Opportunity Title: Quantum sensing and readout with cavity quantum phonodynamics
Opportunity Reference Code: IC-18-29

Organization Office of the Director of National Intelligence (ODNI)

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Complete your application – Enter the rest of the information required for the IC Postdoc Program Research Opportunity. The application itself contains detailed instructions for each one of these components: availability, citizenship, transcripts, dissertation abstract, publication and presentation plan, and information about your Research Advisor co-applicant.

Additional information about the IC Postdoctoral Research Fellowship Program is available on the program website located at: https://orau.org/icpostdoc/.

If you have questions, send an email to ICPostdoc@orau.org. Please include the reference code for this opportunity in your email.

Application Deadline 3/12/2018 11:59:00 PM Eastern Time Zone

Description **Research Topic Description, including Problem Statement:**

- The goal of this effort is to realize strong coupling between phonons and semiconductor qubits (i.e., defects, donors, or quantum dots) in the quantum regime and to explore the application of such systems to quantum sensing and quantum information technology. Cavity-quantum electrodynamics (cQED) refers to the interaction of a single-mode of the electromagnetic field with a dipole emitter. cQED has provided new ways of controlling photons and matter (e.g., atoms, qubits, etc.) in both atomic and solid state systems. Phonons, on the other hand, are more suitable for some tasks than photons due to their slower speeds and smaller wavelengths (e.g., for signal processing, sensing, or nanoscale imaging). The deformation potential can be very large in semiconductors leading to a strong intrinsic electron-phonon interaction. Phonons can also be incredibly long-lived in high quality crystals. These facts led us to propose a sound-based analogue of cavity-QED, cavity quantum phonodynamics in silicon [1,2], although similar physics can be realized in other crystals such as diamond or germanium. Such strong, resonant coupling between a coherent phonon and a matter two-level system leading to the so-called phoniton in analogy with the light-matter polariton has yet to be realized. More importantly, insufficient attention has been paid to the potential of such systems for qubit readout in the context of quantum sensing for example. It has long been known that defects in crystals can be exceptional sensors for electromagnetic fields, temperature, and other environmental parameters. Yet, unlike the NV center in diamond, many defects are not accessible by light to be "read out". In silicon, for example, the indirect bandgap nature of the crystal precludes optical access. Lasers also impose constraints on system design. Because sound couples so strongly to electrons (or holes) in solids and thus to certain defect or donor transitions, phonons can potentially be used as the intermediary to readout or control qubit sensors or as an intermediary between solid-state qubits and optical photons.

[1] Phys. Rev. B 88, 064308 (2013)

[2] Phys. Rev. Lett. 107, 235502 (2011)

Example Approaches:

The aim of this research is to advance the state of the art in phonon-matter systems at the quantum scale, particularly experimental demonstration of systems that offer new functionality over previous systems. Proposals could address one or more of the following questions or goals:

- Can coupling sound to semiconductor defects or qubits enable novel forms of readout or control?
- What types of semiconductor materials and cavity designs are best suited for realizing strong phonon-qubit coupling?
- How high can temperature be and still enable useful functionality? Particularly, can methods of phonon bandgap engineering or optical cooling allow for effective device temperature below ambient?
- Can phonon-qubit physics enable transduction of spin qubits to optical photons non-invasively? And, without needing to be mediated by microwave photons?
- What is the best way to generate and detect phonons in non-piezoelectric materials like silicon?
- Can resonant strong coupling (full hybridization) be achieved at the single photon level with a semiconductor qubit or defect?

Qualifications

Postdoc Eligibility

- U.S. citizens only
- Ph.D. in a relevant field must be completed before beginning the appointment and within five years of the application deadline
- Proposal must be associated with an accredited U.S. university, college, or U.S. government laboratory
- Eligible candidates may only receive one award from the IC Postdoctoral Research Fellowship Program.

Research Advisor Eligibility

- Must be an employee of an accredited U.S. university, college or U.S. government laboratory
- Are not required to be U.S. citizens

Eligibility Requirements

- **Citizenship:** U.S. Citizen Only
- **Degree:** Doctoral Degree.
- **Discipline(s):**
  - **Chemistry and Materials Sciences** (12)
  - **Communications and Graphics Design** (6)
  - **Computer, Information, and Data Sciences** (16)
  - **Earth and Geosciences** (21)
  - **Engineering** (27)
  - **Environmental and Marine Sciences** (14)
  - **Life Health and Medical Sciences** (45)
  - **Mathematics and Statistics** (10)
  - **Other Non-Science & Engineering** (5)
  - **Physics** (16)
  - **Science & Engineering-related** (1)
  - **Social and Behavioral Sciences** (28)