Femtotesla direct magnetic gradiometer using a single multipass cell

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We describe a direct gradiometer using optical pumping with opposite circular polarization in two ⁸⁷Rb atomic ensembles within a single multipass cell [1]. A far-detuned probe laser undergoes a near-zero paramagnetic Faraday rotation due to the intrinsic subtraction of two contributions exceeding 3.5 rad from the highly-polarized ensembles. We develop analysis methods for the direct gradiometer signal and measure a gradiometer sensitivity of 10.1 fT/cm $\sqrt{\text{Hz}}$. We also demonstrate that our multipass design, in addition to increasing the optical depth, provides a fundamental advantage due to the significantly reduced effect of atomic diffusion on the spin noise time-correlation, in excellent agreement with theoretical estimate [2].



Figure 1. a) V-Cell. Picture of the sensor including anodically-bonded spherical mirrors and Pyrex cell. b) Multipass geometry. IR image of the front mirror with probe beam spots after 60 total passes through atomic ensembles before exiting the cavity. c) Layout. Cross-sectional view of the V-cell within a magnetic shielding with the Pyrex cell enclosed by a boron-nitride oven. d) Full experimental sketch. F, Focuser; P, Polarizer; FM, Front mirror; BM_{1,2}, Back mirrors; L, Collimation Lens; HWP, Half wave-plate; PBS, Polarizing beam splitter; DAQ, Data acquisition card. e) Measurement sequence. Optically-induced atomic orientation for top and bottom spins, angle tilt by π/2 pulse and free Larmor precession in the transverse plane.

 V. G. Lucivero, W. Lee, N. Dural and M. V. Romalis, Femtotesla direct magnetic gradiometer using a single multipass cell, Physical Review Applied, **15**, 014004 (2021).
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