Microsoft

Station Q at UCSB and the future of computing: Moore did not predict the power of a qubit!

What will computers look like in the future and how will they function? The answer to these questions could be the quantum computer, the most powerful computing device the world has ever known. But creating such a computer is no easy feat. One of the biggest challenges lies in the delicate temperament of the most basic component of the quantum computer: the qubit. In a conventional computer, transistors store bits of information and each bit has a value of either a 1 or 0. The power to motivate a bit is electricity. With a quantum computer, the classical bit gives way to a quantum bit, or qubit. Qubits are very sensitive to their environment, and are not stored in transistors; rather, they can be stored in a quantum mechanical state such as a photon polarization, electron spin, or in even more exotic degrees of freedom.

About seven years ago, seeing the looming challenges to Moore's Law[1] , Microsoft made a bet that quantum computers could be developed. A key person leading Microsoft to this conclusion was a then Distinguished Engineer at Microsoft, Michael Freedman. He, Kevin Walker, Zhenghan Wang, and Chetan Nayak, all from Microsoft, together with collaborators from around the world, proposed that what one needed to protect a qubit was the environment generated within "topological materials." The problem of finding and harnessing topological materials draws together ideas from condensed matter physics, topology and computer science.

Microsoft created Station Q on the UCSB campus to bring together the right mix of theorists to work on this problem,

collaborating with and drawing on the expertise of UCSB scientists and visitors to the Kavli Institute for Theoretical Physics.

It is a long haul from the rarified air of theory to making computers. With this challenge, Freedman and his colleagues began to look for institutions and collaborators to make good on the promise of topological materials. They searched for leaders in experimental physics and material science, and found collaborators at the Weizmann Institute, Harvard, UC Santa Barbara, CalTech, the University of Chicago and the University of Maryland. Over the years their collaborations have grown, with new collaborations cropping up with Stanford and the University of Illinois.

The group has made significant progress over the past six years in better understanding materials that could prove suitable to build a scalable quantum computer. Microsoft has funded a series of collaborations with faculty from around the world and garnered tremendous insights into topological materials. UC Santa Barbara was a natural choice to house Station Q because of its many renowned experts in condensed matter theory, materials production and characterization. UC Santa Barbara faculty members who participate in Station Q range from theoretical physics (Andreas Ludwig) to experimental physics (John Martinis, David Awschalom) and materials (Chris Palmstrom).

1 For years now technologists and in-the-know computer users have been aware of a theorem posited by Gordon Moore, the co-founder of Intel, that the number of components in integrated circuits would double every year. David House, an Intel colleague, had factored in the increasing performance of transistors to conclude that integrated circuits would double in performance every 18 months, establishing what we recognize as Moore's law. The challenge to the continuation of Moore's law relates to the difficulty of maintaining electrons within the ever shrinking circuits. At some point there will not be enough material between individual circuit elements to block electrons from escaping or influencing their neighbors. This is the fatal flaw in Moore's Law.

Station Q now encompasses about a dozen full-time Microsoft employees, many of whom have faculty positions in their collaborative departments at UC Santa Barbara, and about as many graduate students and post-docs. They co-author papers and grants, and collaborate and share post-docs with many faculty.

“The station sounds and acts as much like a center at a university as it does a program within industry,” says Nayak, who is a professor in UC Santa Barbara’s Physics Department as well as a senior scientist at Microsoft.

Nayak feels part of the program’s success is do to its exposure to collaborators who visit the campus’ Kavli Institute for Theoretical Physics (aka the KITP) and the California Nanosystems Institute (CNSI), in which Station Q resides. These two unique centers have a large physical as well as mental presence on the campus and bring together leading scientists from around the world. The California Nanosystems Institute (CNSI) advances a multidisciplinary approach to developing the information, biomedical and manufacturing technologies that will dominate science and economy in the 21st century. As a California Institute for Science and Innovation (CISI), CNSI builds on a visionary investment in future education, research and technological resources given by the State of California.

For more information about this research please refer to

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