 5 – 50 W:

- Sub-nanosecond pulse
- Low pulse jitter
- Long lifetime and reliability operating in space environment (> 5 and as long as 20 years)
- High modulation and polarization extinction ratio with 1-10 GHz linewidth

Space qualifiable wavelength division multiplexing transmitters and amplifiers with 4 to 20 channels and average output power > 20W per channel; peak-to-average power ratios >200; >10 Gb/s channel modulation capability:

- >20% wall-plug efficiency (DC-to-optical, including support electronics). Describe approach for stated efficiency of space qualifiable lasers. Multi-watt Erbium Doped Fiber Amplifier (EDFA), or alternatives, with high gain bandwidth (> 30nm, 0.5 dB flatness) concepts will be considered.
- Radiation tolerance better than 50 Krad is required, (including resilience to photo-darkening).

Space qualifiable high-speed receivers and low light level sensitive acquisition, tracking, pointing, detectors and detector arrays:

- NIR wavelengths, 1064nm, 1550 nm
- Supporting low irradiance (~ fW/m2 to pW/m2) detection
- Low sub-nanosecond timing jitter and fast rise time
- Novel hybridization of optics and electronic readout schemes with built-in pre-processing capability
- Characteristics compatible with supporting time-of-flight or other means of processing laser communication signals for high precision range and range rate measurements
- Tolerant to space radiation effects, total dose > 50 krad, displacement damage and single event effects

Novel technologies and accessories

Narrow Band Pass Optical Filters:

- Space qualifiable, sub-nanometer to nanometer, noise equivalent bandwidth with ~90% throughput, large spectral range out-of-band blocking (~ 40 dB)
- NIR wavelengths from 1064 – 1550 nm region, with high transmission through Earth's atmosphere
- Reliable tuning over limited range

Novel integrated photonics applications for space with objective of reducing size, weight and power of modulators, improved integration of opto-electronics and efficient coupling to traditional discrete optics

Concepts for offering redundancy to laser transmitters in space:

- Optical fiber routing of high average powers (10's of watts) and high peak powers (1-10 kW)

- Redundancy in actuators and optical components

Ground Assets for Optical Communication

Large aperture receivers for faint optical communication signals from deep space, subsystem technologies:

- Demonstrate innovative subsystem technologies for >10 m diameter deep space ground collector
- Capable of operating to within 3° of solar limb
- 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
- Low-cost techniques for segment alignment and control, including daytime operations.

1550 nm sensitive photon counting detector arrays compatible with large aperture ground collectors:

- Integrated time tagging readout electronics for >5 gigaphotons/s incident rate
- Time resolution <50 ps 1-sigma
- Highest possible single photon detection efficiency, at least 50% at highest incident rate,
- Total detector active area > 0.3 to 1 mm^2
- Integrated dark rate < 3 megacount/s.

Cryogenic optical filters:

- Operate at 40K with sub-nanometer noise equivalent bandwidths
- 1550 nm spectral region, transmission losses < 0.5 dB, clear aperture
- >35 mm, and acceptance angle >40 milliradians with out-of-band rejection of >65 dB from 0.4 to 5 micrometers

Multi-kilowatt laser transmitters for use as ground beacon and uplink laser transmitters:

- Near infrared wavelengths in 1.0 or 1.55 micrometer spectral region
- Capable of modulating with narrow nanosecond with sub-nanosecond rise times
- Low timing jitter and stable operation
- High speed real-time signal processing of serially concatenated pulse position modulation operating at a few bits per photon with user interface outputs

For all technologies lowest cost for small volume production (5 to 20 units) is a driver. 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.

A number of FSOC related NASA projects are ongoing with launch expected in the 2019-2022 time frame. The Laser Communication Relay Demonstration (LCRD) is an earth-to-geostationary satellite relay demonstration to launch in late 2019. The Illuma -T Project will extend the relay demonstration to include a LEO node on the ISS in 2021. In 2022 the EM-2 Optical to Orion (O2O) demonstration will transmit data from the Orion crewed capsule as it travels to the Moon and back. In 2022 the Deep Space Optical Communications (DSOC) Project technology demonstration will be hosted by the Psyche Mission spacecraft extending FSOC links to astronomical unit distances.

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References:

- Don Cornwell, "NASA's optical communications program for 2015 and beyond," SPIE Proceedings, 9354,

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- https://www.nasa.gov/directorates/heo/scan/opticalcommunications/illuma-t
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