Fast nanoscale addressability of individual NV spins via coupling to driven ferromagnetic vortices

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Introduction
Ferromagnetic vortex domains produce strong, localized, rapidly-tunable magnetic fields which may be useful for nanoscale spintronics or quantum information processing devices. A vortex interacting with adjacent NV spins provides a platform for addressing individual spins for coherent manipulation or coupling. Here, we show that this interaction leads to large spin splitting, enhancement of microwave fields and spin manipulation via adiabatic passage.

Experimental set-up

- Diamond nanoparticles with NVs are dispersed on a gold coplanar waveguide (CPW) with fabricated ferromagnetic disks.
- A scanning microscopy set-up is used to initialize and detect NV spins and image magnetization.

Microwave field enhancement

- Rabi oscillations are measured by varying the MW pulse length with constant \( B_{\text{CPW}} \).
- Large enhancement of the Rabi frequency at some vortex positions.
- Enhancement largest with vortex close to NVs.

Fast NV addressability

- Pulse the vortex position to bring a particular NV into resonance.
  - Method 1: Move vortex then manipulate spin
    - Vortex relaxes after voltage step in ~100ns.
    - MW pulse begins 100ns after CPW step.
    - Minimal reduction in oscillation amplitude.
  - Method 2: Move vortex while manipulating spin (adiabatic passage)
    - Relaxation into resonance with MW field yields high fidelity \( \pi/2 \) rotation (‘adiabatic half passage’).
    - AHP aligns spin with MW field in the rotating frame (B1).
    - Subsequent manipulation possible with phase-shifted MW field (B1’ in the rotating frame).

Magnetooptical Kerr effect

- The disk is magnetized in a single vortex domain.
- The vortex core position is controlled by an applied magnetic field.
- See poster on Wednesday for more detail.

Micromagnetic OOMMF simulation

- At \( B_1 \), NV1 is in resonance with \( f_{\text{MW}} \).
- At \( B_2 \), NV2 is in resonance with \( f_{\text{MW}} \).
- At \( B_{12} \), NV1 and NV2 are in resonance with each other but not with \( f_{\text{MW}} \).

Vortex-induced spin splitting

- Sweep vortex past nanoparticle with several NVs.
- Monitor NV spin splitting via optically detected magnetic resonance (ODMR).
- Large splitting when vortex is near NVs.
- Broadening caused by vortex induced MW field enhancement.
- Jumps occur to vortex pinning (see poster on Wednesday).

Pulsing between \( B_1 \), \( B_2 \), and \( B_{12} \) allows operations on NV1 and NV2.

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