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Electrically driven single spin resonance in double quantum dots

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We report on our recent progress in applying semiconductor quantum dots to quantum information processing with electron spin qubits. Mixing the electron's spin and charge degrees of freedom via a magnetic field gradient enables reasonably fast single spin rotations driven by electric fields. We generate sufficiently strong gradients on-chip using micron-size ferromagnets. Our method bypasses the need for localized and strong microwave magnetic fields, which in comparison are difficult to apply in quantum dots. In addition, micro-magnets facilitate the selective manipulation of electron spins. We demonstrate proper operation of our micro-magnet approach using GaAs double quantum dots where single spin resonances and coherent rotations are observed. Preliminary results on combining 1 and 2-qubits operations are also presented. The strong nuclear spin fluctuations in the GaAs lattice cause fast decoherence and limit the quality factor of electron spin qubits. On-going efforts to solve the decoherence problem use material free of nuclear spins (e.g. isotopically purified SiGe). Although the other leading electric coupling mechanism, the spin-orbit interaction, work well in GaAs, it might not be as efficient in these materials. Our micro-magnet method - which is applicable to any material - is therefore a crucial component for the further development of electron spin qubits in quantum dots. Moreover, the micro-magnet design we present has applications to other kind of spin qubits like paramagnetic defects in silicon.

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