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Controlling Nuclear Spin Environment of Quantum Dots

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Electrons in semiconductor quantum dots typically interact with a large ensemble of surrounding nuclear spins via hyperfine coupling. When uncontrolled, this coupling can produce rapid dephasing of electron spin degrees of freedom. These effects of nuclear spin environment were recently observed in several experiments. We describe several approaches to control the interaction between electronic and nuclear degrees of freedom, which allow one to eliminate the dephasing associated with nuclei and to use the localized ensembles of nuclear spins as a useful resource. These approaches make use of the long-lived memory associated with nuclear spins. In particular, we will describe a technique for storing electronic spin qubits in collective states of nuclear ensembles. This can be achieved by controlling hyperfine interaction with external effective magnetic fields, and can result in a robust quantum memory for mesoscopic quantum bits with potential coherence times approaching seconds. Potential applications of this technique for long-distance quantum communication and scalable quantum computation will be discussed.