Controlling and connecting spin qubits in semiconductor defects

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There is a growing interest in exploiting the quantum properties of electronic and nuclear spins for the manipulation and storage of information in the solid state. Recent efforts embrace materials with incorporated defects whose special electronic and nuclear spin states allow the processing of information because of their explicitly quantum nature. Here we focus on recent developments that utilize precise quantum control techniques to explore coherent spin dynamics and interactions at the level of single spins. In particular, we present recent results of manipulating and connecting spins in both silicon carbide and diamond. We find that defect-based electronic states in silicon carbide can be isolated at the single spin level [1, 2] with surprisingly long spin coherence times and high-fidelity control. The revealed spin-photon interface offers an opportunity to implement all-optical holonomic spin gates [3] for quantum information processing within a wafer-scale material operating at near-telecom wavelengths. We also discuss pathways for connecting spins using hybrid spin-ferromagnetic systems that may relax the requirement of direct dipolar coupling. Using ferromagnetic spin-wave modes, we demonstrate long-range coherent control of spins in diamond using YIG thin-films [4]. The magnetic modes amplify the oscillating field of the microwave source by more than two orders of magnitude, thereby efficiently driving remote spin states.

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