ACCELERATE

Opening Quantum for the Benefit of Humanity

Abstract

In 2019, Google used a computer with 54 quantum bits, or qubits, to perform a calculation in 200 seconds that would have taken the world's most powerful supercomputer 10,000 years to complete. The answers had little practical use, but it marked a major inflection point in the development of quantum technology. Over the next decade, quantum computers that can turbocharge the search for new materials and drugs will become a reality. So will quantum communication networks with uncrackable encryption and quantum sensors providing ultra-precise measurements in medicine, Earth sciences and positioning systems. The strategic potential of this new quantum infrastructure will require global coordination to both ensure and control access to it, so that its opportunities are open to everyone, and its applications are beneficial to all.

- What intractable problems could quantum computers help to solve?
- What is the best way to help policymakers understand quantum technology, so they are better prepared to take advantage of quantum advances and to make sensible and forward-looking decisions?
- How can we make sure the benefits of quantum technology applications are open to all?

Participants

Moderated by:

Katia Moskvitch, Communications Lead Europe, IBM Research, UK

With:

Anousheh Ansari, CEO, XPRIZE Foundation; Member, GESDA Diplomacy Forum, USA/Iran

Fabiola Gianotti, Director-General, CERN; Board Member, GESDA, Italy

Nicolas Gisin, Honorary Professor, University of Geneva, Switzerland

Elham Kashefi, Professor of Computer Science; Personal Chair, Quantum Computing, School of Informatics, University of Edinburgh; Director, CNRS, Sorbonne University; Co-Founder, VeriQloud, Iran

Matthias Troyer, Distinguished Scientist, Microsoft Quantum; Member, GESDA Academic Forum, Austria

Peter Knight, Emeritus Professor, Faculty, Natural Sciences, Department of Physics, Imperial College London; Former Defence Scientific Advisory Council, UK Ministry of Defence, UK *(remotely)*

Highlights

Along with artificial intelligence, the pursuit of quantum computing – which promises to crack longstanding, complex scientific problems – is growing among the world's top academic and industry research labs. "It's a revolution that's been a long time coming: at least 30 years of research by a large fundamental research community that has actually been at the heart of everything that we see," said Peter Knight, a physicist and emeritus professor known for his pioneering work into theoretical quantum optics. "But what we see now is science developing into technology, exquisite engineering that is generating new prototype systems under control," he said. "Quantum is a total game changer. And it's a game changer that's been recognized right around the world. There's over $22 billion that's been invested worldwide by governments by 2021, and it's become a kind of international race, fuelled sometimes by the fear of missing out. So, we've got to be extraordinarily careful about avoiding hype. But quantum will affect us all."

So, what is it, concretely? Nicolas Gisin, an experimental physicist and professor working on quantum information, communication, and mechanics, explains. "In your smartphones, you have electronic transistors, [materializing] the so-called bits (represented by the series of 1s and 0s). In the quantum world, you have quantum bits, or qubits. They can be, at the same, in state 1 or state 0, in superposition. This – I agree – is complicated to understand. Let's make it even more complex: if now you have two qubits, the theory tells you they can not only be in combination (00, 11, 01 or 01), but can also be in superposition of all those coupled states. And each time you add a qubit, the number of parameters you need to describe that collection doubles – doubling typically means an exponential increase. Now suppose you have 300 of these qubits: the number of parameters needed to describe that is about the same size as the number of atoms in the entire visible universe. Obviously, a classical computer won't be able to handle [or simulate] that. But if you go quantum, with 300 perfect qubits, [which enables such a large number of parameters], because of the superposition principle – which changes everything – you get to computing power that is unthinkable. And that is probably where all the promises are coming from."

Quantum technologies can theoretically be used in many different fields: "It can change all of chemistry and material science. It can help us predict the properties of the materials accurately," said Matthias Troyer, a theoretical physicist. "It could also let us design a catalyst for carbon fixation, which we can use to deal with global warming. It can help us find new materials, superconducting." Since no one knows yet how to build the best quantum computers or what their full capabilities might be, he said, more collaborative projects and the sort of cooperation that GESDA espouses will be essential. "We are also at the start of the race," he said, "because while we have about 50 qubits now, we need a few hundred perfect qubits for real-world applications to concretize."

Quantum is also being applied to cryptography, which is based on difficult math problems like discrete logs and integer factorization. With enough scale, a quantum computer could dramatically accelerate the time it takes today's computers to solve these problems – posing security risks to all kinds of infrastructure, including diplomatic and military communication, protected by cryptographic algorithms. But quantum also offers a "solution for all of these things", said Elham Kashefi, a professor and researcher at the French National Centre for Scientific Research (CNRS), who co-founded VeriQloud, a Paris-based software provider for quantum networks that is developing a hybrid classical-quantum cloud solution for secure data communication, storage, and computation on local networks. She pointed to her ten-year-old son as an example of how giant leaps in science and technology can radically disrupt our ways of thinking. "Whenever I argue with him, 'You should not do this, you should not do that,' he will say that there is a parallel universe in which you accepted that I had this ice cream and we did not have this argument, and we are happy. And I think he's exactly the example of what it is. For him, it's very normal to think in a parallel universe, quantum, superposition – and to bring a complicated problem to me: 'Mommy, can you solve the problem of poverty using quantum?'"

