Feedback on Building the Foundation for Quantum Industry Event

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The "Building the Foundation for Quantum Industry Event" at NIST, Gaithersburg MD, on Oct. 5 was a great opportunity to convene the representatives from academia, industry, and government to discuss the opportunities and challenges for the research, development, and commercialization of quantum information science (QIS). The partners from the industry showed strong interests in the prospect of QIS, and the government representatives committed to continuing support in this domain. The participants, however, realized that a barrier between the academia and industry remains. In particular, the present QIS research is almost entirely driven by Federal grants while the involvement of the industry is quite weak. As such, it would be imperative to create a QIS ecological system that encompasses the academia, industry, and government. To do so, we should first identify near-term and long-term opportunities and challenges so that the government could formulate the funding strategies and policies to bridge the academia and the industry.

Opportunities

QIS promises unmatched performance in communication, sensing, security, and computing. In the last decade, significant advances in both the theoretical and experimental aspects of QIS have been achieved, but we have yet to witness a single widespread QIS-enabled technology that creates a major impact on the general populace. At this juncture, we should list emerging QIS-enabled technologies on various timescales to identify the areas that should have the highest priority for receiving Federal and industrial investments.

Technologies within 5-10 years

- Quantum-limited sensors for non-invasive and label-free biomedical and chemical sensing
- Nano-sensing materials and devices for high-precision magnetic, navigation, and inertial measurements
- High-rate (gigabit-per-second) quantum key distribution (QKD) networks over metropolitan-area distances (100 km)

Technologies within 10-15 years

- Small-scale quantum simulators for use in biomedicine, physics, and materials science
- Entanglement-based high-precision quantum sensors
- Quantum repeaters for medium-range (500-1000 km) secure data transmission and entanglement distribution in a network

Technologies within 15-20 years

- Universal quantum computers for use in big data, artificial intelligence, and internet of things
- A global quantum-communication network for intercontinental secure data transmission and entanglement distribution

The technology penetration into the market sectors of telecommunication, data services, encryptions, computing, transportation, defense, and security are some of the most anticipated outcomes. In fact, the underpinning QIS technologies will be demanded in the financial sector for tracing transactional breaches. The rapid advances in autonomous and connected vehicle

technology is also driving encryption and security related features through the supply-chain of automobile Industry and is further driving the discussion along the next generation of infrastructure that will need to be deployed.

Assessing the future impact of an emerging development would be difficult, but the following metric might be useful: V = (# of related papers published by industry per year) / (# of related papers published by academia in the last ten years). In a healthy ecological system, the academic and industrial involvements should be balanced, taking into account the time needed for technology transfer. In the areas belonging to applied sciences and engineering, the technologies with high V numbers are likely to drive the economy and create a major impact.

Challenges

Among these QIS-enabled technologies, quantum sensing would likely create a broad impact on a timescale of 10 years. The quantum-sensing devices would be compact, cost effective, and widely deployable and their high sensitivity, resolution, and acquisition rates would benefit a variety of fields ranging from biomedical imaging, to navigation, and to chemical sensing. The deployment of the quantum-sensing technology, however, calls for close collaborations with the conventional sensing fields. A challenge in this regard would be educating the workforces the essential knowledge of QIS.

QKD is another area that would create a market on a timescale of 5-10 years. The technology of QKD is readily available, but there are only future threats, contingent on the development of quantum computing, on the current security infrastructure. As such, the commercialization and deployment of QKD would largely rely on the Federal policies and standards. In countries such as China, the government fosters the commercialization of QKD by encouraging end users such as local government agents and banks [1, 2] to use QKD systems. Quantum communication by itself is broader than QKD. The community should investigate other quantum-communication technologies such as entanglement distribution and quantum repeaters to enable long-distance quantum communication.

Quantum computing is arguably the most promising application of QIS, but the number of qubits and the fidelity of quantum operations in state-of-the-art platforms remain several orders of magnitude lower than what would be needed by a full-up quantum computer. An extensive amount of engineering efforts would be needed to fill this huge gap. Another research focus as a viable route toward universal quantum computing would be exploring new materials, such as 2D and topological materials, that would underpin the next-generation platforms for scalable and robust quantum computing.

Funding Considerations

A consensus from the Event is that the government should help build up a sustainable QIS ecological system in the near future. To do so, the Federal investment should shift toward the QIS-enabled technologies that would have an impact on a relatively short timescale of 5-10 years. At present, quantum sensing and quantum communication are two areas likely to create a market within this timescale, and quantum simulation would become a useful tool for research and development in about 15 years. These areas should have the highest priority for Federal and industrial investments. Industry is an essential layer in the ecological system, but it should not only

encompass large companies like Google and Microsoft — QIS startup companies offer distinct opportunities for educated quantum scientists and engineers so they should become indispensable components of the ecological system too. In this regard, the government should consider providing priority seed funds for QIS startup companies. This could be achieved by special solicitation within SBIR/STTR funding mechanism and can involve or spread across multiple agencies for advancing and maturing the technology and manufacturability readiness levels related to the various facets of QIS.

References

[1] China's 'future-proof' crypto: We talk to firm behind crazy quantum key distribution network, Andrew Silver, The Register, 19 Jul 2017.
[2] China trial paves way for ‘unhackable’ communications network, Yuan Yang, The Financial Times, 10 Jul 2017.