^{3}He absolute magnetometer in the geomagnetic range

Yuefeng Lu[1], Teng Wu[1,*], Hong Guo[1]

[1] State Key Laboratory of Advanced Optical Communication Systems and Networks, School of Electronics, and Center for Quantum Information Technology, Peking University, Beijing 100871, China
[*] Corresponding author: wuteng@pku.edu.cn

Absolute magnetic-field measurement (AMFM) in the geomagnetic range is important for magnetometry studies such as Earth's magnetism investigations [1]. Both ^{3}He and proton are suitable for AMFM due to their highly accurate gyromagnetic ratios [2]. However, AMFM in the geomagnetic range based on ^{3}He has not been achieved since the systematic error caused by RF (Radio Frequency) disharge is difficult to estimate [3]. In this work, we eliminate the influence of RF discharge based on spin exchange theory. Within 50 μT, our approach achieves a magnetic induction measurement accuracy of 26 pT (within a 68 % confidence interval, 0.52 ppm). Atomic densities and relaxation rates of the ground state and the metastable state in the cell are measured with an reletive uncertainty of 0.08 %. Such a measurement scheme can be applied in other cells involving spin exchange like Cs$-^4$He [1].

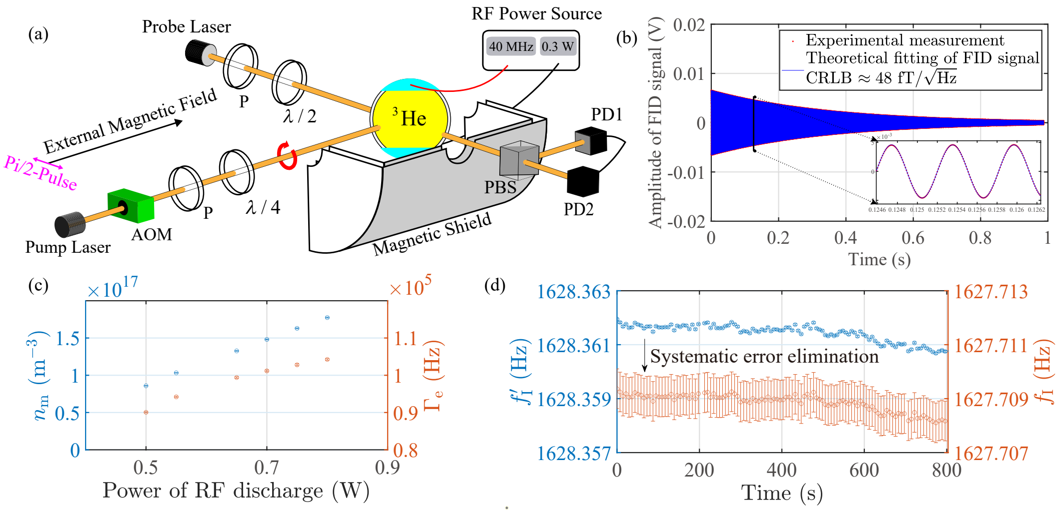

Figure 1. (a) The configuration of the FID magnetometer based on ^{3}He. (b) The measurement and the fitting of the FID signal of ^{3}He. (c) The measured metastable state atomic densitiies n_{m} and relaxation rates Γ_{e} under different RF powers. (d) Precession frequencies of ^{3}He before and after the elimination of spin exchange shift.

[1] V. Y. Shifrin, V. Khorev, V. Kalabin, and P. Park, Experimental estimation of the accuracy of modern scalar quantum magnetometers in measurements of the Earth's magnetic field, Physics of the Earth and Planetary Interiors **166**, 147 (2008).
[2] M. Farooq, T. Chupp, J. Grange, A. Tewsley-Booth, D. Flay, D. Kawall, N. Sachdeva, and P. Winter, Absolute magnetometry with ^{3}He, Physical Review Letters **124**, 223001 (2020).
[3] H. Gilles, Y. Monfort, and J. Hamel, ^{3}He MASER for Earth magnetic field measurement, Review of Scientific Instruments **74**, 4515 (2003).