NASA STTR 2021 Phase I Solicitation

T5.04 Quantum Communications

Lead Center: GRC

Participating Center(s): GSFC, JPL

Scope Title:

Quantum Communications

Scope Description:

NASA seeks to develop quantum networks to support the transmission of quantum information for aerospace applications. This distribution of quantum information could potentially be utilized in secure communication, sensor arrays, and quantum computer networks. Quantum communication may provide new ways to improve sensing the entangling of distributed sensor networks to provide extreme sensitivity for applications such as astrophysics, planetary science, and Earth science. Also of interest are ideas or concepts to support the communication of quantum information between quantum computers over significant free-space distances (greater than 10 km up to geosynchronous equatorial orbit (GEO)) for space applications or supporting linkages between terrestrial fiber-optic quantum networks. Technologies that are needed include quantum memory, quantum entanglement distribution systems, quantum repeaters, high-efficiency detectors, quantum processors, and quantum sensors that make use of quantum communication for distributed arrays and integrated systems that bring several of these aspects together using Integrated Quantum Photonics. A key need for all of these are technologies with low size, weight, and power that can be utilized in aerospace applications. Some examples (not all inclusive) of requested innovation include:

- High-rate free-space quantum entanglement distribution systems.
- Photonic waveguide integrated circuits for quantum information processing and manipulation of entangled quantum states; requires phase stability, low propagation loss, that is, <0.1 dB/cm, and efficient fiber coupling, that is, coupling loss <1.5 dB.
- Waveguide-integrated single-photon detectors for >100 MHz incidence rate, 1-sigma time resolution of <25 ps, dark count rate <100 Hz, and single-photon detection efficiency >50% at highest incidence rate.
- Integrated sensors that support arrays of distributed sensors, such as an entangled interferometric imaging array.
- Integrated photonic circuit quantum memory.
- Quantum entanglement fidelity measurement capabilities.
- Scalable quantum memory.

Quantum sensor-focused proposals that do not include an aspect of quantum communication should propose to the Quantum Sensing and Measurement subtopic as individual quantum sensors are not covered by this subtopic.

Expected TRL or TRL Range at completion of the Project: 2 to 4

Primary Technology Taxonomy:
Level 1: TX 05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
Level 2: TX 05.5 Revolutionary Communications Technologies
Desired Deliverables of Phase I and Phase II:

- Hardware
- Analysis
- Research
- Prototype

Desired Deliverables Description:

Phase I research should (highly encouraged) be conducted to demonstrate technical feasibility with preliminary hardware (i.e., beyond architecture approach/theory; a proof-of-concept) being delivered for NASA testing, as well as show a plan toward Phase II integration.

Phase II new technology development efforts shall deliver components at the TRL 4 to 6 level with mature hardware and preliminary integration and testing in an operational environment. Deliverables are desired that substantiate the quantum communication technology utility for positively impacting the NASA mission. The quantum communication technology should impact one of three key areas: information security, sensor networks, and networks of quantum computers. Deliverables that substantiate technology efficacy include reports of key experimental demonstrations that show significant capabilities, but in general it is desired that the deliverable include some hardware that shows the demonstrated capability.

State of the Art and Critical Gaps:

There is a critical gap between the United States and other countries, such as Japan, Singapore, Austria, and China, in quantum communications in space. Quantum communications is called for in the 2018 National Quantum Initiative (NQI) Act, which directs the National Institute of Standards and Technology (NIST), National Science Foundation (NSF), and Department of Energy (DOE) to pursue research, development, and education activities related to Quantum Information Science. Applications in quantum communication, networking, and sensing, all proposed in this subtopic, are the contributions being pursued by NASA to integrate the advancements being made through the NQI.

Relevance / Science Traceability:

This technology would benefit NASA communications infrastructure as well as enable new capabilities that support its core missions. For instance, advances in quantum communication would provide capabilities for added information security for spacecraft assets as well as provide a capability for linking quantum computers on the ground and in orbit. In terms of quantum sensing arrays, there are a number of sensing applications that could be supported through the use of quantum sensing arrays for dramatically improved sensitivity.

References:

- Evan Katz, Benjamin Child, Ian Nemitz, Brian Vyhnalek, Tony Roberts, Andrew Hohne, Bertram Floyd, Jonathan Dietz, and John Lekki: “Studies on a Time-Energy Entangled Photon Pair Source and Superconducting Nanowire Single-Photon Detectors for Increased Quantum System Efficiency,” SPIE Photonics West, San Francisco, California (Feb. 6, 2019).
- M. Kitagawa and M.Ueda: “Squeezed Spin States," Phys. Rev. A 47, 5138–5143 (1993).
- Daniel Gottesman, Thomas Jennewein, and Sarah Croke: “Longer-Baseline Telescopes Using Quantum Repeaters,” Phys. Rev. Lett. 109 (Aug. 16, 2012).
- Nicolas Gisin and Rob Thew: “Quantum Communication,” Nature Photonics, volume 1, pp. 165–171 (2007).
- H. J. Kimble: “The Quantum Internet,” Nature, volume 453, pp. 1023–1030 (June 19, 2008).
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- Ian, Nemitz, Jonathan Dietz, Evan Katz, Brian Vyhnalek, and Benjamin Child: “Bell Inequality Experiment

for a High Brightness Time-Energy Entangled Source," SPIE Photonics West, San Francisco, CA, (March 1, 2019).