Vector magnetometry in an alkali vapor cell using radio frequency Rabi oscillations

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Optically-pumped magnetometers are popular because of their scalar accuracy, sensitivity, and compact design. However, their use in vector magnetometry often requires mechanical references like, e.g., a coil system, which can be prone to drifts and machining tolerances affecting vector accuracy. Common approaches to address this involve physical rotating the magnetometer system for calibration. An alternate approach uses electromagnetic fields as a reference. In previous work, we demonstrated vector and scalar magnetometry by exciting Rabi oscillations between ground state hyperfine manifolds with self-calibrating microwave polarization ellipses (PEs) using ^{87}Rb, both with cold atoms[1] and in a hot vapor cell[2]. In this talk, I will describe our recent work on using radio frequency (RF) PEs to drive Rabi oscillations between Zeeman levels within hyperfine manifolds. Unlike hyperfine transitions, Zeeman transitions are less affected by spin-exchange decoherence, improving vector sensitivity. Moreover, 3D RF coils allow compact packaging with fast and flexible field control, enabling real-time calibration of PEs and compensation of drifts. We determine the DC field direction by measuring $\sigma\pm$ Rabi frequencies, while its magnitude is obtained from Larmor precession measurements.

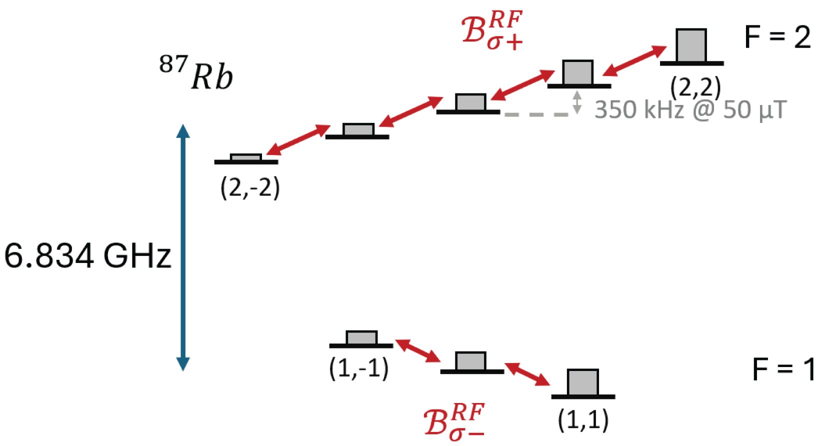

Figure 1. Level diagram showing the Rabi transitions in ^{87}Rb ground state driven by the applied RF field, $\vec{\mathcal{B}}^{RF}$

[1] T. Thiele, Y. Lin, M. O. Brown, and C. A. Regal. "Self-Calibrating Vector Atomic Magnetometry through Microwave Polarization Reconstruction.", Phys. Rev. Lett. **121**,15 (2018)

[2] C. Kiehl, T.S. Menon, S. Knappe, T. Thiele, and C.A. Regal. “Correcting heading errors in optically pumped magnetometers through microwave interrogation.”, Phys. Rev. Appl. (2024, Accepted)