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

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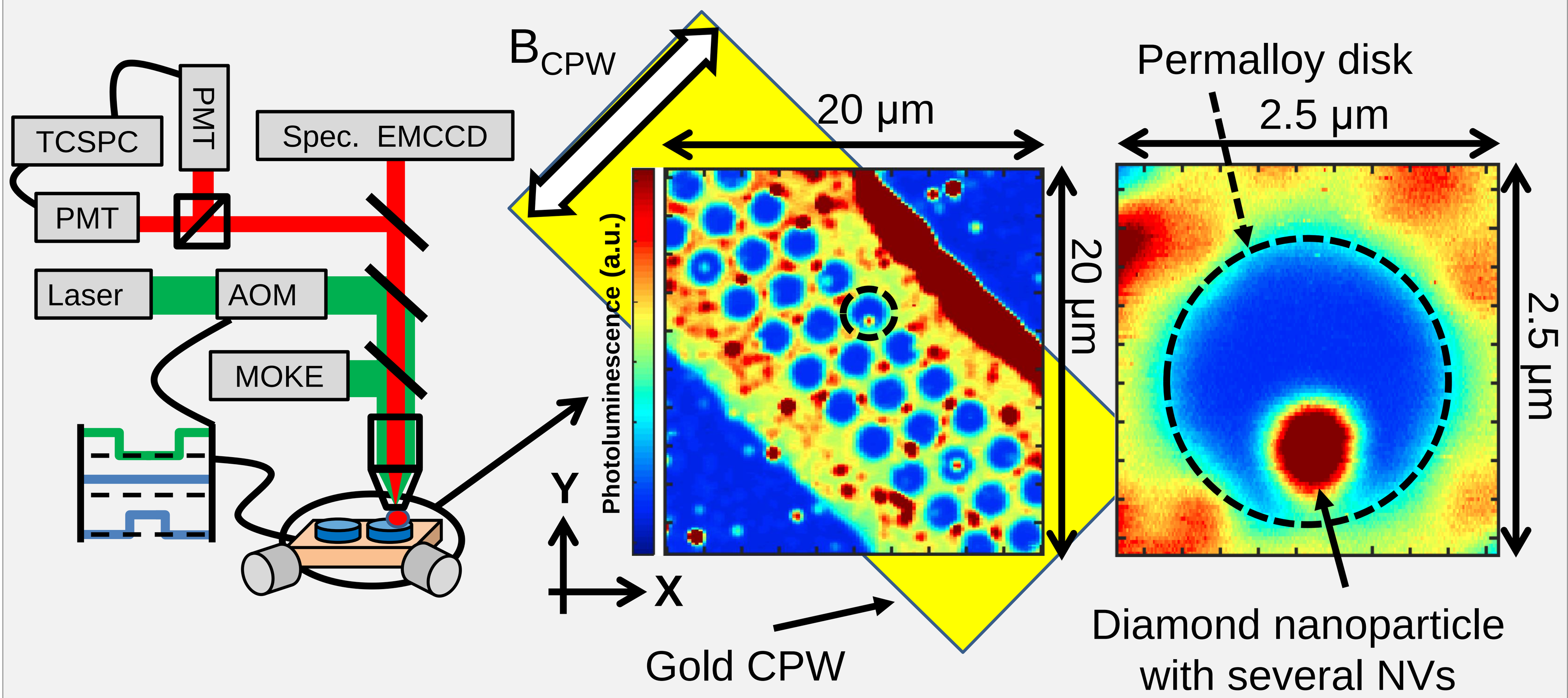
Introduction

Ferromagnetic vortex domains produce strong, localized, rapidly-tunable magnetic fields which may be useful for nanoscale spintronic 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.

