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Qubits Based on Shallow Donor Spins in Ge Phononic Crystals

VADIM SMELYANSKIY, NASA/Ames Res Ctr, VASYL HAFIYCHUCK, Stinger Ghaffarian Technologies Inc., MARK DYKMAN, Michigan State University, ANDRE PETUKHOV, South Dakota School of Mines and Technology — We propose qubits based on shallow donor electron spins in germanium. Spin-orbit interaction for donor spins in germanium is in many orders of magnitude stronger than in silicon. In a uniform bulk material it leads to very short spin lifetimes. However the lifetime increases dramatically when the donor is placed into a quasi-2D phononic crystal (PHC) and the energy of the Zeeman splitting is tuned to lie within a phonon bandgap. In this situation single phonon processes are suppressed by energy conservations. The remaining two-phonon decay channel is very slow. The Zeeman splitting within the gap can be fine tuned to induce a strong coupling between the spins of remote donors via exchange of virtual phonons. The analysis immediately extends to the interaction between nuclear spins. We also show that the long-range longitudinal interaction (z-z) between localized electron spins in PHC is similar to that mediated by Lamb waves in elastic plates. We explore various shapes of PHC cells in order to maximize the coherent effects of the spin-spin coupling while keeping the decay rate minimal. We find that phononic crystals with unit cell sizes 100-150 nm are viable candidates for quantum computing applications.

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