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Coupling nitrogen-vacancy centers to a dynamic ferromagnetic vortex for fast, nanoscale spin addressability and control[1]

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As we begin to look at how spin qubits might be integrated into a scalable platform, a promising strategy is to engineer the magnetic environment of the spins using micron- or nanometer-scale ferromagnetic (FM) elements, for functionalities such as nanoscale addressability, spin-wave mediated coupling, or enhanced sensing. The promise of these FM/spin interactions brings with it the question of how the coherence properties of the spin will be affected by coupling to these complex mesoscopic systems. To explore the physics of individual spins coupled to a proximal, dynamic ferromagnetic structure, we have studied interactions between individual nitrogen-vacancy (NV) spins and a model FM system – a vortex magnetization state. The complex, yet controllable, spin texture of a FM vortex, formed in a thin disk or nanowire, allows one to study different regimes of interaction with a nearby confined spin. The vortex core produces a large static dipole-like fringe field. The vortex state also displays discrete dynamic modes ranging from several 100 MHz to GHz. By applying an in-plane magnetic field, the position of the vortex core relative to the NV spin can be controlled with nanometer-scale resolution, and time resolution of 10s of nanoseconds. As the vortex core is translated into proximity with an NV spin, the fringe field from the core generates a large position-dependent spin splitting, permitting nanoscale spin addressability [1]. We also find that the dynamic interaction of the vortex, NV spin, and applied microwave field results in amplification of the Rabi transition rate by more than an order of magnitude. Finally, we explore how spin decoherence and relaxation mechanisms are enhanced as the vortex core approaches the NVs, with implications for proposed technology incorporating coherent spins and proximal FM elements. [1] Wolf, M. S., Badea, R., and Berezovsky, J. "Fast, Nanoscale Addressability of Nitrogen-Vacancy Spins via Coupling to a Dynamic Ferromagnetic Vortex" Nature Communications 7, (2016): 5.

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