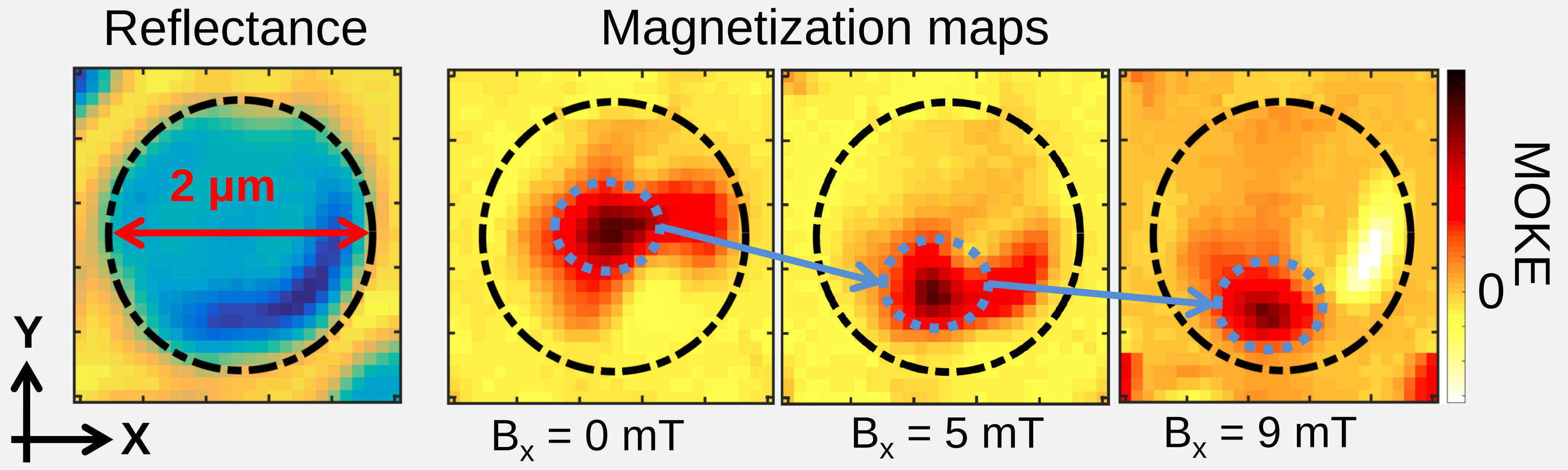
Experimental set-up

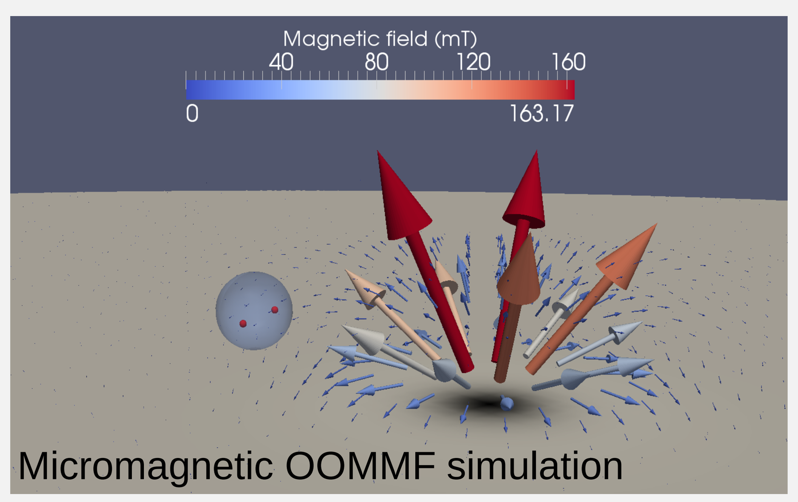
- Diamond nanoparticles with NVs are dispersed on a gold coplanar waveguide (CPW) with fabricated ferromagnetic disks.
- A scanning microscopy set-up is used to initialize and detect NV spins and image magnetization.



