Request for Information (RFI): Multi-qubit Quantum Coherent Operations

Reference: IARPA-RFI-09-01

Posted Date: Apr 10, 2009
Response Date: Apr 24, 2009

Synopsis

The Intelligence Advanced Research Projects Activity (IARPA) often selects its research efforts through the Broad Agency Announcement (BAA) process. This request for information (RFI) is intended to provide information relevant to a possible future IARPA program, so that feedback from potential participants can be considered prior to the issuance of a BAA. Respondents are invited to provide comments on the content of this announcement to include suggestions for improving the scope of a possible solicitation to ensure that every effort is made to adequately address the scientific and technical challenges described below. Responses to this request may be used to support development of, and subsequently be incorporated within, a future IARPA Program BAA and therefore must be available for unrestricted public distribution. The following sections of this announcement contain details of the scope of technical efforts of interest, along with instructions for the submission of responses.

Background & Scope

This year marks the fifteenth anniversary of Peter Shor's seminal work[1] demonstrating that a quantum computer can efficiently solve problems of great intrinsic and practical interest for which there is no known efficient solution on a classical computer. During the following two years, he and others showed[2] how quantum error correction provides a means to create a reliable quantum information processor out of faulty components. Within a few years of Shor's initial paper, several quantum systems of fundamentally different character were proposed[3] as the basic units of quantum information memory and processing, *i.e.* as qubits. The intervening years have witnessed steady progress in the basic understanding and operation of these qubits.

IARPA is requesting information about challenges facing coherent operations of multi-qubit quantum information processing systems. Responses should articulate the specific technical difficulties that face, or will soon face, attempts to construct and operate small quantum information processors, and suggest aggressive but realizable paths toward overcoming them. A particular qubit technology should be addressed, although a hybrid

system is acceptable if its advantages demonstrably outweigh its disadvantages. Qubit systems of interest are those that have clearly demonstrated complete single qubit control, and for which a two qubit coupling, with a clear path toward a scalable universal two qubit gate, has already been demonstrated, or for which this two qubit capability has been well described, has a sound theoretical basis, and for which experimental validation is imminent. There must also be no fundamental roadblocks standing in the way of constructing quantum processors with many of the selected qubit.

Systems of interest must be able to demonstrate arbitrary and controllable entanglement, and are amenable to the circuit model of quantum computing (to include measurement based protocols such as the cluster state approach). Some of the physical systems of particular interest are: ions in surface traps, superconducting Josephson junction circuits, trapped neutral atoms, spins in semiconductor quantum dots, and photons in integrated optical components. Of less interest are solutions that involve distributed quantum systems and so-called Type II quantum processing systems, or early research not yet ready for scaling to implement multi-qubit operations.

Respondents are encouraged to be as succinct as possible while providing specific information that addresses the following questions:

- What is the physical qubit(s)?
- What are the compelling reasons to use this qubit(s) in relation to coherent operations of multi-qubit quantum information processing systems?
- What is known about this qubit(s) in terms of experimental and theoretical results? Please provide suitable references.
- What are the appropriate metrics to measure performance of a multi-qubit quantum processor?
- What are the challenges facing coherent operations of multi-qubit quantum processing systems starting from the known status of this qubit(s)?
- What solutions are being suggested to overcome these challenges?
- What is the timescale needed to demonstrate these solutions?
- What are the resources needed?
- Are supporting technologies readily available?

The responses to this RFI will be used to help in the planning of a one and a half day workshop on multi-qubit quantum processing, the result of which may justify a multi-year competitive program. The selection of topics and setting of the agenda of this workshop will be informed by the responses. It is anticipated that this workshop will be held in early May, 2009. A separate workshop announcement will be posted with further details.

Preparation Instructions to Respondents

IARPA solicits respondents to submit ideas related to this topic for use by the Government in formulating a potential program. IARPA requests that submittals briefly and clearly describe the potential approach or concept, outline critical technical issues, and comment on the expected performance, robustness, and estimated cost of the proposed approach. This announcement contains all of the information required to submit a response. No additional forms, kits, or other materials are needed.

IARPA appreciates responses from all capable and qualified sources from within and outside of the US. **Because IARPA is interested in an integrated approach, responses from teams with complementary areas of expertise are encouraged.** Responses have the following formatting requirements:

1. A one page cover sheet that identifies the title, organization(s), respondent's technical and administrative points of contact - including names, addresses, phone and fax numbers, and email addresses of all co-authors, and clearly indicating its association with IARPA-RFI-09-01;
2. A substantive, focused, one-half page executive summary;
3. A description (limited to 5 pages in minimum 12 point Times New Roman font, appropriate for single-sided, single-spaced 8.5 by 11 inch paper, with 1-inch margins) of the technical challenges and suggested approach(es);
4. A list of citations (any significant claims or reports of success must be accompanied by citations, and reference material MUST be attached);
5. Optionally, a single overview briefing chart graphically depicting the key ideas.

Submission Instructions to Respondents

Responses to this RFI are due no later than 4:00pm, Local Time, College Park, MD on 24 April 2009. All submissions must be electronically submitted to dni-iarpa-rfi-09-01@ugov.gov as a PDF document. Inquiries to this RFI must be submitted to dni-iarpa-rfi-09-01@ugov.gov. Do not send questions with proprietary content. No telephonic inquiries will be accepted.

DISCLAIMERS AND IMPORTANT NOTES

This is an RFI issued solely for information and new program planning purposes and does not constitute a solicitation. Respondents are advised that IARPA is under no obligation to acknowledge receipt of the information received, or provide feedback to respondents with respect to any information submitted under this RFI.

Responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. Respondents are solely responsible for all expenses associated with responding to this RFI. It is the respondents' responsibility to ensure that the submitted material has been approved for public release by the organization that funded whatever research is referred to in their response.

The Government does not intend to award a contract on the basis of this RFI or to otherwise pay for the information solicited, nor is the Government obligated to issue a solicitation based on responses received. Neither proprietary nor classified concepts or information should be included in the submittal. Input on technical aspects of the responses may be solicited by IARPA from non-Government consultants/experts who are bound by appropriate non-disclosure requirements.

---

[1] P. Shor, *Symposium on Foundations of Computer Science*, (1994); P. Shor, *SIAM Journal of Computing* **26,** 1484-1509 (1997).

[2] P. Shor, *Phys. Rev. A* **52**, R2493 - R2496 (1995); A. R. Calderbank and P. W. Shor, *Phys. Rev. A* **54**, 1098 (1996); A. M. Steane, *Phys. Rev. A* **54**, 4741 (1996).

[3] See for example: J. I. Cirac and P. Zoller, *Phys. Rev. Lett.* **74**, 4091 - 4094 (1995); G. K. Brennen *et al*, *Phys. Rev. Lett.* **82**, 1060 - 1063 (1999); D. Jaksch *et al*, *Phys. Rev. Lett.* **82**, 1975 - 1978 (1999); D. Loss and D. P. DiVincenzo, *Phys. Rev. A* **57**, 120 - 126 (1998); E. Knill *et al*, *Nature* **409**, 46-52 (2001); A. Schnirman *et al*, *Phys. Rev. Lett.* **79**, 2371 - 2374 (1997); D. V. Averin, *Solid State Communications*, **105**, 659-664 (1998); Y. Makhlin, *Nature* **398**, 305-307 (1999).