Relaxation mechanisms of a single dark electron spin in diamond

J. C. Marcks[1], M. Onizhuk[2,1], Y.-X. Wang[1], Y. Zhu[1], Y. Jin[1], B. Soloway[1], M. Fukami[1], N. Delegan[3], F. J. Heremans[3,1], A. A. Clerk[1], G. Galli[1,2,3], D. D. Awschalom[1,3]

[1] *Pritzker School of Molecular Engineering, University of Chicago, Chicago, IL 60637, USA*

[2] *Department of Chemistry, University of Chicago, Chicago, IL 60637, USA*

[3] *Center for Molecular Engineering and Materials Science Division, Argonne National Laboratory, Lemont, IL 60439, USA*

marcks@uchicago.edu

1. Abstract

Spin baths in solid state systems present both a limit on coherent central spin operation as well as a potential resource for quantum sensing and quantum communication applications with multi-qubit entangled states. While evolution of a many-body spin bath in general decoheres the central spin via dipolar interactions, these same couplings also enable coherent interaction with suitable qubit control. The optically active nitrogen vacancy (NV) and the optically dark neutrally charged substitutional nitrogen (N_s^0, P1) centers in diamond are a widely studied central spin-spin bath system. However, little work has focused explicitly on the P1 center, and is usually concerned with mesoscopic bath properties, not single spins. A better understanding of single P1 electron spins will inform NV center decoherence as well as help evaluate the feasibility of the P1 center as a qubit. In this work, we realize resonant polarization and off-resonant readout of a single P1 electron spin mediated by the NV center electron spin, enabling polarization-resolved measurements of the P1 spin decay. We first measure decay in the dark, finding a room temperature spin T1 ≈ 2.5 ms despite an environment of resonant bath spins. We then measure anomalously long spin relaxation times under optical illumination with green light, observations that run counter to assumptions about P1 spin baths. These results provide a microscopic view of spin bath dynamics in diamond and advance P1 bath spins as a resource for quantum sensing.

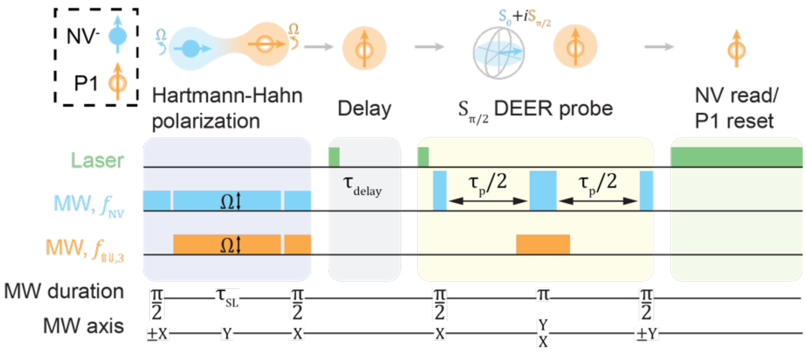

Fig. 1. Polarization- and time-resolved measurement of P1 spin polarization decay. A resonant Hartmann-Hahn polarization step is followed by a variable delay time and an off-resonant double electron-electron resonance polarization probe.