Magneto-optical Kerr effect

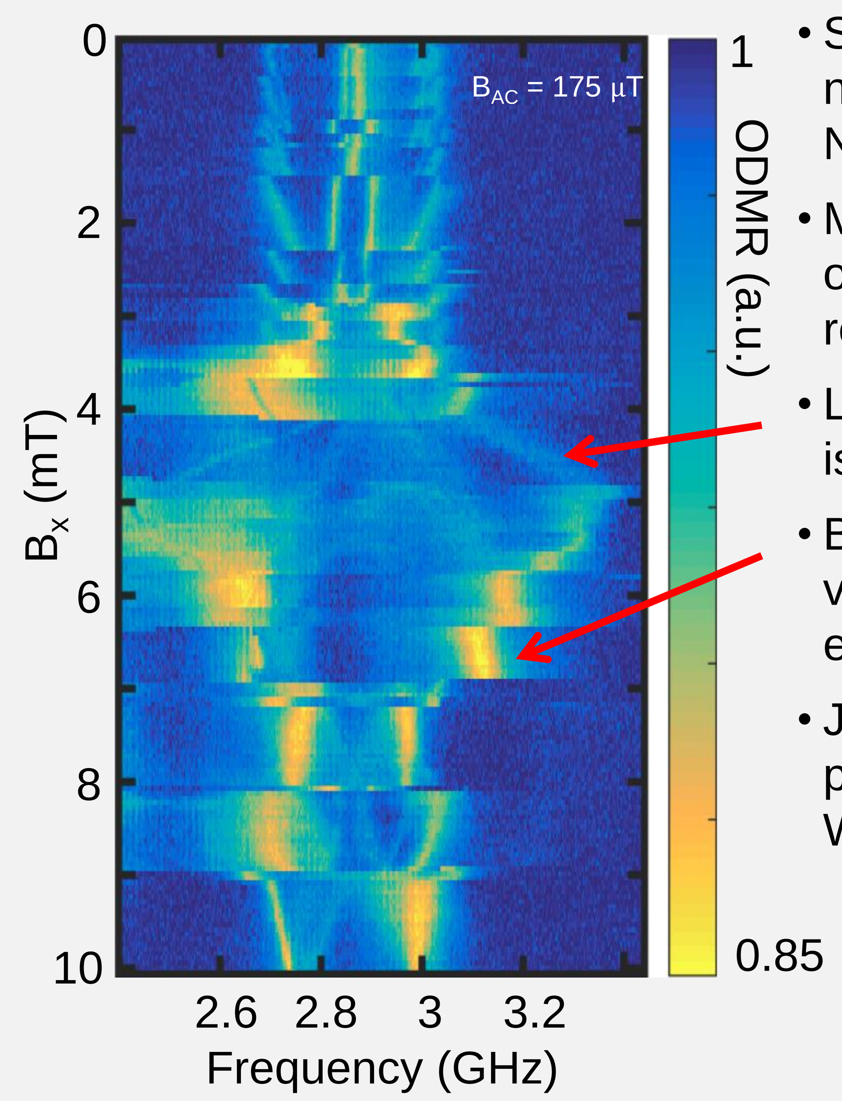
- The disk is magnetized in a single vortex domain.
- The vortex core position is controlled by an applied magnetic field.
- See poster on Wednesday for more detail.



