[6450-01-P]

DEPARTMENT OF ENERGY

Notice of Intent and Request for Information: Quantum Information Science Centers

AGENCY: Offices of Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES), and High Energy Physics (HEP), Office of Science, Department of Energy (DOE).

ACTION: Notice of intent (NOI) and request for information (RFI).

SUMMARY: The Office of Science (SC) in the Department of Energy (DOE) intends to issue a Funding Opportunity Announcement (FOA) in Fiscal Year (FY) 2020 entitled "Quantum Information Science Centers," subject to the availability of appropriated funds. The participating program offices in SC invite interested parties to provide input on the topic areas, organization, requirements, review criteria, and assessment process to be described in this FOA.

DATES: Written comments and information are requested on or before [**INSERT DATE 45 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER***].

ADDRESSES: The DOE Office of Science is using the *http://www.regulations.gov* system for the submission and posting of public comments in this proceeding. All comments in response to this notice are therefore to be submitted electronically through *http://www.regulations.gov*, via the web form accessed by following the "Submit a Formal Comment" link near the top right of the *Federal Register* web page for this notice.

FOR FURTHER INFORMATION CONTACT: Requests for additional information may be submitted to Dr. Ceren Susut, (301) 903-0366, *QIS-Centers-RFI@science.doe.gov*.

SUPPLEMENTARY INFORMATION: Quantum information science (QIS) – the ability to exploit intricate quantum mechanical phenomena to create fundamentally new ways of obtaining and processing information – is at the threshold of a revolution. The rapid progress in this field

promises profound impacts in the coming decades on scientific discovery and technological innovation. In competitive terms, QIS is creating potentially transformative opportunities and technically complex, urgent challenges for the Nation, as growing international interest and investments fuel accelerating global activity in quantum science and technology. These opportunities and challenges demand a long-term, large-scale commitment of U.S. scientific and technological resources to multi-institutional, multidisciplinary efforts that are commensurate with world leadership in this pivotal field. This has been recognized on the Federal level with the recent issuance of a *National Strategic Overview for Quantum Information Science* in September 2018[1] and the subsequent enactment of the *National Quantum Initiative Act* in December 2018.[2] DOE, with its unparalleled breadth and depth of activity as the Nation's leading supporter of basic research in the physical sciences, and drawing on the unique expertise and capabilities of the DOE National Laboratory complex, has key resources and infrastructure that are integral to this strategic and targeted U.S. initiative. DOE SC's activities in QIS are driven by its mission needs and connect to the specific foci of its subsidiary program offices, and will be enhanced by strategic partnerships and collaborations among SC program offices and between SC and other Federal agencies.

The U.S. Department of Energy's Office of Science (SC) hereby announces its intent to issue a FOA seeking to establish two or more multidisciplinary Quantum Information Science Centers to perform research to address the opportunities and challenges referred to above and described in the referenced documents. This is a Notice of Intent (NOI) only. DOE-SC may issue a FOA as described herein, may issue a FOA that is significantly different than the FOA described herein,

[1] National Science and Technology Council publication, *https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf*
[2] Public Law 115-368, *https://www.congress.gov/115/bills/hr6227/BILLS-115hr6227enr.pdf*

or DOE-SC may not issue a FOA at all. In addition, DOE-SC seeks input from stakeholders regarding the potential FOA, including the topic areas, organization, requirements, review criteria, and assessment process of prospective QIS Centers. The information received in response to this RFI will inform and be considered by the Office of Science in program planning and development. Please be aware that this notice (NOI and RFI) *is not* a Funding Opportunity Announcement, a Request for Proposal, or other form of solicitation, or bid of DOE to fund potential research, development, planning, centers, or other activity.

Notice of Intent: The Office of Science (SC) intends to issue a Funding Opportunity Announcement (FOA) entitled "Quantum Information Science Centers" in FY 2020, subject to the availability of appropriated funds.

This FOA will seek applications for two or more DOE QIS Centers (referred to as "Centers") to support the National Quantum Initiative enacted by Congress in December 2018, and to accelerate the transformational advances in basic science and quantum-based technology.

