High-fidelity quantum information processing and quantum simulation with spin qubits and phonons

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We propose and analyze the implementation of high-fidelity, phonon-meditated gate operations and quantum simulation schemes for spin qubits associated with silicon vacancy centers in diamond. Specifically, we show how the application of continuous spin-echo techniques can substantially boost the coherence of the qubit states while increasing at the same time the variety of effective spin models that can be implemented in this way. Our detailed analytical and numerical simulations show that this technique can be used to suppress gate errors by more than two orders of magnitude and to reach gate infidelities of $\sim 10^{-4}$ for experimentally relevant noise parameters. Therefore, the generalization of this approach to phononic lattices with arrays of implanted defect centers offers a realistic path toward moderate- and large-scale quantum devices with spins and phonons, at a level of control that is comparable to other leading quantum-technology platforms.