NASA STTR 2020 Phase I Solicitation

T8.06 Quantum Sensing and Measurement

Lead Center: GSFC

Participating Center(s): GRC, JPL

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

Scope Title
Quantum Sensing and Measurement

Scope Description

This Quantum Sensing subtopic calls for proposals using quantum systems to achieve unprecedented measurement sensitivity and performance, including quantum-enhanced methodologies that outperform their classical counterparts. Shepherded by advancements in our ability to detect and manipulate single quantum objects, the so called "Second Quantum Revolution" is upon us. The emerging quantum sensing technologies promise unrivaled sensitivities and are potentially game changing in precision measurement fields. Significant gains include technology important for a range of NASA missions such as: efficient photon detection, optical clocks, gravitational wave sensing, ranging, and interferometry. Atom Interferometry and Quantum Communication focused proposals should apply to those specific subtopics and are not covered in this Quantum Sensing and Measurement subtopic.

Specifically identified applications of interested include quantum sensing methodologies achieving the optimal collection light for photon-starved astronomical observations, quantum-enhanced ground penetrating radar, and quantum-enhanced telescope interferometry.

- Superconducting Quantum Interference Device (SQUIDs) systems for enhanced multiplexing factor reading out of arrays of cryogenic energy-resolving single-photon detectors, including the supporting resonator circuits, amplifiers, and room temperature readout electronics.
- Quantum light sources capable of efficiently and reliably producing prescribed quantum states including entangled photons, squeezed states, photon number states, and broadband correlated light pulses. Such entangled sources are sought for the vis-IR and in the microwave entangled photons sources for quantum ranging and ground penetrating radar.
- On-demand single photon sources with narrow spectral linewidth are needed for system calibration of single photon counting detectors and energy-resolving single-photon detector arrays in the MIR, NIR, and visible. Such sources are sought for operation at cryogenic temperatures for calibration on the ground and aboard space instruments.

References

- 2019 NASA Fundamental Physics and Quantum Technology Workshop. Washington DC April 8-10, 2019.
- Quantum Communication, Sensing and Measurement in Space, Team Leads: Erkmen, Shapiro, and Schwab 2012
    - http://kiss.caltech.edu/final_reports/Quantum_final_report.pdf
- National Quantum Initiative Act:
    - https://www.congress.gov/congressional-report/115th-congress/house-report/950/1
    - https://www.congress.gov/congressional-report/115th-congress/senate-report/389
    - https://www.lightourfuture.org/getattachment/7ad9e04f-4d21-4d98-bd28-e1239977e262/NPI-Recommendations-to-HSC-for-National-Quantum-Initiative-062217.pdf
- European Union Quantum Flagship Program: https://qt.eu
- UK National Quantum Technologies Programme http://uknqt.epsrc.ac.uk
- DLR Institute of Quantum Technologies https://www.dlr.de/qt/en/desktopdefault.aspx/tabid-13498/23503_read-54020/
- C.?L. Degen, F. Reinhard, and P. Cappellaro, Quantum Sensing, Rev. Mod. Phys. **89**, 035002 (2017).

Expected TRL or TRL range at completion of the project: 2 to 4

Desired Deliverables of Phase II

Prototype, Analysis, Research

Desired Deliverables Description

NASA is seeking innovative ideas and creative concepts for science sensor technologies using quantum sensing techniques. The proposals should include results from designs and models, proof-of-concept demonstrations and prototypes showing the performance of the novel quantum sensor.

State of the Art and Critical Gaps

Sources for entangled photons.

Quantum dot source produced entangled photons with a fidelity of 0.90, a pair generation rate of 0.59, a pair extraction efficiency of 0.62, and a photon indistinguishability of 0.90 simultaneously. (881 nm light) at 10 MHz. Wang Phys. Rev. Lett. 122, 113602 2019.

Spectral brightness of 0.41 MHz/mW/nm for multi-mode and 0.025 MHz/mW/nm for single mode coupling. Jabir *Scientific Reports* **volume 7**, Article number: 12613 (2017).

Higher brightness and multiple entanglement and heralded multiphoton entanglement and boson sampling sources. Sources that produce photon number states or Fock states are also sought for various applications including energy-resolving single photon detector applications.

For energy resolving single photon detectors current state of the art multiplexing can achieve kilopixel detector arrays which with advances in microwave SQUID mux can be increased to megapixel arrays. (Morgan Physics Today 71, 8, 28 (2018)).

Relevance / Science Traceability

Quantum technologies enable a new generation in sensitivities and performance. Including atomic clocks and ultra-precise sensors with applications ranging from natural resource exploration and biomedical diagnostic to navigation.

HEOMD - Astronaut Health Monitoring.

SMD - Earth, Planetary and Astrophysics including imaging spectrometers on a chip across the electromagnetic spectrum from X-ray through the IR.

STMD - Game changing technology for small spacecraft communication and navigation (optical communication, laser ranging, gyroscopes).

STTR- Rapid increased interest.

Space Technology Roadmap - 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, and 14.3.3.