The purpose of these Centers will be to push the current state-of-the-art science and technology toward realizing the full potential of quantum-based applications, from computing, to communication, to sensing. The interdisciplinary nature of the field, the reliance on complex, sophisticated, and precise physical arrangements in order to observe and utilize quantum behavior, and the potential for substantial economic consequences are the major drivers of the National Quantum Initiative. The SC QIS Centers, coupled with a robust core research portfolio stewarded by the individual SC programs, will create the ecosystem needed to foster and

facilitate advancement of QIS with public benefits in national security, economic competitiveness, and leadership in scientific discovery.

The Centers will require highly collaborative research teams, spanning multiple scientific and engineering disciplines. It is anticipated that all types of domestic entities, including DOE/National Nuclear Security Administration (NNSA) Federally Funded Research and Development Center (FFRDC) contractors, will be eligible to apply as prime applicants, with the exception of other Federal agencies, non-DOE/NNSA FFRDC contractors, and certain nonprofit organizations engaged in lobbying. By bringing together top talent from across the full spectrum of research and development (R&D) performers—including universities, private industry, non-profits, and National Laboratories—the Centers will serve as world- leading R&D centers in Quantum Information Science.

Successful QIS Centers will be expected to demonstrate the following attributes:

- Attack a major challenge of sufficient difficulty and urgency to warrant a large, multi-institutional, multi-disciplinary effort over a significant time period. The potential impact of success must be large.
- Advance both science and technology in its focus area, accelerating progress from discovery to prototypical technology and use-inspired research, taking advantage of co-design approaches that integrate these stages and incorporate feedbacks between them.
- Achieve self-integration across the science and engineering disciplines that it spans to accomplish its mission; in its vein, SC expects the center to catalyze integration in the wider scientific/technical community related to its focus area.

- Utilize well-structured "projectized" approach with clearly defined near, intermediate, and long-term goals for assessing progress.
- Led by a team of experts in the multiple disciplines that blend basic scientific research, early stage technology development, engineering design, and prototype development, drawing on expertise from DOE labs, academic institutions, and industry as appropriate.
- Serve as national resources, conveners, and leaders in their technical domains.

The QIS Center effort is being jointly supported by multiple programs within DOE SC in recognition that the rapidly advancing progress in QIS is inherently multidisciplinary and interdisciplinary. QIS Centers are intended to complement the existing base research and other activities within individual program offices, and to represent coherent efforts beyond the scope of what would normally be supported by those programs individually.

Request for Information: The objective of this request for information is to gather input about the topic areas, organization, requirements, review criteria, and assessment process for prospective QIS Centers, in order to inform the DOE SC formulation of the corresponding FOA.

Technical Areas of Interest that have been identified for the QIS Centers include the following. Subsidiary bullets provide examples of subtopics that would be valuable to address, but these lists should not be considered exhaustive. *It is expected that each Center will address the mission needs of more than one DOE SC program office, integrate elements from multiple such topical areas, and have national scope and impact.*

- **Quantum Communication**

- Requirements for materials research for quantum communication applications
- Requirements for scalable and adaptable quantum network infrastructures designed to support the transmission of diverse types of quantum information
- Fundamental limits on information transfer in quantum systems
- Communication techniques and tools exploiting entanglement
- Test facilities to support network development and test

- **Materials and Chemistry for QIS Systems and Applications**
  - Fundamental theory of materials and molecular systems for quantum applications
  - Research leading to materials and molecular systems that control quantum phenomena to meet quantum communication, computation, and sensor requirements
  - Fundamental research on device physics for next generation QIS systems, including interface science and modeling of materials performance
  - Synthesis, characterization, and fabrication research for quantum materials and processes, including integration in novel device architectures
- **Qubit Devices and Sensors for QIS Applications and for Research Supported by SC**
  - Development of requirements for qubit devices for quantum sensor and detector applications
  - Development of devices to meet quantum communication or quantum computation application requirements
  - Progress on quantum-enabled imaging devices or systems, such as for soft-matter imaging, magnetic mapping, or improved microscopy
  - Development of integration, interface, transduction, and control schemes for quantum device arrays

