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Control and Manipulation of Two-Electron Spin Qubits in GaAs Quantum Dots[1]

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We have developed means to both couple and decouple a two electron spin qubit from its environment. Using dynamic nuclear polarization we are able to suppress fluctuations in the nuclear environment and prolong T2* by nearly an order of magnitude reaching 150 nano seconds. Our polarization scheme employs a quantum feedback mechanism that directly conditions the rate at which the qubit polarizes its nuclear environment on a quantum limited measurement of the hyperfine field seen by the same qubit. In addition, the stabilized state of the nuclear environment allows us to perform controlled X rotations and thereby demonstrate full control over the entire Bloch sphere as well as full quantum state tomography. Using dynamic decoupling of the two electron spin qubit from its environment we are able to prolong T2 by nearly three orders of magnitude reaching nearly 300 micro seconds. Our results indicate that gate fidelities of up to 99.99% are within reach despite the fluctuating nuclear environment. Moreover, the demonstrated ultra long coherence time allows for more than 10^5 coherent gate operations which exceed the estimated threshold for quantum error corrections by a substantial margin.

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