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Fault-tolerant encoding of a logical qubit[1]

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The discovery of quantum error correction codes gave credibility to the idea of scaling up quantum computers to large sizes [1]. Showing that all elements of error correction can be realized in a fault-tolerant way is therefore of fundamental interest. Fault tolerance removes the assumption of perfect encoding and decoding operations of logical qubits. We present the implementation of the [[4,2,2]] code, an error detection protocol [2] which uses four physical qubits to encode two logical qubits, one of which can be made fault-tolerant by appropriate construction of the encoding and stabilizer circuits [3]. Remarkably, it works with a bare ancilla qubit.

The results demonstrate for the first time the robustness of a fault-tolerant qubit to imperfections in the very operations used to encode it, as errors are suppressed by an order of magnitude below the physical error probability. We present data to show that this advantage over a non-fault-tolerant qubit persists even with large added error rates and experimental calibration errors [4].

The experiment is performed on a programmable quantum computer comprised of five trapped $^{171}\mathrm{Yb}^{+}$ ions. It provides a fully connected system of atomic clock qubits with long coherence times and high gate fidelities that can be programmed to execute arbitrary quantum circuits [5].

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