A cloud-accessible four-qubit electron spin QPU in a 300 mm metal-oxide-semiconductor process

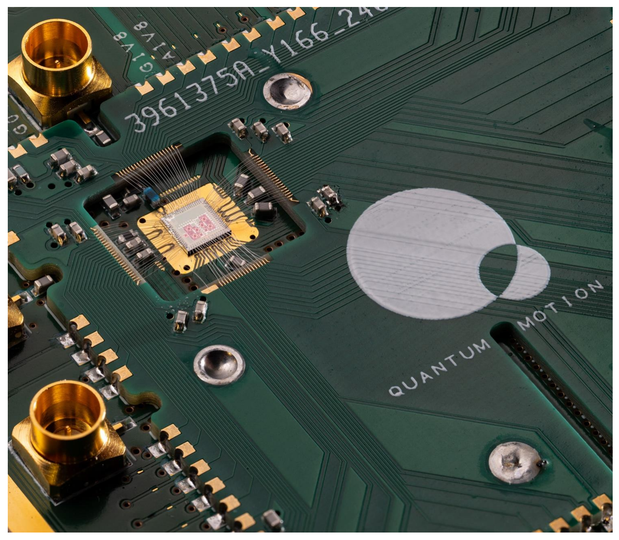
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Qubits from silicon transistors

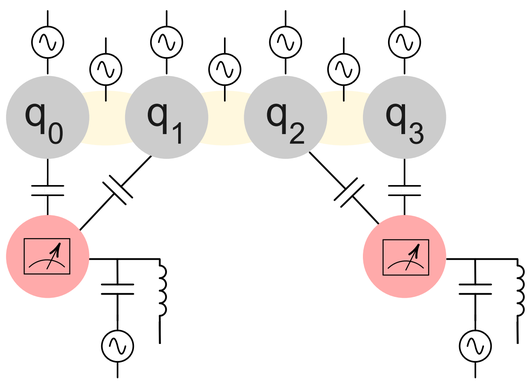
We have delivered a cloud accessible full-stack four spin-qubit system at the UK's National Quantum Computing Centre. The QPU consists of a scalable architecture consisting of a bilinear array manufactured using imec's 300 mm metal-oxide-semiconductor process.

The QPU has a cloud-accessible interface that accepts quantum circuits defined in industry standard frameworks including Qiskit and Cirq, allowing researchers to demonstrate applications including quantum chemistry and error correction.



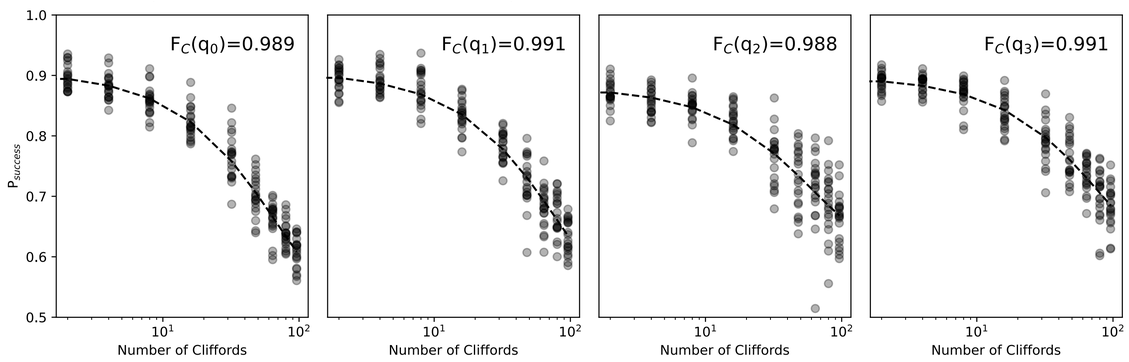
A scalable unit cell

For quantum computing to be viable, qubits must be demonstrated using manufacturing processes that can scale to sizes that support fault-tolerance. We have demonstrated a 4 qubit QPU implemented using a foundry SiMOS process on a 300 mm wafer.



The QPU consists of two linear arrays of gate defined quantum dots. Qubits are defined in the top array, sensors are defined in the bottom array.

These arrays can be tiled to support increasing QPU sizes



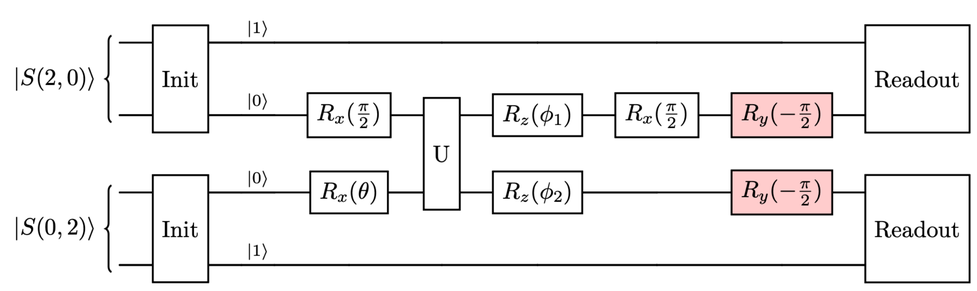
Single qubit randomized benchmarking sequence performed on all four qubits, resulting in an average single qubit gate of 99%.