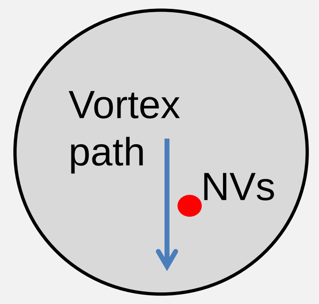


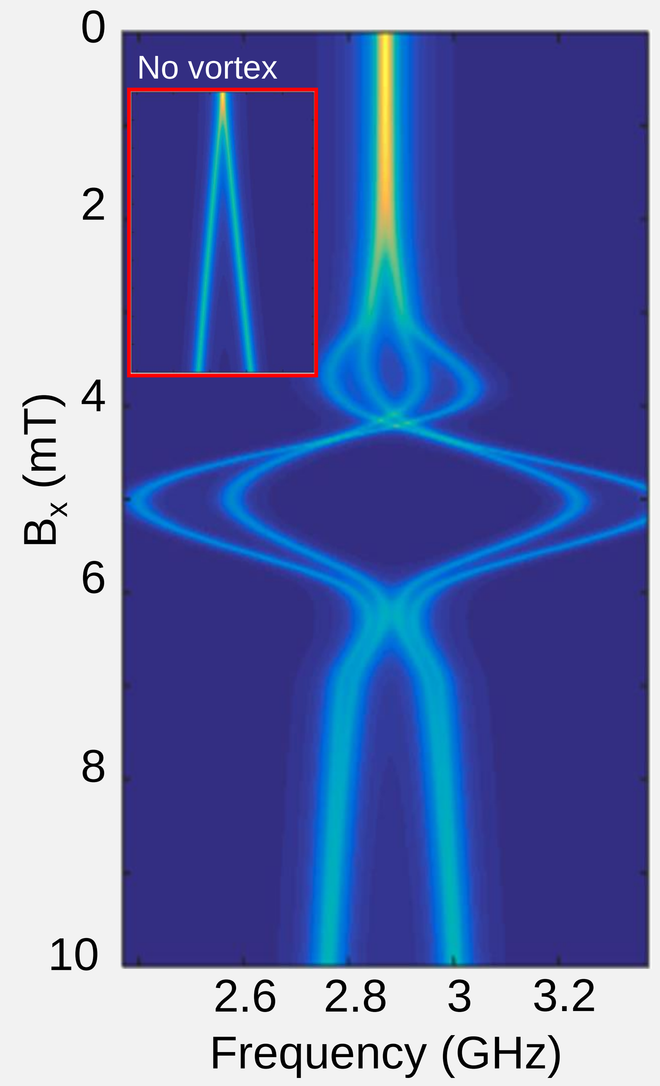
- B_{CPW} is capable of translating the vortex within tens of ns over several hundreds of nm.
- Vortex magnetic field near the surface of the disk can reach several hundred mT.