Despite their open minds, not enough young people are being trained to work on quantum, which will be creating hiring challenges for all sorts of conventional and new jobs such as quantum coders, quantum algorithm developers and error correction scientists. This is a challenge that goes to the heart of GESDA's work "because we are not ready; we are not ready because most people don't even know about it", said Anousheh Ansari, an engineer and the first self-funded female astronaut to go to the International Space Station, whose XPRIZE Foundation is partnering with GESDA to launch a GESDA-XPRIZE Quantum competition over the next several years. "They don't know how to use it. There's a huge skills gap that already exists today and is anticipated to widen in the future. Even the companies who are working on it have issues hiring the right kind of talent and skills they need to actually advance the technologies," she said. "And you know, what worries me is that the small number of people who are working on it will be persuaded by governments to work on military applications and applications that we really don't want to see, because that's where the money is, and it can be done in a closed, dark room and no one can see it."

Quantum computing, though complicated, could be taught earlier than at university; high school students could be introduced to quantum physics, according to Gisin. "Today we have enough understanding that we can teach quantum physics on a relatively easy, mathematically easy level. It's conceptually complicated, but the mathematics are relatively easy, so we could study indeed earlier. I think that's the first thing to do," he said. "About educating not only the advanced countries and the rich countries – on the theory side, the theory is not something very expensive. Making a quantum computer is expensive, but not understanding the principle and developing algorithms. These are things which are not so expensive and that could be done really on the entire planet and should be done on the entire planet."

André Xuereb, a theoretical quantum physicist and associate professor who is Malta's ambassador for digital affairs, said as the father of two young girls that quantum should be taught to kids at an even earlier age; kids, after all, drop things on the floor to learn the laws of mechanics. "And if we somehow bring quantum and other kinds of technologies to even younger kids, then they will learn an innate sense for how the universe works in a different way than we did. And that can make the most of a quantum nature of generation, so to speak. And my gut feeling is that we will not realize the power of these machines. We will not get a proper generation of quantum computer scientists, so to speak, until we do that, until that generation grows up."

One of the ideas that GESDA has identified as a potential solution is a hybrid organization to guarantee safe access to and use of critical quantum infrastructures for communication and computing, such as those related to strategic national and international security agendas. If that were to proceed, said Fabiola Gianotti, the experimental particle physicist who has led CERN since the start of 2016, the development of quantum computers and their deployment also could be shaped according to the core values that CERN embraces and promotes, particularly the importance of fundamental research regardless of any potential applications in the practical or commercial worlds.

"Quantum mechanics was considered a useless knowledge, because we had no applications in a normal life," she recalled. Today its applications are wide-ranging including telecommunication, GPS systems, lasers, transistors, magnetic resonance imaging (MRI), computers and mobile phones. "One never knows what are the impacts that the fundamental research will have one day," said Gianotti. "But we can say there will always be an impact sooner or later." CERN emphasizes collaboration across borders, disciplines and the private-public sectors, and the use of open technologies and open access to information. "If you can share information among scientists, you can share data, we can share knowledge. Of course, developments would be faster," she said. "But also, because knowledge and education are capacity-building and empowering tools, they must be available to everybody if you want to reduce inequities across the world."

Takeaway Messages

Quantum computing is a revolution long in the making: at least 30 years of research by a large fundamental research community. It is a total game-changer with over $22 billion invested worldwide by governments by 2021, prompting international competition fuelled by fear and hype.

Quantum can change chemistry and material science and help us predict the properties of materials accurately. It could let us design a catalyst for negative carbon fixation for global warming.

Not enough young people are being trained to work on quantum, which is creating hiring challenges for all sorts of jobs due to a huge skills gap. Governments with money to hire young talent could put them to work on military and less desirable uses.

More collaborative projects and the sort of cooperation that GESDA espouses will be essential, because building a quantum system is complex and there is a need to steer research towards beneficial applications that are not only focused on economic, geopolitical or military advantages.

Quantum computing, though complicated, can be taught earlier than at university: it could be introduced to high school students or even at an earlier age, so kids get an innate sense of it.

A hybrid organization for quantum could guarantee safe access to and use of critical quantum infrastructures for communication and computing.

Sharing information and data are important because knowledge and education are capacity-building and empowering tools that can reduce inequities across the world.

More information

Session recording on YouTube

Related interviews: Anousheh Ansari

Tweets related to the session

Related content in the 2021 Science Breakthrough Radar®

Quantum Technologies and related breakthroughs at five, ten and 25 years: Full breakthrough brief, Quantum Communication, Quantum Computing, Quantum Sensing and Imaging, Quantum Foundations