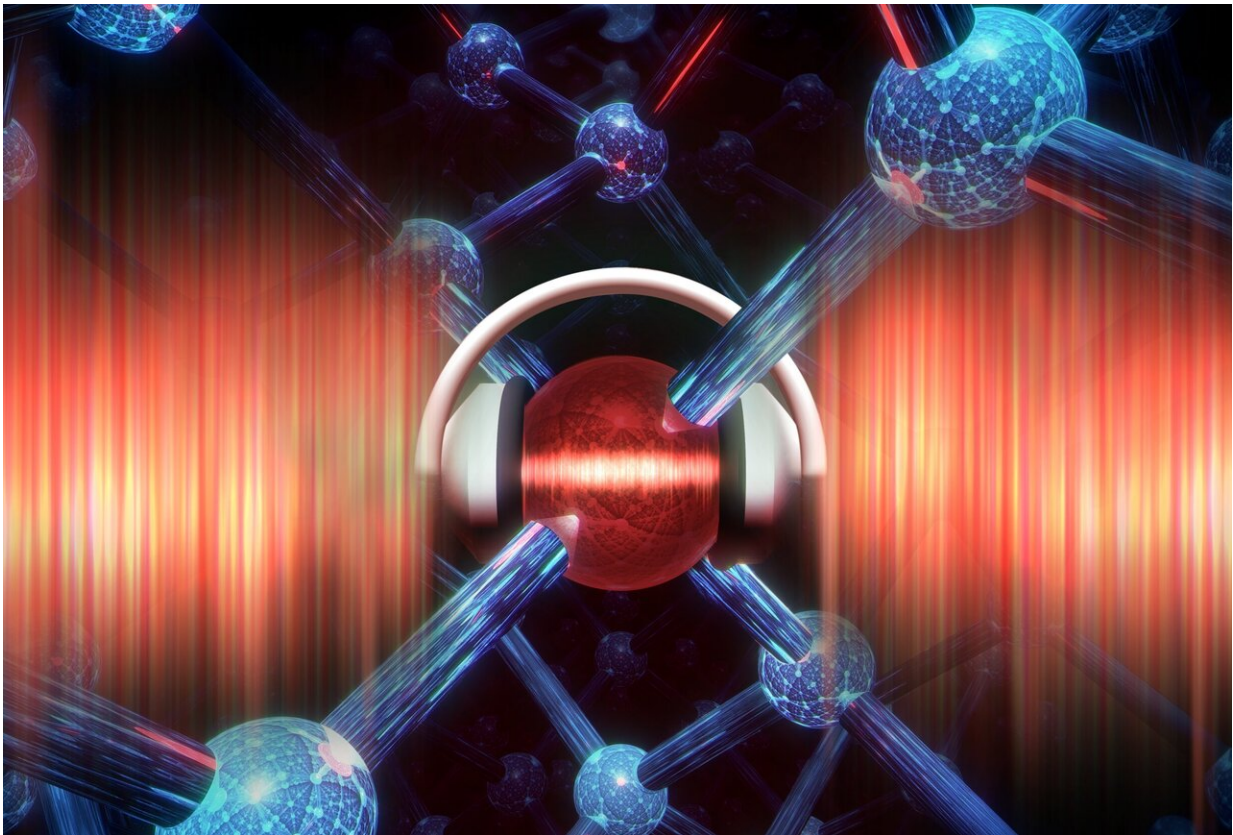


Scientists create quietest semiconductor quantum bits on record

October 8 2020



Artists impression of an atom qubit in silicon being protected from charge noise caused by imperfections in the material environment. Credit: Tony Melov

Researchers at UNSW Sydney have demonstrated the lowest noise level on record for a semiconductor quantum bit, or qubit. The research was

published in *Advanced Materials*.

For quantum computers to perform useful calculations, [quantum information](#) must be close to 100 percent accurate. Charge [noise](#)—caused by imperfections in the material environment that hosts qubits—interferes with quantum information encoded on qubits, impacting the accuracy of the information.