Vortex-induced spin splitting

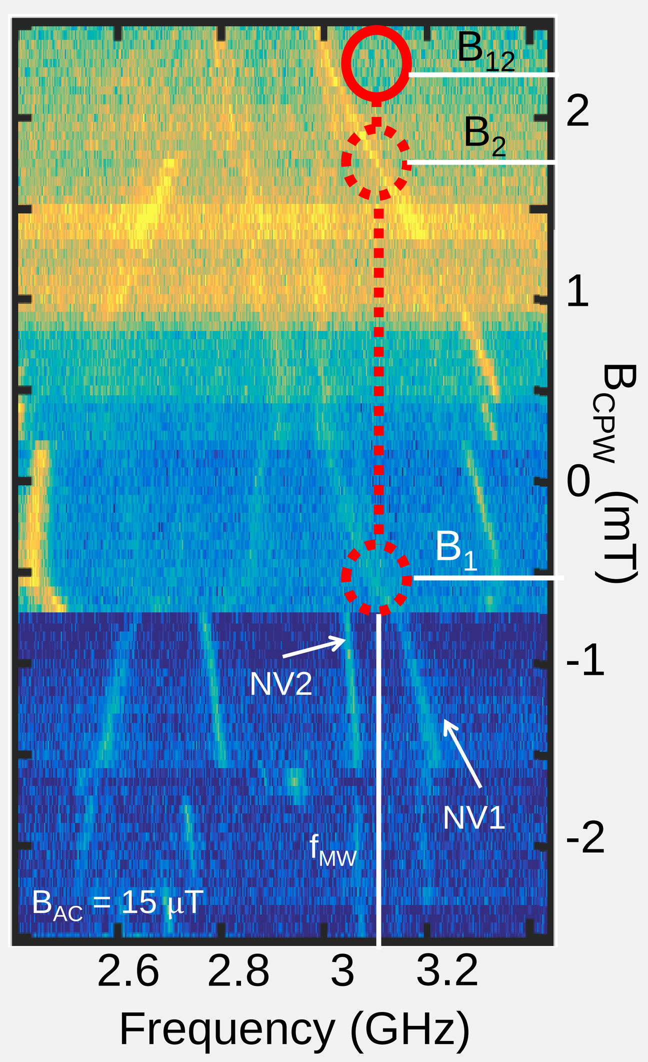


- Sweep vortex past nanoparticle with several NVs.
- Monitor NV spin spitting via optically detected magnetic resonance (ODMR).
- Large splitting when vortex is near NVs.
- Broadening caused by vortex induced MW field enhancement.
- Jumps occur to vortex pinning (see poster on Wednesday).



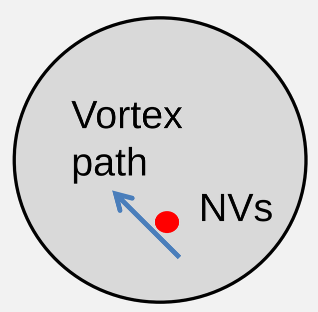


- Simulated ODMR of two NVs coupled to vortex.
- NVs 10 nm apart, 20 nm above vortex.
- Significant splitting between the two NVs.



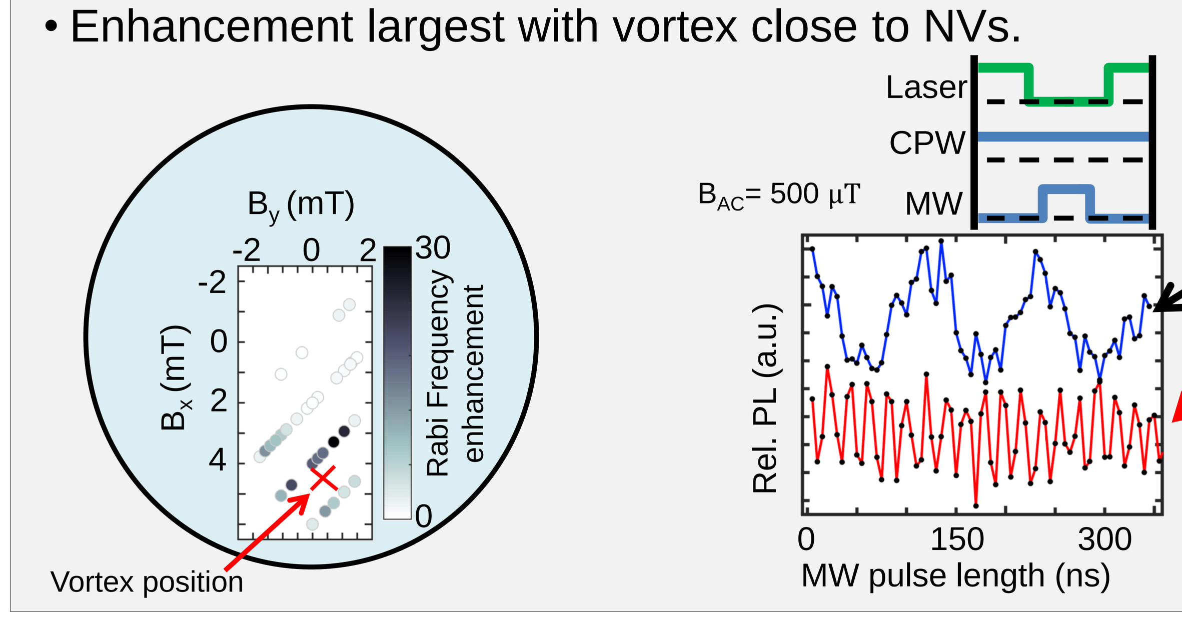
- At B_1 NV1 is in resonance with f_{MW}
- At B_2 NV2 is in resonance with f_{MW}
- At B_{12} NV1 and NV2 are in resonance with each other but not with f_{MW}.

