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6450-01-P

DEPARTMENT OF ENERGY

Preparing a Future Workforce in Quantum Information Science

AGENCY: Office of Science, Department of Energy.

ACTION: Request for information (RFI).

SUMMARY: The rapidly emerging field of Quantum Information Science (QIS) has the potential to produce innovations in quantum computing, simulation, communication, sensing and other technologies which are critical to our nation's future economic and national security. As a new and strongly technology-oriented field, QIS requires a well-trained workforce to fill positions ranging from research and development to design and manufacturing. The Office of Science in the U.S. Department of Energy (DOE) invites input from higher education institutions on approaches needed to prepare students for careers related to QIS, including identification of opportunities where DOE's network of national laboratories could assist in training the future scientific and technological QIS workforce. Higher education institutions, including public and private universities, Historically Black Colleges and Universities (HBCUs), Minority Serving Institutions, community colleges, and emerging research institutions (defined as "an institution of higher education with an established undergraduate or graduate program that has less than$50,000,000 in Federal research expenditures" [CHIPS and Science Act]), are especially encouraged to provide input.

DATES: Responses to the RFI must be received by [**INSERT DATE 45 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER***].

ADDRESSES: DOE is using the *www.regulations.gov* system for the submission and posting of public comments in this proceeding. All comments in response to this RFI are, therefore, to be submitted electronically through *www.regulations.gov* via the web form accessed by following the "Submit a Formal Comment" link.

FOR FURTHER INFORMATION CONTACT: Questions may be submitted to *sc.wdts@science.doe.gov* or Ping Ge at (202) 287-6490.

SUPPLEMENTARY INFORMATION:

Background

QIS is a rapidly developing area of science and technology (S&T) and advances in this area have the potential of profoundly impacting the U.S. economy and national security, through innovations in quantum computing, simulation, communication, and sensing. Recognizing the great potential of QIS, and aware of the growing international competition in this promising new area of S&T, Congress passed the National Quantum Initiative Act in 2018. DOE's Office of Science (SC) is an integral partner in the National Quantum Initiative (NQI) and has supported a range of research programs in QIS since 2016 (*https://science.osti.gov/Initiatives/QIS*), including establishing 5 National QIS Research Centers (NQISRC) (*https://science.osti.gov/Initiatives/QIS/QIS-Centers/)*, as well as single- and multi-investigator research projects.

As part of the 2021 Consolidated Appropriations Act, Congress directed DOE to establish a working group comprised of representatives from SC, DOE national laboratories, and universities to assess how to assist institutions of higher education in developing curricula to promote the next generation of scientists working in QIS at all levels, ranging from the manufacture and troubleshooting of quantum information devices, to the design, research and development of novel QIS technologies and fundamental science. A workshop *(https://science.osti.gov/wdts/STEM-Resources/Quantum-Workforce-Development-in-DOE*) was held in early 2021 which recognized that two communities should contribute to curriculum development for QIS, the "demand side" and the "supply side." The demand side is composed of industries supporting development and manufacturing of technologies based on QIS, as well as government laboratories and universities conducting research and development in QIS. It is in this demand side that DOE has its most important role. The 17 DOE national laboratories are a

large and growing employer of QIS scientists, engineers, and technical professionals. The supply side is primarily composed of degree-granting institutions and the National Science Foundation (NSF), which directly supports educational research. In addition to DOE's role in defining the knowledge base, skills, and experience needed to participate in DOE-funded QIS activities, DOE contributes to the supply side via the training of QIS scientists, engineers, and technical professionals through DOE's portfolio of research internships, summer schools, and fellowships for all educational levels, ranging from high school to established faculty (*see* for example: *https://science.osti.gov/wdts*). In addition, students receive training as part of QIS research supported by DOE, including the NQISRCs and single- and multi-investigator research projects. Guided by the understanding of DOE's dual role in both the demand side and supply side, SC surveyed QIS experts from across the DOE national laboratories to identify: 1) the essential skills needed for preparing students for future QIS careers and 2) potential approaches in which the national laboratories could assist educational institutions with developing those skills. Their responses form the basis of the input requested in questions 3 and 4 below and are summarized in the document at *https://science.osti.gov/-/media/wdts/excel/Appendix---Undergraduate-and-Graduate-Essential-QIS-Skills.xlsx*. Based on these findings, SC now seeks input from higher education institutions to gain further understanding of how SC resources, especially at the DOE national laboratories, can uniquely contribute to preparing a future QIS workforce in partnership with educational institutions.

