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Title:

Directly Observing Quantum Spin Dynamics and Relaxation via Electron Magnetic Resonance

Abstract

This tutorial will focus on the quantum dynamics of a central electron spin, e.g., a target qubit, subjected to static and dynamic external magnetic fields, that is embedded within an insulating host in which there exist other magnetic (electron and nuclear spins) and non-magnetic (vibrational) degrees of freedom. Coupling to the collective dynamics associated with the surrounding spin bath causes stochastic fluctuations in the quantum phase of the central spin, leading to decoherence, while coupling to vibrations leads to energy relaxation that ultimately influences coherence. Being primarily an experimental tutorial, the first part will focus on measurement of the quantum dynamics of the central spin using pulsed electron spin resonance techniques. Examples of both ensemble and single-spin measurements will be presented. In the dilute electron case at low temperatures, decoherence of the central electron spin is driven primarily by the nuclear bath and may be thought of as arising from the coherent deterministic dynamics of the coupled electron and nuclear systems. Experiments that directly observe this coherent, coupled dynamics will be presented [1], along with several quantum simulation methods [1-3]. It will then be shown that one can effectively decouple the central spin from the nuclear bath via use of so-called clock-transitions [4,5] – optimal operating points at which the electron dynamics are insensitive (to first-order) to the local magnetic induction – leading to enhanced coherence. This decoupling enables an assessment of other sources of decoherence. In particular, the role of resonant electron spin-spin interactions and spin-vibrational coupling will be considered. Time permitting, methods for achieving non-equilibrium electron spin configurations (i.e., initialization) based on the use of arbitrary shaped microwave pulses will be presented.

[1] Chen, Hill et al., arXiv:2106.05185 [quant-ph]. https://arxiv.org/abs/2106.05185

[2] Chen, Hill et al, J. Phys. Chem. Lett. **11**, 2074 (2020). https://doi.org/10.1021/acs.jpclett.0c00193

[3] Canarie, Stoll et al., J. Phys. Chem. Lett. **11**, 3396 (2020). https://doi.org/10.1021/acs.jpclett.0c00768

[4] Komijani, Hill et al., Nature **531**, 348 (2016). https://doi.org/10.1038/nature16984

[5] Gaita-Ariño, Hill et al., Nature Chemistry **11**, 301 (2019). https://doi.org/10.1038/s41557-019-0232-y