NASA STTR 2019 Phase I Solicitation

T8.02 Photonic Integrated Circuits

Lead Center: GSFC

Participating Center(s): GRC, JSC

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

Integrated photonics generally is the integration of multiple lithographically defined photonic and electronic components and devices (e.g., lasers, detectors, waveguides/passive structures, modulators, electronic control and optical interconnects) on a single platform with nanometer-scale feature sizes. The development of photonic integrated circuits permits size, weight, power and cost reductions for spacecraft microprocessors, communication buses, processor buses, advanced data processing, free space communications and integrated optic science instrument optical systems, subsystems and components, whichÂ is particularly critical for small spacecraft platforms. This subtopic solicits methods, technology and systems for development and incorporation of active and passive circuit elements for integrated photonic circuits for:

- *Integrated photonic sensors (physical, chemical and/or biological) circuits* - NASA applicationÂ examples include but are not limited to: Lab-on-a-chip systems for landers, astronaut health monitoring, front-end and back-end for remote sensing instruments including trace gas lidars, large telescope spectrometers for exoplanets using photonic lanterns and narrow band filters. On-chip generation and detection of light of appropriate wavelength may not be practical, requiring compact hybrid packaging for providing broadband optical input-output and also, as a means to provide coupling of light between the sensor-chip waveguides and samples, unique optical components (e.g., plasmonic waveguides, microfluidic channel) may be beneficial. Examples: Terahertz spectrometer, optical spectrometer, gyroscope, magnetometer, urine/breath/blood analysis.
- *Integrated photonic circuits for analog RF applications* - NASA applications include new methods due to size, weight and power improvements, passive and active microwave signal processing, radio astronomy, and Terahertz spectroscopy. As an example, integrated photonic circuits having very low insertion loss (e.g., ~1dB) and high spur free dynamic range for analog and RF signal processing and transmission which incorporate, for example, monolithic high-Q waveguide microresonators or Fabry-Perot filters with multi-GHz RF pass bands. These components should be suitable for designing chip-scale tunable opto-electronic RF oscillator and high precision optical clock modules. Examples: Ka, W, V band radar/receivers.
- *Integrated photonic circuits for very high-speed computing and free space communications* - advanced computing engines that approach TeraFLOP per second computing power for spacecraft in a fully integrated combined photonic and electronic package. Free space communications downlink modems at the > 1 Terabit per second level for Near-Earth (Low-Earth Orbit to ground) and > 100 Mbls for > 1 AU distances. Examples: transmitters, receivers, microprocessors.

This subtopic also investigates new science that may be enabled by quantum mechanical technologies in space implemented in a photonic integrated circuitÂ e.g.:

- Spaceâ€based atomic and optical clocks.
- Atomic inertial sensors.
- Nitrogen-vacancy diamond (or other) magnetometers.
- Atomic vapor magnetometers.
- Additional quantum sensors that provide an advantage (e.g., sensitivity, SWaP, cost, operating temperature) over present-day sensors.

The expected Technology Readiness Level (TRL) range at completion of this project is 2 to 4.Â

There are multiple Mission Directorates within NASA for which this technology is relevant:

- *Human Exploration & Operations Mission DirectorateÂ (HEOMD)* - astronaut health monitoring
- *Science Mission Directorate (SMD)* - Earth, planetary and astrophysics compact science instrument (e.g., optical and terahertz spectrometers, magnetometers on a chip)
- *Space Technology Mission Directorate (STMD)* - game changing technology for small spacecraft communication and navigation (optical communication, laser ranging, gyroscopes)
- *STTR* - Exponentially increasing interest and programs at universities and start-ups in integrated photonics.

References:

NASA Space Technology Area Roadmaps **-** 6.2.2, 13.1.3, 13.3.7, all sensors, 6.4.1, 7.1.3, 10.4.1, 13.1.3, 13.4.3, 14.3

- System-on-Chip Photonic Integrated Circuits By: Kish, Fred; Lal, Vikrant; Evans, Peter; et al. IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS Volume: 24 Issue: 1 Article Number: 6100120 Published: JAN-FEB 2018
- Integrated photonics in the 21st century By: Thylen, Lars; Wosinski, Lech PHOTONICS RESEARCH Volume: 2 Issue: 2 Pages: 75-81 Published: APR 2014
- Photonic Integrated Circuits for Communication Systems By: Chovan, Jozef; Uherek, Frantisek RADIOENGINEERING Volume: 27 Issue: 2 Pages: 357-363 Published: JUN 2018
- Mid-infrared integrated photonics on silicon: a perspective By: Lin, Hongtao; Luo, Zhengqian; Gu, Tian; et al., NANOPHOTONICS Volume: 7 Issue: 2 Pages: 393-420 Published: FEB 2018
- Photonic Integrated Circuit Based on Hybrid III-V/Silicon Integration By: de Valicourt, Guilhem; Chang, Chia-Ming; Eggleston, Michael S.; et al., JOURNAL OF LIGHTWAVE TECHNOLOGY Volume: 36 Issue: 2 Special Issue: SI Pages: 265-273 Published: JAN 15 2018
- Silicon Nitride Photonic Integration Platforms for Visible, Near-Infrared and Mid-Infrared Applications By: Munoz, Pascual; Mico, Gloria; Bru, Luis A.; et al. SENSORS Volume: 17 Issue: 9 Article Number: 2088 Published: SEP 2017
- Quantum Sensing, C. L. Degen, F. Reinhard, P. Cappellaro; REVIEWS OF MODERN PHYSICS, VOLUME 89, JULYâ€“SEPTEMBER 2017