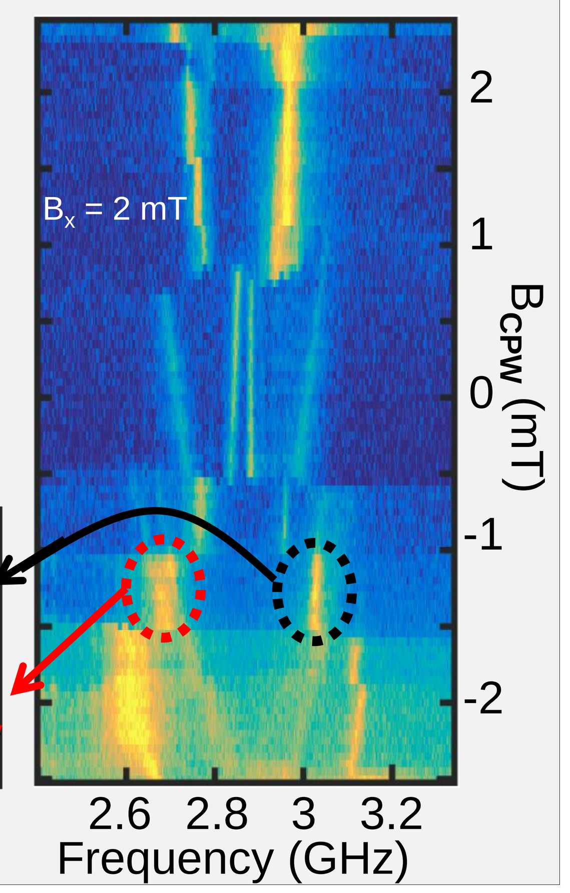
Pulsing between B_1, B_2, and B_{12} allows operations on NV1 and NV2.



Microwave field enhancement

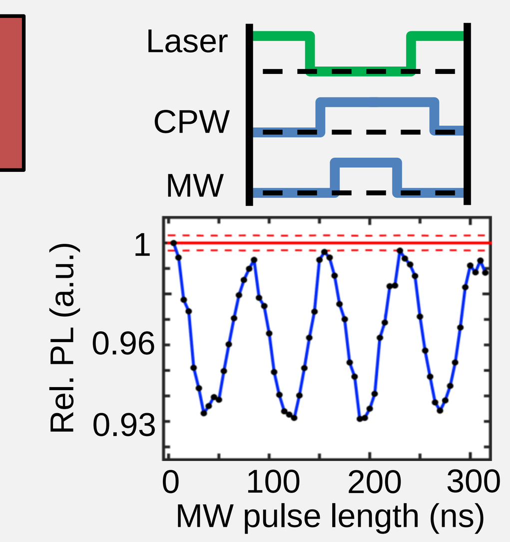
- Rabi oscillations are measured by varying the MW pulse length with constant B_{CPW}.
- Large enhancement of the Rabi frequency at some vortex positions.
- Enhancement largest with vortex close to NVs.





Fast NV addressability

Pulse the vortex position to bring a particular NV into resonance.

