A new strategy for detecting non-conformist particles called anyons

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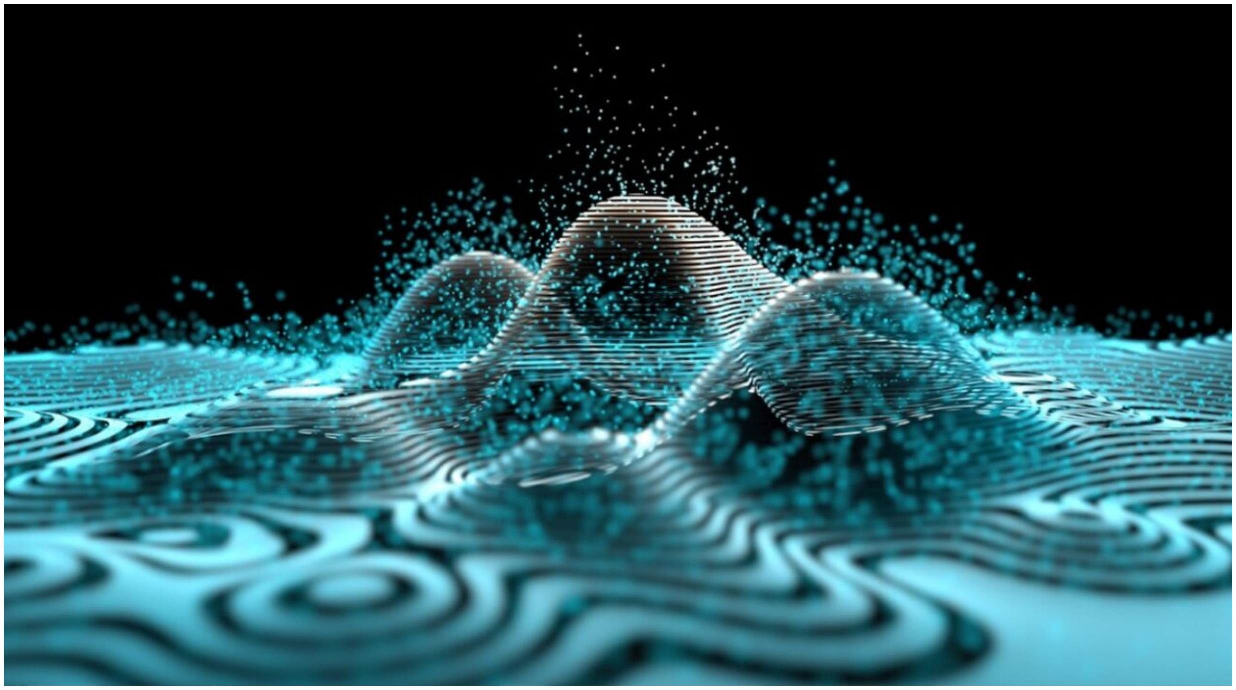

Credit: Brown University

A team of Brown University researchers has shown a new method of probing the properties of anyons, strange quasiparticles that could be useful in future quantum computers.

In research published in the journal *Physical Review Letters*, the team describes a means of probing anyons by measuring subtle properties of the way in which they conduct heat. Whereas other methods probe these particles using electrical charge, this new method enables researchers to probe anyons even in non-conducting materials. That's critical, the researchers say, because non-conducting systems have far less stringent temperature requirements, making them a more practical option for quantum computing.

"We have beautiful ways of probing anyons using charge, but the question has been how do you detect them in the insulating systems that would be useful in what's known as topological quantum computing," said Dima Feldman, a physics professor at Brown and study co-author. "We show that it can be done using heat conductance. Essentially, this is a universal test for anyons that works in any state of matter."

Anyons are of interest because they don't follow the same rules as particles in the everyday, three-dimensional world. In three dimensions, there are only two broad kinds of particles: bosons and fermions. Bosons follow what's known as Bose-Einstein statistics, while fermions follow Fermi-Dirac statistics. Generally speaking, those different sets of statistical rules mean that if one boson orbits around another in a quantum system, the particle's wave function—the equation that fully describes its quantum state—does not change. On the other hand, if a fermion orbits around another fermion, the phase value of its wave function flips from a positive integer to a negative integer. If it orbits again, the wave function returns to its original state.

Anyons, which emerge only in systems that are confined to two dimensions, don't follow either rule. When one anyon orbits another, its wave function changes by some fraction of an integer. And another orbit does not necessarily restore the original value of the wave function. Instead, it has a new value—almost as if the particle maintains a "memory" of its interactions with the other particle even though it ended up back where it started.

That memory of past interactions can be used to encode information in a robust way, which is why the particles are interesting tools for quantum computing. Quantum computers promise to perform certain types of calculations that are virtually impossible for today's computers. A quantum computer using anyons—known as a topological quantum computer—has the potential to operate without elaborate error correction, which is a major stumbling block in the quest for usable quantum computers.

But using anyons for computing requires first being able to identify these particles by probing their quantum statistics. Last year, researchers did that for the first time using a technique known as charge interferometry. Essentially, anyons are spun around each other, causing their wave functions to interfere with each other occasionally. The pattern of interference reveals the particles' quantum statistics. That technique of probing anyons using charge works beautifully in systems that conduct electricity, the researchers say, but it can't be used to probe anyons in non-conducting systems. And non-conducting systems have the potential to be useful at higher temperatures than conducting systems, which need to be near absolute zero. That makes them a more practical option of topological quantum computing.

For this new research, Feldman, who in 2017 was part of a team that measured the heat conductance of anyons for the first time, collaborated with Brown graduate student Zezhu Wei and Vesna Mitrovic, a Brown physics professor and experimentalist. Wei, Feldman and Mitrovic showed that comparing properties of heat conductance in two-dimensional solids etched in very specific geometries could reveal the statistics of the anyons in those systems.

"Any difference in the heat conductance in the two geometries would be smoking gun evidence of fractional statistics," Mitrovic said. "What this study does is show exactly how people should set up experiments in their labs to test for these strange statistics."

Ultimately, the researchers hope the study is a step toward understanding whether the strange behavior of anyons can indeed be harnessed for topological quantum computing.

More information: Zezhu Wei et al, Thermal Interferometry of Anyons in Spin Liquids, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.127.167204

Provided by Brown University

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