This RFI seeks input from higher education institutions on the state and needs of current educational and training programs for supporting the preparation of scientists, engineers, and technical professionals in QIS. Specifically, the DOE Office of Science seeks feedback on which essential skills required for training a new QIS workforce are likely to be provided by higher education institutions, and which could be provided or enriched by training opportunities and resources at DOE national laboratories. Higher education institutions include public and

private universities, Historically Black Colleges and Universities (HBCUs), Minority Serving Institutions (MSIs), community colleges, and emerging research institutions.

Informed by the feedback collected from this RFI, the DOE Office of Science will develop a plan to complement workforce development training provided by higher education institutions in preparing their students for a future workforce in QIS. This plan will augment DOE's existing portfolio of research internships, summer schools, and fellowships for all educational levels, ranging from high school to established faculty.

Questions for Input

This RFI will provide a foundation for DOE to develop a plan to complement training provided by higher education institutions to prepare students for a future scientific and technological workforce in QIS. The RFI is a solicitation for public input to help identify approaches through which DOE can contribute to the training of students for future careers in QIS. Higher education institutions, including public and private universities, HBCUs, MSIs, community colleges, and emerging research institutions, are especially encouraged to provide input.

Responses are requested for the 8 questions listed below. Respondents may provide input regarding any or all of these questions. Each response should be numbered to match the specific question listed.

(1) Briefly describe the types of training related to QIS offered at your institution at the undergraduate and/or and graduate levels, including coursework and research experiences.

(2) Does your institution offer degrees specific to QIS or QIS-related fields? Consider each of the following degree types in your response, and specify for which QIS or QIS-related field(s) the degree type is offered:

- Certificate
- Associate Degree
- Bachelor's Degree
- Master's Degree

- Doctoral Degree
- Other Degree (please specify)

(3) The lists below describe the top ten skills needed for (3a) undergraduate students and (3b) graduate students who are preparing for careers in QIS, as identified in a survey of QIS experts at DOE national laboratories. The detailed description for each skill at a specific academic level can be found at *https://science.osti.gov/-/media/wdts/excel/Appendix---Undergraduate-and-Graduate-Essential-QIS-Skills.xlsx*.

For each skill and academic level, please identify those that are **offered** by your institution (O), **not** offered by your institution with **no interest to offer** in the future (N), **not** currently offered by your institution but planned to be **offered in the future** (F), or **not** offered by your institution due to **resource constraints** (RC) such as lack of people (time/expertise) or equipment.

(3a) Top ten skills essential for an **undergraduate** student to obtain a position in QIS.

- Apply existing algorithms to specific problems
- Apply statistical methods for data analysis
- Code
- Debug code
- Implement existing algorithms on hardware
- Troubleshoot experiments in the laboratory
- Understand cryogenic systems
- Understand the Hamiltonian description of a system
- Use electronics to control and power hardware
- Use qubit hardware

(3b) Top ten skills essential for a **graduate** student to obtain a position in QIS.

- Apply statistical methods for data analysis
- Code

- Debug code
- Develop new algorithms
- Troubleshoot experiments in the laboratory
- Understand cryogenic systems
- Understand material properties relevant to specific hardware
- Understand the Hamiltonian description of a system
- Use electronics to control and power hardware
- Use laser systems

(4) The below list summarizes the responses to the survey by QIS experts across the DOE national laboratories about potential training opportunities that could be provided at national laboratories. As DOE begins to develop internships and other training programs specifically designed for QIS, input is needed on activities that would be most valuable to the students and complement training offered at your institutions. For (4a) undergraduate and (4b) graduate students, please identify: (1) how useful the proposed training opportunities at the DOE national laboratories would be in assisting your institution in equipping students with essential skills for the future QIS workforce (High, Medium, or Low) and (2) the likelihood of your institution encouraging student participation in the proposed opportunities, if they were offered by the DOE national labs (Likely, or Unlikely).

