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Magnetic flux density measurements using MEOP hyperpolarized ^{3}He in low fields

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The current method for disseminating the unit Tesla relies on NMR measurements on field polarized proton spins, using water [1]. However, the relative measurement uncertainties are restricted to values between 10^{-4} and 10^{-6} by limited SNR at fields below 2 mT and a rather insensitive absorption technique at fields above 10 mT. To overcome these limitations, we explore the use of hyperpolarized ^{3}He gas, which offers field independent enhanced SNR in combination with longer precession times T_2^* [2], thereby promising higher precision over a very wide magnetic field range. Using metastability exchange optical pumping (MEOP) to achieve hyperpolarization [3] promises fast buildup times and avoids interaction of the polarized alkali atoms on ^{3}He precession and the application of complicated pulse sequences for sufficient decoupling thereof[4].

Our experimental setup ^{3}He MEOP magnetometry includes a commercial table-top four-layer magnetic shield with integrated coils, enabling the generation of a constant B_0 field in the µT-range alongside a perpendicular, resonant B_1 field to initiate spin precession. Utilizing a commercial Rubidium (Rb) optical pumped magnetic gradiometer (OMG) with a 2.3 cm baseline, we have measured the ^3He magnetization precession, allowing us to deduce the Larmor frequency at varying B_0 magnetic field strengths. With the setup we determine polarization buildup times and T_2^* relaxation times. By varying the flip angle, we show systematic effects of residual longitudinal magnetization in the ^{3}He on the detected Larmor frequency. This allows conclusions to be drawn about the imperfect sphericity of the cell geometry.

To validate the precision of our setup, experiments are planned within a large magnetically shielded room, which offers a more stable magnetic field and enables the measurement with superconducting quantum interference devices (SQUIDs) for the ^{3}He magnetization precession. Using SQUIDS facilitates higher SNR and measurements at lower B_0 fields compared to the Rb gradiometer. These investigations will compare the detectable B_0 field by ^{3}He nuclei using different sensor types—OMG versus SQUID—enhancing our understanding of the influence of sensors on the precision of magnetic field metrology.

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