NASA SBIR 2015 Phase I Solicitation

H9.01 Long Range Optical Telecommunications

Lead Center: JPL

Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long range (> 0.1 AU) optical telecommunications supporting the needs of space missions where human and robotic explorers will visit distant bodies within the solar system and beyond. Multi-use technologies that will also benefit high rate optical communications in cis-lunar and Earth-Sun Lagrange point domains are of particular interest. Goals are increased data-rate capability in both directions and significant reductions of telecommunications system mass, power-consumption, and volume at the spacecraft.

Proposals are sought in the following areas (TRL3 Phase I, and TRL4-5 Phase II):Â

- *Spacecraft Disturbance Isolation Platforms and Related Technologies* - Compact, low mass, space-qualifiable, vibration isolation and spacecraft disturbance rejection assemblies with included re-usable launch lock that require less than 5 W of average power and mass less than 3 kg that will attenuate an integrated spacecraft micro-vibration angular disturbance of 150 micro-radians (with a spectrum of 10E-6 rad^2/Hz below 0.1 Hz, with a 20 dB/decade roll-off), plus an assumed translational disturbance resulting from an offset of 2 m between the payload and the center of rotation of the spacecraft, to less than 0.15 micro-radians (1-sigma), for payloads massing between 3 and 25 kg. Proposed solutions may use control inputs from ground-beacon-based pointing sensor with noise of 150 nrad/sqrt (Hz). Also desired are innovative low-noise, low mass, low power, DC-kHz bandwidth inertial, angular, position, or rate sensors to assist platform stabilization, including beaconless pointing.
- *PPM Space Laser Transmitters* - Space-qualifiable, 1520 to 1630 nm laser transmitter for pulse-position modulated (PPM) with >25% DC-to-optical (wall-plug) efficiency. Transmitter must support laser pulse widths from 0.2 ns (or lower) to 16 ns (or greater) for PPM orders from 16 slots per symbol (6.25% average duty cycle) to 256 slots per symbol plus 64 slots of inter-symbol guard time (0.31% average duty cycle). Other desired parameters include: <35 ps pulse rise and fall times and jitter; <25% pulse-to pulse energy variation (at a given pulse width); single spatial mode output with near transform limited spectral width, single polarization with at least 20 dB polarization extinction ratio; amplitude extinction ratio greater than 48dB, average output power of 10 to 100W; massing less than 500 g/W. Laser transmitter to feature slot-serial PPM data input at CML, LVDS, or AC-coupled PCEL levels and an RS-422 or LVDS levels control port. All power consumed by control electronics will be considered as part of DC-to-optical efficiency. Also of interest for the laser transmitter is robust and compact packaging with >100krad radiation tolerant electronics inherent in the design. Detailed description of approaches to achieve the stated efficiency is a must. Also of interest is a space-qualifiable high power fiber switch for implementing redundant space laser transmitters.
- *PPM Ground Laser Transmitters* - >2000W average power PPM laser transmitters for nested modulation forward links to support simultaneous data rates of ~10 b/s (outer code) and at least 10 Mb/s (inner code) with an outer rate inter-symbol guard time of 50%. Operational wavelength in either 1030 - 1080 nm or

1480 - 1570 nm bands. Other desired parameters include: spectral line width of 0.5 nm or less; amplitude extinction ratio greater than 35 dB; output M-squared of 1.2 or less; projected MTTF of at least 20,000 hours; high wall-plug AC-to-optical power efficiency.

- *Photon Counting Near-infrared Detectors Arrays for Ground Receivers* - Close packed (not lens-coupled) kilo-pixel arrays sensitive to 1520 to 1630 nm wavelength range with single photon detection efficiencies greater than 90%, single photon detection jitters less than 40 ps FWHM, total active diameter greater than 500 microns, 1 dB saturation rates of at least 10 mega-photons (detected) per pixel, false count rates (intrinsic dark rate plus after-pulsing rate) of less than 1 MHz/square-mm. Also desired are cryogenic read-out integrated circuits with an operating temperature of 40K capable of time-tagging electronic pulses from 64 high-bandwidth readout channels to an accuracy of 100 ps or better and a maximum count rate of 10 MHz per channel. The approach should demonstrate scalability to >1000 readout channels Also of interest are: sub-Kelvin cryogenic systems which can support >1000 channels of high-bandwidth (2 GHz or higher) readout signals with a low-temperature hold time of 24 hours, and preferably can be tilted from vertical to near-horizontal during operations; cryogenic interconnects and vacuum feedthroughs for high-density cabling solutions capable of supporting kilochannel readouts from a 1 K detector focal plane stage to room temperature.
- *Photon Counting PPM Digital Ground Receivers* - Digital receiver and decoder assemblies for processing photon counting detector array outputs of PPM encoded data. Receiver to support PPM orders from 2 to 256, data rates to at least 1 Gb/s, and PPM slot widths down to 200 ps. Receiver shall support SCPPM or other demonstrated low-gap-to-capacity (< 1 dB) forward error correction code for PPM. Receiver shall provide signal and background photon flux estimates at kHz rates to support 2-axis control of a fine pointing mirror in a ground receiver telescope.*Â*
- *Photon Counting Near-infrared Detectors Arrays for Flight Receivers* - 128x128 or larger array with integrated read-out integrated circuit and thermo-electric cooling for the 1030 to 1080 nm or 1520 to 1650 nm wavelength range with single photon detection efficiencies greater than 40% and 1dB saturation loss rates of at least 2 mega-photons/pixel and dark count rates of <10 kHz/pixel. ROIC to provide time-stamping of each photon arrival with a precision of 500 ps or better, and an interface bus bandwidth of 125 MHz or less. Radiation doses of at least 5 Krad (unshielded) shall result in less than 10% drop in single photon detection efficiency and less than 2X increase in dark count rate.
- *Advanced Flight Opto-electronics* - Ultra-small, low-mass, low-cost, low-power, modular transceivers, transponders, amplifiers, and components for 1520 to 1630 nm optical links at GHz modulation bandwidths, incorporating integrated photonic circuits and other components such as commercially-available ASICs to provide forward-error-correction and other digital signal processing as required.
- *Ground-based Telescope Assembly* - All-weather ground station telescope/photon-bucket technologies for implementing effective receive areas of > 100 square meters at a projected production cost of < $300K per square meter. Operations wavelength is monochromatic at a wavelength in the range of 1000-1600nm. Key requirements: a maximum image spot size of <20 microradian (static error); capable of operation while pointing to within 3Â° of the solar limb; and field-of-view of >50 micro-radian. Telescope shall be positioned with a two-axis gimbal capable of <50 micro-radian pointing accuracy, with dynamic error <10 micro-radian RMS while tracking after tip-tilt correction.

Research should be conducted to convincingly prove technical feasibility (proof-of-concept) during Phase I, ideally through hardware development, with clear pathways to demonstrating and delivering functional hardware meeting all objectives and specifications, in Phase II.

References:Â

- (http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/42091/1/11-1338.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-183/183A.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-185/185D.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-182/182C.pdf)