Podcast Interview: Christopher Monroe

PNAS: I'm Brian Doctrow, and welcome again to Science Sessions.

Classical computing encodes information in bits, each of which can be either a 0 or 1. This paradigm underlies technology ranging from everyday smartphones to the most powerful supercomputers. Yet with only two possible states for each bit, there are limits to how much data a given number of bits can handle, making certain types of calculations a challenge for even the best classical computers. Quantum computers, unlike classical computers, encode information in quantum bits, or qubits, each of which can be an arbitrary combination of both 0 and 1 simultaneously. Although the technology is still in its infancy, quantum computers have the potential to efficiently perform calculations that are difficult, if not impossible, for classical computers. Christopher Monroe, a physicist at the University of Maryland, a fellow of the Joint Quantum Institute, and a National Academy of Sciences member, is at the forefront of quantum computing research. I recently spoke with Monroe about recent developments in quantum computing, and where he thinks the field is heading.

Monroe: Over the last several years, the field has attracted a great deal of interest, and I think it's largely because there's a big industrial involvement now. And that wasn't true just 5 or 8 years ago. This is really important because with industry, we have the potential for building devices—building devices that can be used by others, not just scientists, not just Ph.Ds.

PNAS: Monroe researches quantum computing hardware using individual trapped ions as qubits, which can be manipulated using lasers. An alternative hardware, developed by researchers at universities, Google, IBM, and others, uses superconducting circuits as qubits.

Monroe: In the last few years, I think both of these technologies have developed—not just IBM and us, but other companies, other research institutes, are starting to make big bets in these two technologies. These are the only two right now that you can think about building up at a very high level; you can do engineering with these two. There are a handful of other technologies that are still in the research stage, and in the coming years we hope some of them will spring up. But I think over the last few years, it's solidified the positions of individual atoms and superconductors as the most promising hardwares right now.

PNAS: One of the current challenges for quantum computing hardware is to increase the number of operations that can be performed on the qubits, in addition to increasing the number of qubits itself.

Monroe: If you give me a million qubits, but you can only execute one operation, it's useless. If I give you two qubits, but I can operate a million operations, it's useless. You want the number of qubits to roughly scale with the number of operations. And over the last few years there's steady progress on all hardwares improving that.

PNAS: Monroe believes that one of the most promising applications for quantum computing is for solving optimization problems, in which the best solution must be found out of a large number of possibilities. A classic example of such a problem is the traveling salesman problem: given a map of various cities, find the shortest path connecting all of them.

Monroe: The traveling salesman problem is a logistics problem, very important to many sectors of society from UPS, FedEx, and so forth, to even armies. Another sector that's important is the financial sector. Many of the big finance firms in Manhattan are very interested in quantum. They have people on the ground thinking about this. But that type of optimization problem to me is very similar to what we have in chemistry. If you take a molecule with, say, a few hundred electrons, how do those electrons decide to arrange themselves in that molecule to form the stable molecule that we know? And there's something called the binding energy—what's the energy that you lose by forming this molecule? If we know what that binding energy is, we can understand better how it reacts with other molecules. There's only one answer that minimizes the energy, and a quantum computer might be able to test all of these configurations at the same time.

PNAS: Recently Monroe launched his own startup company, IonQ, to create a practical quantum computing platform based on hardware developed in his lab.

Monroe: What I like most about that company is that only about a third of us are quantum physicists like me. Another third are engineers—electrical engineers—making very agile and fast programmable systems to control our atoms. The other third of the company, these are software folks. They write self-calibrating software to automate the trapping of individual atoms. It's a little like a sociological laboratory of getting quantum physicists and engineers to play together.

PNAS: Quantum computing is also starting to attract the attention of the federal government. Congress is working on establishing a National Quantum Initiative to help bridge the gap between academic research and industry.

Monroe: At the universities we're comfortable with quantum physics but we don't build things like the iPhone that can be used by everybody. Industry builds things, but they're not so comfortable with quantum. So there's a workforce issue in that big divide between universities and companies. And historically governments can help this, and bring these exotic things from the laboratory to the commercial market.

PNAS: For Monroe, having industry investment in quantum computing is a promising sign for the future of the field as a whole.

Monroe: What I lose sleep over is, will quantum computing as a whole take a foothold? Will it grow? We have to have medium-term applications, otherwise we're never going to get to the big systems, because frankly, nobody's going to pay for it. It'll always be great science, and the government labs and the universities will always invest in it, but industrial investment is a little tricky. In the end there has to be some product behind it, some commercial justification. Well, having the big companies invest is a big deal, because they are making a bet that there's something these computers will do. We're still in the demonstration stage, and eventually we're going to push through that point where we learn something that we couldn't calculate otherwise.

PNAS: Thank you for listening to PNAS Science Sessions. We would love to hear your thoughts about this show. Get in touch with us at PNAS on Facebook, Twitter, PNAS.org, or with the hashtag #sciencesessions. If you liked this episode, please consider leaving us a review on iTunes. Your review helps us spread the word, and we really appreciate it. Also, don’t forget to subscribe to Science Sessions on iTunes.