Seminar/Talk

Spin-Orbit Qubits with Holes in Silicon and Germanium

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Quantum computers promise to solve key tasks exponentially faster than classical computers, holding great potential for society. Classical transistor scaling integrated billions of transistors on-chip, reaching transistor sizes so small that a single electron can be trapped and held in place. The spin of such a trapped charge is a prime contender for building scalable qubits out of classical transistors. Spin Qubits are small, fast and scalable, and operate even at temperatures above 1 K, thus allowing the integration of cryoCMOS control electronics. These advantageous properties make silicon spins a leading candidate for full-scale quantum computing. Hole spins can be coherently manipulated with all-electrical control due to the spin-orbit interaction (SOI) without requiring micromagnets, but this also opens the door for decoherence by charge noise. Across a broad range of qubits, a pervasive trade-off becomes obvious: increased speed seems only possible at the cost of qubit coherence. This qubit speed-coherence dilemma is posing a fundamental challenge for quantum computation. In this talk, I will present how the qubit speed can be increased without compromising coherence, thus boosting the qubit Q-factor by over an order of magnitude [1]. This is made possible by heavy-hole light-hole mixing providing a maximum of spin-orbit strength at finite electrical field. Further, we employed machine learning for fully autonomous tuning of a qubit from grounded gates to operational qubit [2]. Finally, the two-hole exchange is also highly anisotropic [3], opening the door for fast high fidelity gate operation. These experiments provide a new way forward for quantum computing with fast and coherent spins in Si and Ge.This work was supported by the NCCR SPIN, the Swiss National quantum computation program of the Swiss NSF, the Swiss Nanoscience Institute (SNI), and the EU H2020 European Microkelvin Platform EMP, TOPSQUAD, QUSTEC and QLSI programs.[1] Compromise-free scaling of qubit speed and coherence, M. J. Carballido et al., arXiv:2402.07313.[2] Fully autonomous tuning of a spin qubit, J. Schuff, M. J. Carballido, et al., arXiv:2402.03931.[3] Anisotropic exchange interaction in a fin field-effect transistor, S. Geyer, B. Hetnyi, et al., Nature Physics 20, 1152 (2024).

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