Quantum engineers create a 'Schrödinger's cat' inside a silicon chip

January 14 2025

This metaphorical cat has seven lives. Credit: UNSW Sydney

UNSW engineers have demonstrated a well-known quantum thought experiment in the real world. Their findings deliver a new and more robust way to perform quantum computations—and they have important implications for error correction, one of the biggest obstacles standing between them and a working quantum computer.

Quantum mechanics has puzzled scientists and philosophers for more than a century. One of the most famous quantum thought experiments is that of the "Schrödinger's cat"—a cat whose life or death depends on the decay of a radioactive atom.

According to quantum mechanics, unless the atom is directly observed, it must be considered to be in a superposition—that is, being in multiple states at the same time—of decayed and not decayed. This leads to the troubling conclusion that the cat is in a superposition of dead and alive.

"No one has ever seen an actual cat in a state of being both dead and alive at the same time, but people use the Schrödinger's cat metaphor to describe a superposition of quantum states that differ by a large amount," says UNSW Professor Andrea Morello, leader of the team that conducted the research, published in the journal *Nature Physics*.

Atomic cat

For this research paper, Prof. Morello's team used an atom of antimony, which is much more complex than standard "qubits," or quantum building blocks.

"In our work, the 'cat' is an atom of antimony," says Xi Yu, lead author of the paper.

"Antimony is a heavy atom, which possesses a large nuclear spin, meaning a large magnetic dipole. The spin of antimony can take eight different directions, instead of just two. This may not seem much, but in fact it completely changes the behavior of the system.

"A superposition of the antimony spin pointing in opposite directions is not just a superposition of 'up' and 'down,' because there are multiple quantum states separating the two branches of the superposition."

This has profound consequences for scientists working on building a quantum computer using the nuclear spin of an atom as the basic building block.

"Normally, people use a quantum bit, or 'qubit'—an object described by only two quantum states—as the basic unit of quantum information," says co-author Benjamin Wilhelm.

"If the qubit is a spin, we can call 'spin down' the '0' state, and 'spin up' the '1' state. But if the direction of the spin suddenly changes, we have immediately a logical error: 0 turns to 1 or vice versa, in just one go. This is why quantum information is so fragile."

Left to right: UNSW researchers Benjamin Wilhelm, Xi Yu, Prof Andrea Morello, Dr. Danielle Holmes. Credit: UNSW Sydney

But in the antimony atom that has eight different spin directions, if the '0' is encoded as a '"dead cat," and the "1" as an "alive cat," a single error is not enough to scramble the quantum code.

"As the proverb goes, a cat has nine lives. One little scratch is not enough to kill it. Our metaphorical 'cat' has seven lives: it would take seven consecutive errors to turn the '0' into a '1'! This is the sense in which the superposition of antimony spin states in opposite directions is 'macroscopic'—because it's happening on a larger scale, and realizes a Schrödinger cat," explains Yu.

Scalable technology

The antimony cat is embedded inside a silicon quantum chip, similar to the ones we have in our computers and mobile phones, but adapted to give access to the quantum state of a single atom. The chip was fabricated by UNSW's Dr. Danielle Holmes, while the atom of antimony was inserted in the chip by colleagues at the University of Melbourne.

"By hosting the atomic 'Schrödinger cat' inside a silicon chip, we gain an exquisite control over its quantum state—or, if you wish, over its life and death," says Dr. Holmes.

"Moreover, hosting the 'cat' in silicon means that, in the long term, this technology can be scaled up using similar methods as those we already adopt to build the computer chips we have today."

The significance of this breakthrough is that it opens the door to a new way to perform quantum computations. The information is still encoded in binary code, 0 or 1, but there is more "room for error" between the logical codes.

"A single, or even a few errors, do not immediately scramble the information," Prof. Morello says.

"If an error occurs, we detect it straight away, and we can correct it before further errors accumulate. To continue the 'Schrödinger cat' metaphor, it's as if we saw our cat coming home with a big scratch on his face. He's far from dead, but we know that he got into a fight; we can go and find who caused the fight, before it happens again and our cat gets further injuries."

The demonstration of quantum error detection and correction—a "Holy Grail" in quantum computing—is the next milestone that the team will address.

The work was the result of a vast international collaboration. Several authors from UNSW Sydney, plus colleagues at the University of Melbourne, fabricated and operated the quantum devices.

Theory collaborators in the U.S., at Sandia National Laboratories and NASA Ames, and Canada, at the University of Calgary, provided precious ideas on how to create the cat, and how to assess its complicated quantum state.

"This work is a wonderful example of open-borders collaboration between world-leading teams with complementary expertise," says Prof. Morello.

More information: *Nature Physics* (2025). DOI: 10.1038/s41567-024-02745-0

Provided by University of New South Wales