Control of solid-state qubit decoherence in spin baths
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A qubit loses its quantum coherence when it interacts with a bath. A quantum theory has been developed to treat qubit decoherence in interacting spin baths [1]. Repeatedly flipping a qubit can eliminate the qubit-bath interaction to certain orders. Thus, the spin coherence is preserved. This method, called dynamical decoupling (DD), has been experimentally proved an efficient approach to prolonging the qubit spin coherence time [2].

In a nitrogen-vacancy (NV) center in diamond, the electron spin is coupled to hundreds of $^{13}$C nuclear spins. We find that some characteristic oscillations, which arise from a bonded $^{13}$C nuclear spin pair (a dimer), are imprinted on the electron spin decoherence profile. The oscillation features are sensitive to the position and orientation of the dimer, and can identify the dimer. Therefore, we propose a magnetometer with single-nucleus spin sensitivity and atomic-scale resolution (Fig. 1) [3].

We further find that qubit decoherence under the many-pulse DD controls reveals information about elementary excitations and many-body correlations in baths. As shown in Fig. 2, under the 100-pulse periodic DD control, the sharp dips correspond to the excitations in the nuclear spin bath of an NV center. Their relative distances between the dips reveal the many-body correlations in the spin bath.

![Figure 1](image1.png)

Figure 1. (a) NV center as a magnetometer to detect nuclear spins in a single C$_{60}$ molecule. (b) Strong oscillation features of the qubit coherence depending on the position and orientation can be used to characterize the spin-labeled molecule.

![Figure 2](image2.png)

Figure 2. NV center spin coherence under the 100-pulse periodic DD control for two different spin baths. Sharp dips arise from the elementary excitations of the interacting spin bath. The relation $t_1^{-1} + t_2^{-1} = t_3^{-1}$ reveals a 3-spin correlation in the bath.

References: