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Exotic state of matter propels quantum computing theory

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So far it exists mainly in theory, but if invented, the large-scale quantum computer would change computing forever. Rather than the classical data-encoding method using binary digits, a quantum computer would process information millions of times faster through the use of quantum states of matter.

But there's a reason quantum computers aren't in every home yet. Scientists are still working on how to make a computer do calculations reliably on the quantum scale. Cornell physicists have come up with a key piece of the theoretical puzzle, bringing science one step closer to revealing the first quantum computer.

Abolhassan Vaezi, a Bethe postdoctoral fellow working with Eun-Ah Kim, associate professor of physics, authored a paper published earlier this month in *Physical Review X* that answers a long-standing problem in quantum computing. He made a "fractional topological superconductor," an exotic state of matter in which emergent quasi-particles perform quantum computations without error.

To work on quantum computing, physicists explore electronic interactions in two dimensions, where never-before-seen states of matter can exist. The states are exotic because particles can carry what's called fractional charges – that is, rather than being limited to a charge of 1 (1 electron), within two-dimensional planes, charges can have a value of, for example, 1/3. In this theoretical realm, quantum computation could become reality.

Scientists had already theorized that for a quantum computing system to be robust and able to store data effectively, it would have to employ such fractionalized excitations of particles, some of which are called non-Abelian anyons. The simplest example of a non-Abelian anyon is called a Majorana fermion, which has been conjectured to exist in many physical systems and to form the basis for fault tolerance, meaning resistant to error.

In his paper, Vaezi demonstrates more efficient non-Abelian quasi-particles, Fibonacci anyons, through the use of a superconducting vortex, at the interface of a 2/3 fractional quantum Hall-superconductor structure. He demonstrates how this system undergoes a phase transition to the Fibonacci state that is the most coveted platform for building fault-tolerant quantum computers.

This discovery provides a novel mechanism for how to make universal topological quantum computers.

More information: Abolhassan Vaezi. "Superconducting Analogue of the Parafermion Fractional Quantum Hall States." *Phys. Rev. X* 4, 031009 – Published 15 July 2014. DOI: 10.1103/PhysRevX.4.031009

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