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Ultrafast cohererent control of a hole spin qubit in a germanium quantum dot

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Spin qubits based on semiconductor material are being employed as building blocks for scalable quantum computing. And it has been advancing rapidly in recent years, due to its favorable coherence time and CMOS compatible techniques. Researchers have implemented high, quality and multi-qubit operation in both electron and hole spin system. Compared to electron, the p-type symmetry of the valence band of hole excludes the contact hyperfine interaction, which extends the coherence time. Also, the hole material system contains strong intrinsic spin orbit interaction (SOI). This mechanism allows all electrical control of the spin state, called electrical dipole spin resonance (EDSR), without the artificial SOI which is realized by constructing magnetic field gradient. This all-electrical approach promises faster Rabi rotations and reduced power consumption, as well as paving the way towards scalability, since electric fields are much easier to apply and localize than magnetic fields. In a Si QD, with relatively weak intrinsic SOI, a synthetic SOI has been introduced to provide fast and high-fidelity gates: a Rabi frequency above 10 MHz and gate fidelity of 99.9% have been reported in an isotopically enriched dot. However, the magnetic field gradient enabling the synthetic SOI also exposes the system to charge-noise-induced spin dephasing, posing a formidable technical challenge. As such, the search for a high quality spin qubit with fast manipulation and slow decoherence remains open. In our work, we focus on a hole spin qubit confined in a Ge/Si hut wire (HW) double quantum dot (DQD). We have fabricated a highly tunable double quantum dot on a Ge/Si HW. Based on a high-frequency microwave control circuit built in a dilution refrigerator, we have achieved full electrical control of a hole spin qubit and observed several EDSR spectrum lines. Mediated by the strong SOI, a Rabi frequency exceeding 540 MHz is observed at a magnetic field of 100 mT, setting a record for ultrafast spin qubit control in semiconductor systems. We demonstrate that the strong SOI of heavy holes (HHs) in our GHW, characterized by a very short spin-orbit length of 1.5 nm, enables the rapid gate operations we accomplish. Our results demonstrate the potential of ultrafast coherent control of hole spin qubits to meet the requirement of DiVincenzo's criteria for a scalable quantum information processor.

Biography

Ke Wang is a Postdoctoral Researcher at University of Science and Technology of China (USTC). He obtained his Phd degree in Physics from this university. He has been graduated from Nanjing University of Science and Technology, China, BSc in Optic Information Science and Technology. His previous experience involved being a member of Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum. He has been studying quantum dots in low dimensional materials for many years.