Towards a pulsed dead-zone free gradiometer in Earth's field

Kaleb Campbell[1,2], Ying-Ju Wang [3], Igor Savukov[4], Peter D.D Schwindt[1], Vishal Shah[3]

1. *Sandia National Laboratory, 1515 Eubank SE, 87123 Albuquerque, USA*
2. *Department of Physics and Astronomy, University of New Mexico, 1919 Lomas Blvd NE, Albuquerque, USA*
3. *QuSpin Inc., 331 S 104th St Unit 130, 80027 Louisville, USA*
4. *Los Alamos National Laboratory, 87545 Los Alamos, USA*

Measuring ambient magnetic field gradients in a single device is an important problem in atomic magnetometry. We report on the development of an atomic gradiometer based on the hyperfine splitting in two vapor cells of warm ^{87}Rb atoms. By applying a π/2 pulse of microwave magnetic energy, we maximize the coherence between disparate energy levels, producing a sideband at the frequency of the coupling microwave radiation [1]. By beating together the sidebands from each vapor cell, we measure the beat frequency and thus the magnetic field gradient between the cells [2]. For a practical gradiometer, it is important to be able to measure the gradient regardless of the direction of the ambient magnetic field $\mathbf{B_A}$, either perpendicular or parallel to the laser beam propagation axis. For the perpendicular case, we first apply a magnetic field $\mathbf{B_C}$ collinear to the laser beams so that a circularly polarized Pump beam at 795 nm can optically pump the atoms to the |F=2, m_F=2> state. To obey selection rules for sideband generation on the |1, 1> and |2, 2> states, we quickly turn off the pump, and adiabatically turn off $\mathbf{B_C}$ to rotate the quantization axis to be along $\mathbf{B_A}$. Then, the microwave π/2 pulse is applied, the Carrier is applied, and the beat note of the generated sidebands is detected. For the other case, if the ambient field is along the direction of the laser beams, we turn off the pump, and then use adiabatic rapid passage (ARP) to transfer the atomic population from the |2, 2> to the |1, 1> state, and we generate sidebands using a coherence between the |2, 1> and |1, 1> states. Experimental details for each case will be provided. We report preliminary noise sensitivities as low as $\frac{30fT}{\sqrt{Hz}*cm}$ with magnetic shielding and $\frac{65fT}{\sqrt{Hz}*cm}$ for measurements performed in the Earth's field.

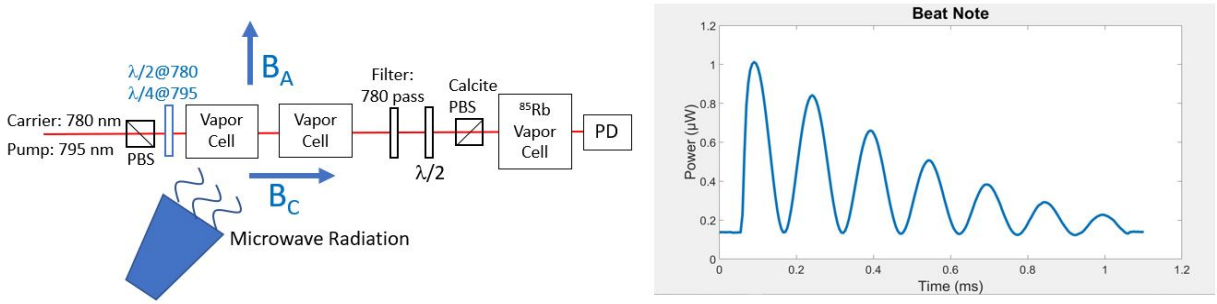

Fig. 1 (Left) Experimental gradiometer setup with collinear Pump and Carrier beams [2]. For this case, we assume the ambient field, B_A, is perpendicular to the Carrier direction. The sideband is orthogonally polarized to the carrier, so the beat note can be picked off using a polarizing beam splitter (PBS). (Right) An example of the beat note data.

References

[1] Henry Tang, *Parametric Frequency Conversion of Resonance Radiation in Optically Pumped ^{87}Rb Vapor*. Phys. Rev. A **7**, 2010 (1973).

[2] Vishal Shah, *System and Method for Measuring a Magnetic Gradient Field*. Patent. US10088535 (2018)