- Improving device coherence, qubit lifetime, and other performance parameters
- Modeling of device and controls performance
- Synthesis and fabrication of engineered quantum devices

- **Quantum Emulation and Computing**
  - System architecture selection and optimization for problem domains studied by SC-supported investigators
  - Qubit device requirements to match architectural plans
  - Programming paradigms and algorithms on selected architectures
  - Programmable modular quantum emulator development addressing uses for SC-supported researchers (incorporating requirements input from all SC offices), including analog simulators
  - System integration of emulation, quantum communication, and quantum compute systems from device/array level up
  - System testbeds for performance measurement and algorithm development; modeling and integration of computing/communication
  - Fundamental limits of quantum computation
- **Quantum Foundries**
  - Synthesis of quantum materials, structures, and devices with atomic precision
  - Fabrication and integration of photon and spin qubit systems
  - Advanced instrumentation and tool development for quantum computers, sensors, and metrology
  - Facilities to support device test, packaging, and integration

The participating program offices of DOE SC are specifically interested in receiving input pertaining to any of the following questions:

(1) Topical Areas and Scope:

Are the topic areas listed above adequately defined? Should DOE SC consider removing, or consolidating, any of the subtopics in these areas? Conversely, are there aspects of quantum information science that are closely tied to DOE SC missions but missing from the above topics? If so, are there other subtopics or components that should be considered for inclusion under the listed topic areas? What is the appropriate period of performance for the proposed Centers? How might the DOE SC program offices consider evaluating or weighting proposed Centers that respond to multiple topic areas?

(2) Collaboration and Partnerships:

What partnership and collaboration models would be most effective in furthering QIS Center goals? What is the appropriate role of industry in the proposed Centers? What approaches or concerns with respect to intellectual property rights should be considered for the envisioned Centers? What external resources or capabilities are valuable or necessary for such QIS Centers?

(3) Management and Organization:

What are effective models for management of Centers of the proposed scale and scope? How should Centers be managed to promote the desired synergy of their participants and disciplines? What extent of co-location is optimal, or necessary, for a QIS Center to be effective and coherent?

(4) Assessment and Criteria for Success:

What kinds of metrics or criteria would be useful in measuring the success of a QIS

Center and its impact on the field? What metrics or criteria should be used to assess the extent to which the proposed Centers are using an effective co-design approach that integrates the stages from scientific discovery to use-inspired research and incorporates feedbacks between them?

(5) National Impact and Contribution to/Alignment With NQI (and) Unique DOE Role and Contribution:

How can these QIS Centers contribute to advancement of the field in ways that are not possible with other existing or envisioned centers (supported by DOE, other Federal agencies, or non-Federal sources)? How do they complement and build on existing research programs and facilities supported by ASCR, BES, and HEP?

(6) Other:

What are key obstacles, impediments, or bottlenecks to progress by and success of interdisciplinary QIS Centers? Are there other factors, issues, or opportunities, not addressed by the questions above, which should be considered in the establishment of QIS Centers by DOE SC?

Comments containing references, studies, research, and other empirical data that are not widely published should include copies of the referenced materials. Note that comments will be made publicly available as submitted. Any information that may be confidential and exempt by law from public disclosure should be submitted as described below.

Confidential Business Information: Pursuant to 10 CFR 1004.11, any person submitting information he or she believes to be confidential and exempt by law from public disclosure should submit via email: one copy of the document marked "confidential" including all the

information believed to be confidential, and one copy of the document marked "non-confidential" with the information believed to be confidential deleted. DOE will make its own determination about the confidential status of the information and treat it according to its determination. Factors of interest to DOE when evaluating requests to treat submitted information as confidential include: (1) a description of the items, (2) whether and why such items are customarily treated as confidential within the industry, (3) whether the information is generally known by or available from other sources, (4) whether the information has previously been made available to others without obligation concerning confidentiality, (5) an explanation of the competitive injury to the submitting person which would result from public disclosure, (6) when such information might lose its confidential character due to the passage of time, and (7) why disclosure of the information would be contrary to the public interest.

Signed in Washington, DC, on May 14, 2019

J. Stephen Binkley,
Deputy Director for Science Programs,
Office of Science.
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