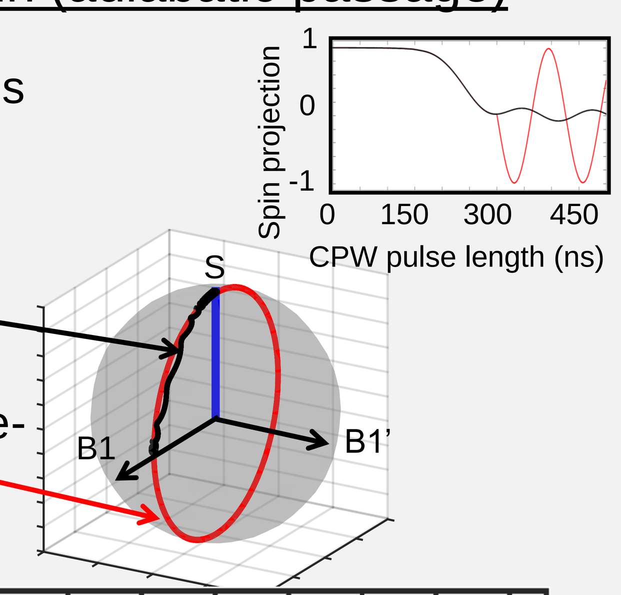


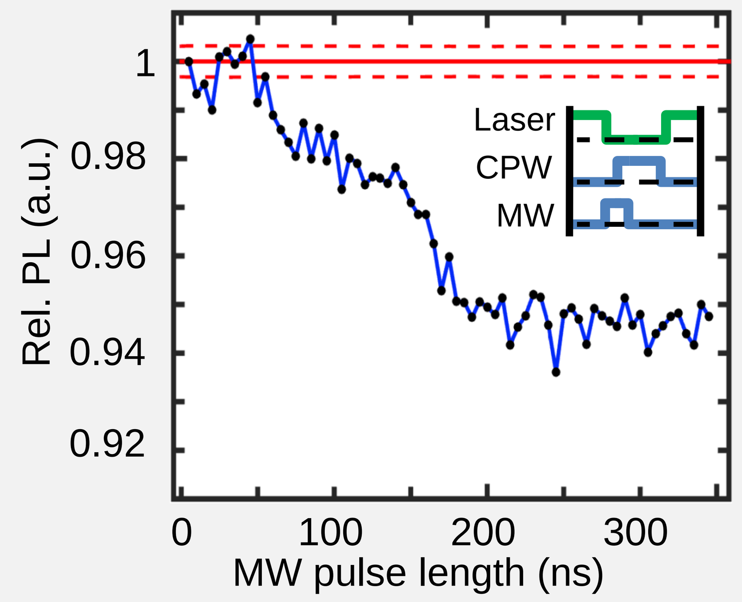
Method 1: Move vortex then manipulate spin

- Vortex relaxes after voltage step in ≈100ns.
- MW pulse begins 100ns after CPW step.
- Minimal reduction in oscillation amplitude.

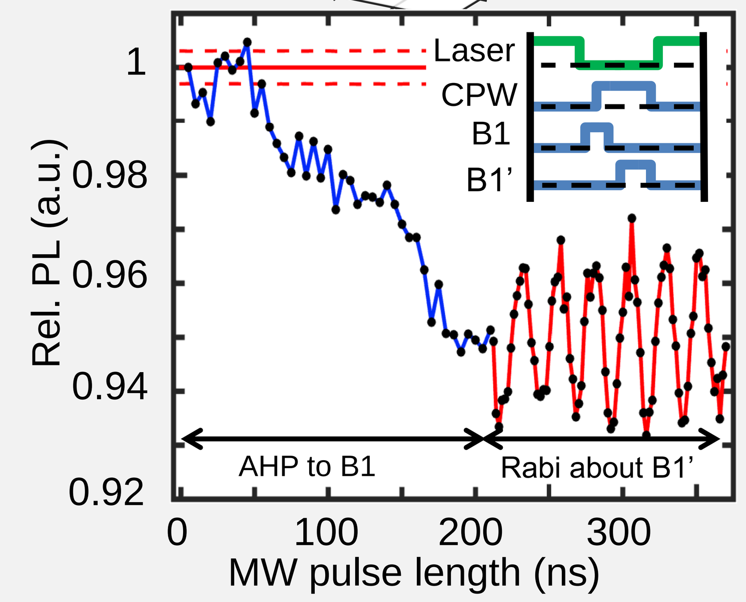
Method 2: Move vortex while manipulating spin (adiabatic passage)

- Relaxation into resonance with MW field yields high fidelity π/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).





- Spin rotated to B1 direction via adiabatic passage



- Confirmed coherence by observing Rabi oscillations about B1'

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