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Coherent manipulation of individual electronic and nuclear spin qubits in diamond[1]

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The complex environment of solid-state quantum bits is generally believed to form a central challenge for solid state realizations of quantum information science. We here demonstrate how the environment of a single electronic spin can be understood, controlled, and utilized as a resource. Specifically, coherent manipulation of a single electronic spin associated with a nitrogen-vacancy (NV) center in diamond was used to probe its interactions with the ^{13}C nuclear spin bath formed by isotopic impurities in the surrounding diamond lattice. We show that this environment is effectively separated into a set of individual, proximal ^{13}C nuclear spins which are coupled coherently to the electron spin, and the remainder of the ^{13}C nuclear spins, which cause the loss of coherence. A proximal nuclear spin can be addressed individually because of quantum back-action from the electron, which modifies its energy levels and magnetic moment, effectively distinguishing it from the rest of the spin bath. By manipulating the NV center via microwave and optical excitation, we demonstrate robust, room-temperature initialization of the two-qubit register formed by the electronic spin and the neearest-neighbor ^{13}C nuclear spin. Within this register, arbitrary quantum states can be transferred between the electronic and nuclear spin, while the nuclear spin qubit can be well isolated from the electron spin, even during optical polarization and measurement of the electronic state. Finally, we observe coherent interactions between individual nuclear spins, and demonstrate that they have excellent coherence properties, approaching those of isolated atoms and ions. Such registers may be used as a basis for scalable, optically coupled quantum information systems.

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