First hybrid quantum bit based on topological insulators
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With their superior properties, topological qubits could help achieve a breakthrough in the development of a quantum computer designed for universal applications. So far, no one has yet succeeded in unambiguously demonstrating a quantum bit, or qubit for short, of this kind in a lab. However, scientists from Forschungszentrum Jülich have now gone some way to making this a reality. For the first time, they succeeded in integrating a topological insulator into a conventional superconducting qubit. Just in time for "World Quantum Day" on 14 April, their novel hybrid qubit made it to the cover of the latest issue of the journal Nano Letters.

Quantum computers are regarded as the computers of the future. Using quantum effects, they promise to deliver solutions for highly complex problems that cannot be processed by conventional computers in a realistic time frame. However, the widespread use of such computers is still a long way off. Current quantum computers generally contain only a small number of qubits. The main problem is that they are highly prone to error. The bigger the system, the more difficult it is to fully isolate it from its environment.

Many hopes are therefore pinned on a new type of quantum bit—the topological qubit. This approach is being pursued by several research groups as well as companies such as Microsoft. This type of qubit exhibits the special feature that it is topologically protected; the particular geometric structure of the superconductors as well as their special electronic material properties ensure that quantum information is retained. Topological qubits are therefore considered to be particularly robust and largely immune to external sources of decoherence. They also appear to enable fast switching times comparable to those achieved by the conventional superconducting qubits used by Google and IBM in current quantum processors.

However, it is not yet clear whether we will ever succeed in actually producing topological qubits. This is because a suitable material basis is still lacking to experimentally generate the special quasiparticles required for this without any doubt. These quasiparticles are also known as Majorana states. Until now, they could only be unambiguously demonstrated in theory, but not in experiments. Hybrid qubits, as they have now been constructed for the first time by the research group led by Dr. Peter Schüffelgen at the Peter Grünberg Institute (PGI-9) of Forschungszentrum Jülich, are now opening up new possibilities in this area. They already contain topological materials at crucial points. Therefore, this novel type of hybrid qubit provides researchers with a new experimental platform to test the behavior of topological materials in highly sensitive quantum circuits.