VQE demonstrator algorithm

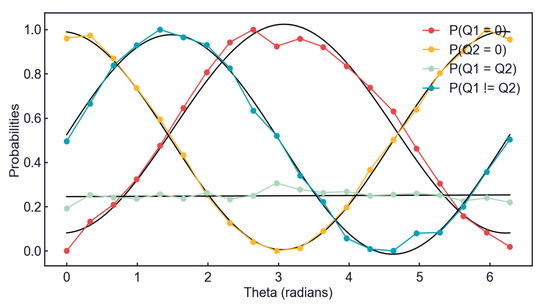
We benchmark the system by modelling an idealized hydrogen (H_2) and using a variational approach to find its ground state.

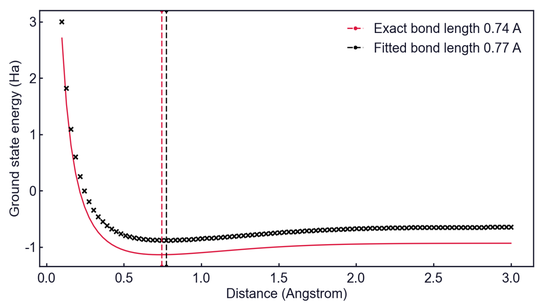
$$H = h_0 + h_1 ZI + h_2 IZ + h_3 XX + h_4 YY + h_5 ZZ$$

We use a chemically inspired ansatz with optimal compilation

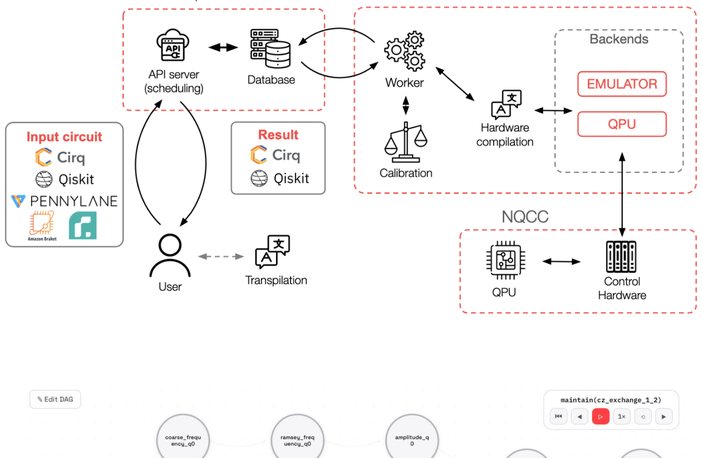


We extract the probability at different θ values for each term in the Hamiltonian to estimate the bond length of the H_2 molecule.



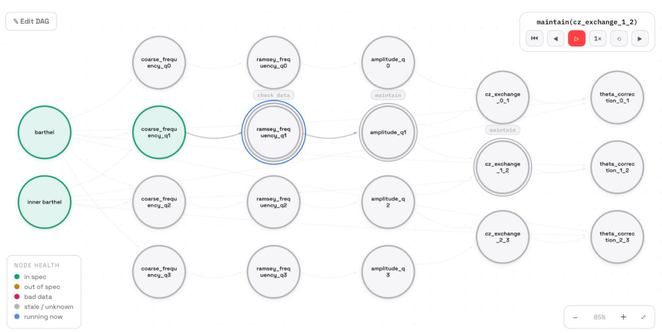


Cloud access and automated calibration



Access to the QPU is via a Python package that includes Oauth for authentication. Circuits are then verified for correctness locally and submitted to a cloud database. Job results are stored in the cloud and accessed via the same package.

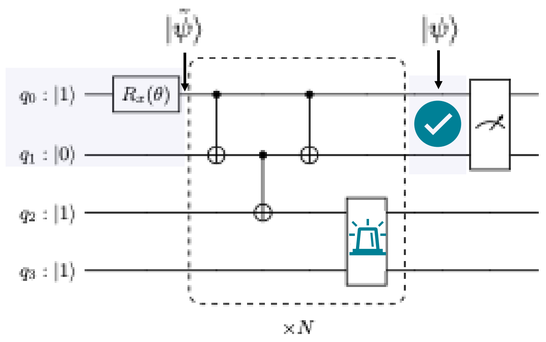
Automated calibration runs on a graph to minimize downtime vs chosen operation fidelity.

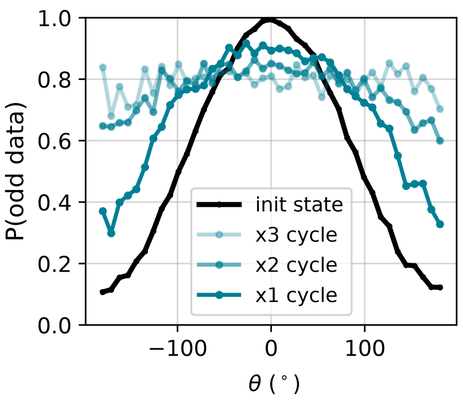


Error detection

Another application benchmarked on the QPU is a 2-qubit ZZ stabilizer error detection circuit. The parity of a pair of data qubits is projected onto the neighboring ancilla qubits. A bit flip error is injected and the stabilizer is repeated multiple times.

Post-selecting only those results where an error is not detected show a purification of the state over multiple cycles vs the injected error. Noise in the circuit means that for small errors, outcomes are worse.





QUANTUM MOTION