"The level of charge noise in semiconductor qubits has been a critical obstacle to achieving the accuracy levels we need for large-scale error-corrected quantum computers," says lead author Ludwik Kranz, a Ph.D. student at UNSW's Centre for Quantum Computation and Communication Technology (CQC²T) working with the Centre's spin off company Silicon Quantum Computing (SQC).

"Our research has demonstrated that we can reduce charge noise to a significantly low level, minimising the impact it has on our qubits," says Kranz.

"By optimising the fabrication process of the [silicon](#) chip, we achieved a [noise level](#) 10 times lower than previously recorded. This is the lowest recorded charge noise of any semiconductor [qubit](#)."

Creating quiet qubits

Qubits made from electrons hosted on atom qubits in silicon—the approach that Prof. Simmons has championed since 2000—are a promising platform for large-scale quantum computers.

However, qubits hosted in any semiconductor platform such as silicon, are sensitive to charge noise.

The team's research revealed that the presence of defects either within

the silicon chip or at the interface to the surface were significant contributors to the charge noise.

"This was a surprise, as we have spent a lot of time optimising the quality of our silicon chip but this showed that even a few impurities nearby can affect the noise," says Kranz.

By reducing the impurities in the silicon chip and positioning the atoms away from the surface and interfaces where most of the noise originates, the team were able to produce the record-breaking result.

"Our results continue to show that silicon is a terrific material to host qubits. With our ability to engineer every aspect of the qubit environment, we are systematically proving that atom qubits in silicon are reproducible, fast and stable," says Prof. Michelle Simmons, Director CQC²T.

"Our next challenge is to move to isotopically pure crystalline Si-28 to capitalise on the long coherence times already demonstrated in this system."



Lead author Ludwik Kranz with a scanning tunnelling microscope used to precisely place and encapsulate phosphorus atoms in silicon Credit: CQC²T

Timing is everything

Using the newly fabricated silicon chip, the team then performed a range of experiments to characterise the charge noise, with unanticipated results.

"We measured the charge noise using both a single electron transistor and an exchange-coupled qubit pair that collectively provide a consistent charge noise spectrum across a wide frequency range," says CQC²T co-author Dr. Sam Gorman.

The measurements revealed a key factor that impacts charge

noise—time.

"From the noise spectrum we measured, we know that the longer the computation—the more noise affects our system," says Dr. Gorman.

"This has major implications for the design of future devices, with quantum operations needing to be completed in exceptionally short time frames so that the charge noise doesn't become worse over time, adding errors to the computation."

Working systematically towards a commercially available silicon quantum computer

To perform error-free calculations required for large-scale [quantum computing](#), a two-qubit gate—the central building block of any quantum computer—needs a fidelity—or accuracy—of over 99%. To reach this fidelity threshold quantum operations need to be stable and fast.

In a recent paper—published in [Physical Review X](#) - the Simmons group, using their atomic precision capability, demonstrated the ability to read out the qubits in 1 microsecond.

"This research combined with our lowest charge noise results shows that it is possible to achieve a 99.99% fidelity in atom qubits in silicon," says Prof. Simmons, who is also the founder of SQC.

"Our team is now working towards delivering all of these key results on a single device—fast, stable, high fidelity and with long coherence times—moving a major step closer to a full-scale quantum processor in silicon."

Professor Simmons is working with SQC to build the first useful,

commercial quantum computer in silicon. Co-located with CQC²T on the UNSW Sydney campus, SQC's goal is to demonstrate the capability required to reliably produce a 10-qubit prototype quantum integrated processor by 2023.

"Our team's results further confirm that our unique approach—of precisely positioning phosphorus atoms in silicon—is an extremely promising prospect for building the error-corrected, large-scale architecture required for the commercialisation of silicon quantum computers," Prof. Simmons says.

More information: Ludwik Kranz et al, Exploiting a Single-Crystal Environment to Minimize the Charge Noise on Qubits in Silicon, *Advanced Materials* (2020). [DOI: 10.1002/adma.202003361](https://doi.org/10.1002/adma.202003361)

Provided by Centre for Quantum Computation & Communication Technology

Citation: Scientists create quietest semiconductor quantum bits on record (2020, October 8) retrieved 25 April 2024 from <https://phys.org/news/2020-10-scientists-quietest-semiconductor-quantum-bits.html>

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