Performance of Academic and Industrial Spin-1/2 Qubits in Si-28/SiGe

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Abstract

Spin qubits in semiconductors are a promising platform for quantum computing due to their compact size, compatibility with existing fabrication technology, and potential for large-scale integration. While spin qubit research has long been spearheaded by academic laboratories, the field is now entering a new phase as industrial players introduce advanced large-scale fabrication capabilities, leveraging one of the core strengths of the platform. Yet, direct comparisons between academic and industrial spin qubit platforms remain rare.

Here, we compare state-of-the-art Si-28/SiGe spin qubit devices with integrated micromagnets, fabricated at RIKEN's academic cleanroom and Intel's 300 mm industrial foundry. Both devices use highly isotopically purified silicon (Si-28) quantum wells with comparable residual nuclear spin content (~800 ppm) and similar strain.

Both platforms achieve single-qubit fidelities well above 99.9%. RIKEN devices, operated at higher gate speeds, reach fidelities near 99.999% and sustain fidelities above 99.99% during simultaneous control of up to three qubits with a shared control line. Intel devices achieve fidelities of 99.99%, limited by their architecture, which results in weaker micromagnet gradients.

As a consequence, the industrial devices exhibit significantly lower qubit noise. In the RIKEN devices, as in most spin qubit systems, the dominant noise source is charge noise originating from two-level systems (TLS) associated with atomic-scale defects in the oxide. In contrast, the weaker micromagnet gradients in the Intel devices reduce sensitivity to charge noise, making nuclear spin noise originating from the remaining Si-29 nuclei the dominant contribution at low frequencies, even in highly purified Si-28. This difference in physical noise sources is relevant because charge noise leads to correlated errors between qubits due to shared two-level systems, which is particularly important in our compact and densely integrated devices. Nuclear spin noise, by comparison, is largely uncorrelated. As a result, the Intel devices display much less correlated low-frequency noise, which could offer a significant advantage for quantum error correction, where correlated errors are particularly difficult to correct or mitigate.

This comparison reveals a key trade-off: the academic devices offer higher fidelities and faster gate speeds, while the industrial devices provide improved noise resilience and greater potential for scaling. Together, these results underscore the promise of industrial fabrication for enabling the next generation of spin-based quantum processors.

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