Si/SiGe based quantum dot devices for memory and micron-scale connectivity with more than 200 gate electrodes

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Abstract

Si/SiGe based gate-defined spin qubits have been matured to such a degree over recent years that high density, high quantum dot count devices are technologically feasible. We recently demonstrated the capability of our Quantum Bus (QuBus) device [1] to initialize a register of 34 quantum dots (Fig. 1), with a per-dot filling of a single or no electrons at will (Fig. 2) [2]. All the while the entire "electron pattern" can be shifted along the register using conveyor-mode shuttling and electrons can be loaded and detected at the end of the shuttle [2, 3]. Despite more than 100 gate electrodes along the shuttle lane, only six control terminals are required. We demonstrated the shuttling of a single electron across the entire device back and forth (19 µm) with 99.8 % fidelity. In a related work [4], we show coherent separation and rejoining of an entangled spin-pair up to an accumulated shuttling distance of 3.36 µm using a similar QuBus device.

In this talk, I will discuss our fabrication processes at the Helmholz-Nanofacility at Research Center Jülich. They enable, in general, a large gate-electrode count beyond the 200 gate mark and specifically a T-junction connecting shuttle device featuring three single electron transistors as proximate charge sensors. I will also elaborate on a pre-screening process we developed to validate our devices electrically at an intermediate temperature of 4 K.

References

[1] Langrock et al., PRX Quantum **4**, 020305 (2023)
[2] Xue *et al.*, preprint, arXiv:2306.16375 (accepted for Nat. Commun.)
[3] Seidler *et al.*, npj Quantum Inf. **8**, 100 (2022)
[4] Struck *et al.*, preprint, arXiv:2307.04897 (accepted for Nat. Commun.)

Figures

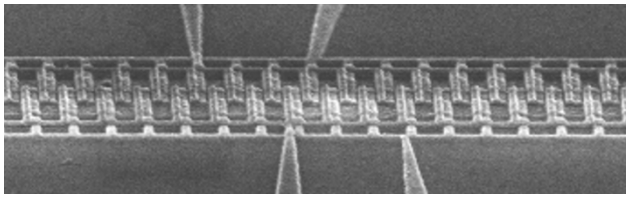

Figure 1: Scanning electron micrograph of the center section of a QuBus device. The width of the image covers approximately 4.3 µm.

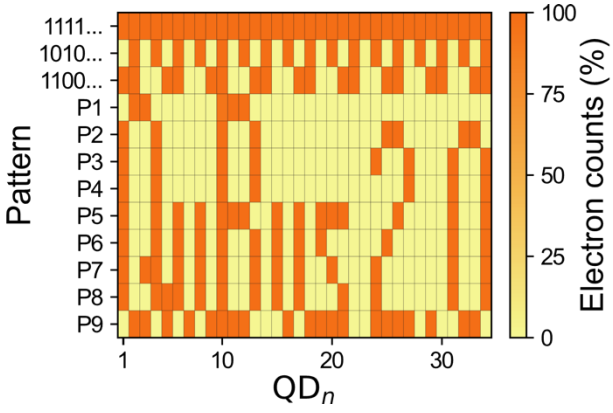

Figure 2: Fidelity analysis of the encoding of several "electron patterns" given by the quantum dot filling (either 0 or 1 at will). Each line represents one filling pattern for the full device containing 34 QDs. Adapted from [2].