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Nonideality of quantum operations with the electron spin of a 31P donor in a Si crystal due to interaction with a nuclear spin system

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Abstract

We examine a 31P donor electron spin in a Si crystal to be used for the purpose of quantum computation. The interaction with an uncontrolled system of 29Si nuclear spins influences the electron-spin dynamics appreciably. The hyperfine field at the 29Si nuclei positions is noncollinear with the external magnetic field. Quantum operations with the electron wave function, i.e., using magnetic-field pulses or electrical gates, change the orientation of hyperfine field and disturb the nuclear-spin system. This disturbance produces a deviation of the electron spin qubit from an ideal state, at a short-time scale in comparison with the nuclear-spin diffusion time. For Hext≈9 T the estimated error rate is comparable to the threshold value required by the quantum error correction algorithms. The rate is lower at higher external magnetic fields.