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Picking up the quantum technology baton

Shivaji Sondhi R. Vijayaraghavan

Sandip Trivedi Umesh Vazirani

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With the Budget announcement providing direction, the stakeholders need to roll-out the national mission quickly

In the Budget 2020 speech, Finance Minister Nirmala Sitharaman made a welcome announcement for Indian science — over the next five years she proposed spending ₹8,000 crore (~ $1.2 billion) on a National Mission on Quantum Technologies and Applications. This promises to catapult India into the midst of the second quantum revolution, a major scientific effort that is being pursued by the United States, Europe, China and others. In this article we describe the scientific seeds of this mission, the promise of quantum technology and some critical constraints on its success that can be lifted with some imagination on the part of Indian scientific institutions and, crucially, some strategic support from Indian industry and philanthropy.

A timeline

Quantum mechanics was developed in the early 20th century to describe nature in the small — at the scale of atoms and elementary particles. For over a century it has provided the foundations of our understanding of the physical world, including the interaction of light and matter, and led to ubiquitous inventions such as lasers and semiconductor transistors. Despite a century of research, the quantum world still remains mysterious and far removed from our experiences based on everyday life. A second revolution is currently under way with the goal of putting our growing understanding of these mysteries to use by actually controlling nature and harnessing the benefits of the weird and wondrous properties of quantum mechanics. One of the most striking of these is the tremendous computing power of quantum computers, whose actual experimental realisation is one of the great challenges of our times. The announcement by Google, in October 2019, where they claimed to have demonstrated the so-called "quantum supremacy", is one of the first steps towards this goal.

Promising future

Besides computing, exploring the quantum world promises other dramatic applications including the creation of novel materials, enhanced metrology, secure communication, to name just a few. Some of these are already around the corner. For example, China recently demonstrated secure quantum communication links between terrestrial stations and satellites. And computer scientists are working towards deploying schemes for post-quantum cryptography — clever schemes by which existing computers can keep communication secure even against quantum computers of the future. Beyond these applications, some of the deepest foundational questions in physics and computer science are being driven by quantum information science. This includes subjects such as quantum gravity and black holes.

Pursuing these challenges will require an unprecedented collaboration between physicists (both experimentalists and theorists), computer scientists, material scientists and engineers. On the experimental front, the challenge lies in harnessing the weird and wonderful properties of quantum superposition and entanglement in a highly controlled manner by building a system composed of carefully designed building blocks called quantum bits or qubits. These qubits tend to be very fragile and lose their "quantumness" if not controlled properly, and a careful choice of materials, design and engineering is required to get them to work. On the theoretical front lies the challenge of creating the algorithms and applications for quantum computers. These projects will also place new demands on classical control hardware as well as software platforms.

Where India stands

Globally, research in this area is about two decades old, but in India, serious experimental work has been under way for only about five years, and in a handful of locations. What are the constraints on Indian progress in this field? So far we have been plagued by a lack of sufficient resources, high quality manpower, timeliness and flexibility. The new announcement in the Budget would greatly help fix the resource problem but high quality manpower is in global demand. In a fast moving field like this, timeliness is everything — delayed funding by even one year is an enormous hit.

A previous programme called Quantum Enabled Science and Technology has just been fully rolled out, more than two years after the call for proposals. Nevertheless, one has to laud the government’s announcement of this new mission on a massive scale and on a par with similar programmes announced recently by the United States and Europe. This is indeed unprecedented, and for the most part it is now up to the government, its partner institutions and the scientific community to work out details of the mission and roll it out quickly.

But there are some limits that come from how the government must do business with public funds. Here, private funding, both via industry and philanthropy, can play an outsized role even with much smaller amounts. For example, unrestricted funds that can be used to attract and retain high quality manpower and to build international networks — all at short notice — can and will make an enormous difference to the success of this enterprise. This is the most effective way (as China and Singapore discovered) to catch up scientifically with the international community, while quickly creating a vibrant intellectual environment to help attract top researchers.

Further, connections with Indian industry from the start would also help quantum technologies become commercialised successfully, allowing Indian industry to benefit from the quantum revolution. We must encourage industrial houses and strategic philanthropists to take an interest and reach out to Indian institutions with an existing presence in this emerging field. As two of us can personally attest, the Tata Institute of Fundamental Research (TIFR), home to India's first superconducting quantum computing lab, would be delighted to engage.

R. Vijayaraghavan is Associate Professor of Physics at the Tata Institute of Fundamental Research and leads its experimental quantum computing effort; Shivaji Sondhi is Professor of Physics at Princeton University and has briefed the PM-STIAC on the challenges of quantum science and technology development; Sandip Trivedi, a Theoretical Physicist, is Distinguished Professor and Director of the Tata Institute of Fundamental Research; Umesh Vazirani is Professor of Computer Science and Director, Berkeley Quantum Information and Computation Center and has briefed the PM-STIAC on the challenges of quantum science and technology development