Tunable Gyromagnetic Augmentation of Nuclear Spins in Diamond

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Nuclear spins in solids have attracted significant interest as a qubit platform, as they exhibit long coherence times due to an intrinsically weak coupling to magnetic fields. The reduced coupling to magnetic noise, however, comes with concomitantly weaker coupling to control fields, which leads to slow and error prone nuclear spin gate operations. For nuclear spins that are hyperfine-coupled to nearby electrons, such as the paramagnetic P1 defect in diamond, application of a magnetic field mixes electron spin state characteristics into the P1 ^{14}N nuclear spin states [1, 2]. Electron-nuclear spin-mixing augments the gyromagnetic ratio of the nuclear spin, resulting in greatly enhanced coupling to radiofrequency control fields. In this talk, I will present our work that demonstrates rapid control of nuclear spins, which are typically well isolated from external fields, through magnetic-field induced augmentation [3].

Our experiments use an ensemble of nitrogen-vacancy (NV) centres to detect optically-dark paramagnetic defects (P1 centres) in diamond. Using spin-echo interferometry to measure the magnetic signatures of P1 electron and nuclear spins, we demonstrate that gyromagnetic augmentation can be tuned by variation of the strength of an external magnetic field. We identify that at low magnetic fields, we can perform rapid quantum control of the P1 nuclear spin state at MHz Rabi frequencies, which are up to 5000 times faster than those measured at higher magnetic fields and are comparable to the Rabi frequencies of the P1 and NV electron spin. Our results are well explained by theoretical calculations that compute the augmented nuclear gyromagnetic ratio for any P1 quantisation axis and magnetic field orientation. In this talk, I will also report on experiments in which we examine the the coherence of the P1 electron and nuclear spin as the magnetic field is varied and the consequences of gyromagnetic augmentation on the coherent properties of the multi-spin system.

[1] S. Sangtawesin C. A. McLellan, B. A. Myers, A. C. B. Jayich, D. D. Awschalom, and J. R. Petta, *New J. Phys.* **18**, 083016 (2016).

[2] M. J. Degen, S. J. H. Loenen, H. P. Bartling, C. E. Bradley, A. L. Meinsma, M. Markham, D. J. Twitchen, and T. H. Taminiau, *Nat. Commun.* **12**, 3470 (2021).

[3] R. M. Goldblatt, A. M. Martin and A. A. Wood, *Phys. Rev. B* **105**, L020405 (2022).