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Preserving electron spin coherence in solids by optimal dynamical decoupling

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To exploit the quantum coherence of electron spins in solids in future technologies such as quantum computing, it is first vital to overcome the problem of spin decoherence due to their coupling to the noisy environment. Dynamical decoupling, which uses stroboscopic spin flips to give an average coupling to the environment that is effectively zero, is a particularly promising strategy for combating decoherence because it can be naturally integrated with other desired functionalities, such as quantum gates. Errors are inevitably introduced in each spin flip, so it is desirable to minimize the number of control pulses used to realize dynamical decoupling having a given level of precision. Such optimal dynamical decoupling sequences have recently been explored. The experimental realization of optimal dynamical decoupling in solid-state systems, however, remains elusive. Here we use pulsed electron paramagnetic resonance to demonstrate experimentally optimal dynamical decoupling for preserving electron spin coherence in irradiated malonic acid crystals at temperatures from 50K to room temperature [1]. Using a seven-pulse optimal dynamical decoupling sequence, we prolonged the spin coherence time to about 30 ms; it would otherwise be about 0.04 ms without control or 6.2 ms under one-pulse control. By comparing experiments with microscopic theories, we have identified the relevant electron spin decoherence mechanisms in the solid. Recently, we demonstrate experimentally that dynamical decoupling can preserve bipartite pseudo-entanglement in phosphorous donors in a silicon system [2]. In particular, the lifetime of pseudo entangled states is extended from 0.4 us in the absence of decoherence control to 30 us in the presence of a two-flip dynamical decoupling sequence.

[1]. Jiangfeng Du, Xing Rong, Nan Zhao, Ya Wang, Jiahui Yang and R. B. Liu, Preserving electron spin coherence in solids by optimal dynamical decoupling, Nature 461, 1265-1268 (2009).
[2] Ya Wang, Xing Rong, Pengbo Feng, Wanjie Xu, Bo Chong, Ji-Hu Su, Jiangbin Gong, and Jiangfeng Du, Preservation of bipartite pseudo-entanglement in solids using dynamical decoupling, submitted to Phys. Rev. Lett.