Coherent hole spin qubit shuttling in germanium: quantum links and high-fidelity quantum logic

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Résumé

The coupling of distant qubits or quantum processors presents clear advantages for the implementation of modular, fault-tolerant and large-scale quantum computers. In semiconductor spin qubits, such long-distance coupling can be implemented by shuttling coherently spins between neighbouring quantum dots. Long distance and coherent electron spin state transports via shuttling have been demonstrated in GaAs (1-4) and in silicon (5,6) enabling the implementation of quantum operations between distant spin qubits (7).
In this work, we investigate the coherent shuttling of hole spin qubits in germanium quantum dot arrays. We demonstrate the coherent transfer of single hole spin qubits through the quantum dots of a 2x2 germanium quantum processor (8). Transferring spin basis states in few nanoseconds, we observe coherent oscillations which witness significant changes in the direction of the quantization axes of neighboring quantum dots. They arise from the strong spin-orbit interaction and lead to rotations of the qubit state during the shuttling. Mitigating their effects, we demonstrate that hole spin qubits can be shuttled coherently up to few hundreds of times between quantum dots. Alternatively, we show that these rotations can also be harvested to perform high-fidelity single qubit operations based only on shuttling thus without the need of microwave signals.

Our work evidences the potential and the versatility of coherent shuttling for the operation of hole spin qubit processors in germanium. It opens new perspectives for the development of scalable architectures and distributed quantum computing on-chip.

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