(4a) Possible training opportunities at national laboratories for **undergraduate** students.

Short courses/Summer schools:

- Apply statistical methods for data analysis
- Apply existing algorithms to specific problems
- Code
- Implement existing algorithms on hardware
- Understand the Hamiltonian description of a system
- Use qubit hardware

Lab-based experiences, e.g., internships:

- Debug code
- Troubleshoot experiments in the lab
- Understand cryogenic systems
- Use electronics to control and power hardware

(4b) Possible training opportunities at national laboratories for **graduate** students.

Short courses/Summer schools:

- Apply statistical methods for data analysis
- Code
- Debug code
- Understand the Hamiltonian description of a system

Lab-based experiences, e.g., internships:

- Develop new algorithms
- Troubleshoot experiments in the lab
- Understand cryogenic systems
- Understand material properties relevant to specific hardware
- Use electronics to control and power hardware
- Use laser systems

(5) Are there mechanisms (either formal or informal) by which your institutions could acknowledge the participation in a training activity at DOE national laboratories? Please select all mechanisms that apply to your institution(s):

- Recognizing completion for a short course/summer school offered by DOE national laboratories as a proof of knowledge and skill acquisition
- Giving credits for a short course/summer school offered by DOE national laboratories
- Accepting laboratory-based research internships as an alternative Capstone project for a course at home institution

- Other (please explain)

(6) Through what approaches can DOE best support institutions in adding QIS content to existing curriculum or offering new courses in Quantum areas? Please rank the approaches that you select, including other approaches you have added.

Please select all approaches that apply to your institution(s):

- Offering a series of open source, online, short courses on QIS fundamentals developed by DOE scientists and engineers
- Supporting faculty with research and training opportunities at DOE laboratories to build knowledge and teaching capacity
- Having DOE scientists/engineers provide special topic lectures at a university
- Other (please explain)

(7) The hands-on training opportunities at the DOE national laboratories, such as laboratory-based experiences and short courses on technical knowledge and skills, offer students and faculty unique possibilities for their professional development and career preparation that are often not available at home institutions. Please indicate to what extent (High, Medium, or Low) the opportunities listed below can contribute to preparing your students to enter the future QIS workforce.

Benefits for preparing students:

- Access to the unique QIS equipment, facilities, and instruments available at the DOE national labs.
- Working side-by-side with world leading QIS experts
- Working in a multi-disciplinary team to solve complex real-world problems
- Test-driving career options and building network with scientific, technical, and administrative staff at the DOE national labs

(8) Please describe any additional types of training opportunities that DOE might provide or identify any models that you are aware of that could be used for preparing students at your

institution to enter the future QIS workforce. For each opportunity or model, please include the following information:

- Academic level (undergraduate or graduate);
- Description of the opportunity or model, and if there is an existing program that provides such an opportunity (please provide name and website of existing program, if available).

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.

Signing Authority

This document of the Department of Energy was signed on February 22, 2023, by Asmeret Asefaw Berhe, Director, Office of Science, pursuant to delegated authority from the Secretary of Energy. The document with the original signature and date is maintained by DOE. For administrative purposes only, and in compliance with requirements of the Office of the Federal Register, the undersigned DOE Federal Register Liaison Officer has been authorized to sign and submit the document in electronic format for publication, as an official document of the

Department of Energy. This administrative process in no way alters the legal effect of this document upon publication in the *Federal Register*.

Signed in Washington, DC, on March 1, 2023.

Treena V. Garrett,
Federal Register Liaison Officer,
U.S. Department of Energy.

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