Tuning the coherent interaction of an electron qubit and a many-body register

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A central spin qubit interacting coherently with a large register of nuclear spins can be used for the realization of a quantum memory [1,2] or for the realization of coherent collective phenomena [3]. Here we demonstrate tuning of the coherent interaction between an electron spin qubit and a register of nuclear spins in a GaAs quantum dot (QD). The low inhomogenous broadening of the nuclear spin satellite transitions in the GaAs system, paired with an all-optical nuclear cooling algorithm, allows us to perform high-resolution spectroscopy of the nuclear ensemble, enabling measurement of the electronic Knight field and time-dependent revivals of electronic coherence, which fully characterize the electron-nuclear interaction. By precisely selecting the nuclear mean-field polarization via a polarization locking pulse sequence, we vary the strength of the electron-nuclear exchange interaction *in situ*, a result enabled by the electron g-factor anisotropy mediated nature of the interaction. We then demonstrate tuning of the coherent interaction explicitly via the activation rate of a single collective nuclear excitation and the coherence time of the electron spin qubit. This technique enables the programmatic tuning of the Hamiltonian of a central-spin system in the many-body regime.

References

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Figures

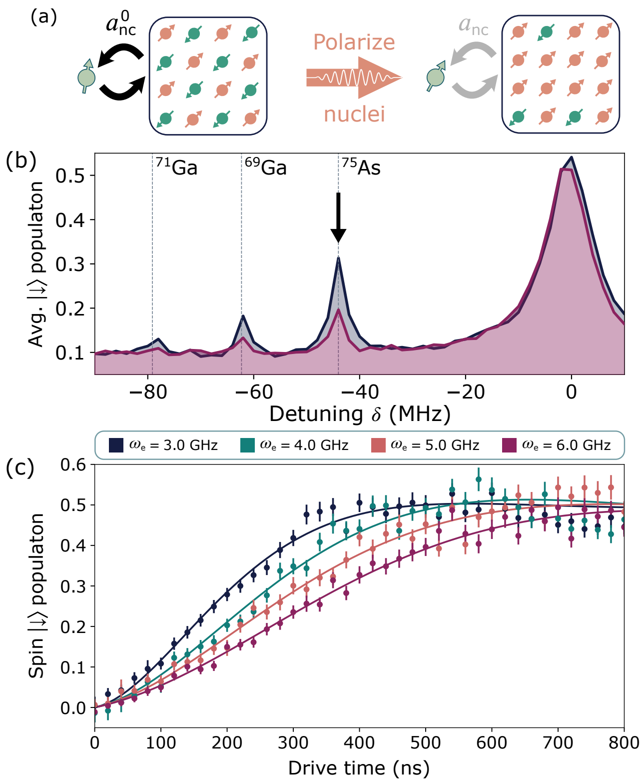

Figure 1: (a) Left: the optically addressed electron spin is in contact with a bath of ~10^5 As and Ga nuclear spins, forming a central spin system. An electron g-factor anisotropy leads to a different quantization axis for the electron and for the nuclei, leading to a non-collinear interaction. Right: As the nuclei are polarized, increasing the mean-field Overhauser shift, the electron and nuclear quantization axes tilt together, decreasing the non-collinear interaction. (b) The electron spin resonance spectrum. The blue line is the spectrum measured at the unpolarized electron Zeeman frequency of 3GHz, while the maroon line is measured for a polarized nuclear ensemble at 6GHz. (c) The spin down population of the negative ^{75}As sideband as a function of Rabi drive time for several electron splittings.