

## Quantum information is exciting and important

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**F**or the March–April 2007 issue of *Computing in Science & Engineering*, I wrote an essay entitled “Quantum Computing Is Exciting and Important—Really!” The essay’s inspiration came from a sardonic disclaimer that Rolf Landauer (1927–99) proposed be added to papers about quantum computing:

This proposal, like all proposals for quantum computation, relies on speculative technology, does not in current form take into account all possible sources of noise, unreliability and manufacturing error, and probably will not work.

Fourteen years ago I argued that even if Landauer’s skepticism remained valid, the quest to build a quantum computer had already paid off. As supporting evidence, I cited the work of David Wineland and his collaborators at the NIST lab in Boulder, Colorado. Having developed logic gates based on trapped ions, they repurposed the technology to make new, entanglement-based clocks of unprecedented precision (see *PHYSICS TODAY*, October 2005, page 24).

I also cited the work of Princeton University’s Jason Petta. In developing quantum dots as a platform for quantum computing, he and his collaborators at Harvard University measured the puny fluctuating magnetic field of  $10^6$  gallium and arsenic nuclei inside a quantum dot (see *PHYSICS TODAY*, March 2006, page 16).

Theorists were just as productive, I noted. The work of Caltech’s Alexei Kitaev and others on topological quantum computation has spawned rich and fruitful explorations of the mathematical similarities of field theory, knots, and the fractional quantum Hall effect (see *PHYSICS TODAY*, October 2005, page 21). Princeton’s Robert Calderbank applied the theory of quantum error correction to understand radar polarimetry.

Physicists continue to advance the field of quantum information. Perhaps the most spectacular recent feat is that of Jian-Wei Pan of the University of Science and Technology of China (USTC) and his collaborators. In 2017 their experiment aboard the satellite *Micius* beamed down pairs of entangled photons to the Chinese cities of Delingha and Lijiang, which are 1200 km apart. “Never has the spooky action of quantum mechanics been observed at so great a distance,” wrote Ashley



Smart in his news story (*PHYSICS TODAY*, August 2017, page 14).

This past summer, the team known as Google AI Quantum and collaborators reported the use of a quantum processor in combination with a classical computer to calculate the binding energy of chains of 6, 8, 10, and 12 atoms of hydrogen and the cis–trans isomerization energy of a diazene molecule, HNNH.

The Google team’s calculations are not beyond the abilities of a classical computer. However, in October 2019 the Google team published a report in *Nature* that described achieving so-called quantum supremacy: Its 53-qubit device made of Josephson junctions took 200 seconds to solve a sampling problem that would take a classical system  $10^4$  years. This past December, USTC’s Pan and his collaborators reported a similar feat in *Science*: Their 76-qubit device based on entangled photons solved a sampling problem  $10^{14}$  times faster than a classical device could.

If Landauer were alive today, would he concede that a quantum computer probably will work? That’s hard to say. The sampling problems tackled by the Google and USTC teams were expressly devised as benchmarks of quantum supremacy. They

fall short of a universal quantum computer capable of, say, proving that the Hubbard model is sufficient to account for high- $T_c$  superconductivity or the particles that result when protons and antiprotons collide at 14 TeV in an upgraded LHC.

Despite his skepticism about quantum computing, Landauer was a pioneer in investigating the quantum limits of information. One of his most cited papers is his 1961 derivation of the minimum amount of heat that is dissipated when one bit of information is erased:  $kT \log 2$ . PT

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