Multi-parameter quantum sensing and magnetic communications with a squeezed-light enhanced hybrid dc/rf optically-pumped magnetometer

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Optically-pumped magnetometers (OPMs) are paradigmatic quantum sensors that provide insight into quantum sensitivity limits and have applications in bio-medicine, space science and fundamental physics [1]. Multi-parameter quantum sensing [2] aims to extend quantum enhancement to simultaneous measurement of multiple physical parameters. Here we report an OPM capable of simultaneously measuring dc and rf fields with quantum-limited sub-pT/$\sqrt{\text{Hz}}$ sensitivity (see Fig.1), making it a practical test-bed for quantum multi-parameter estimation (MPE) [3]. We demonstrate MPE-enabled spread spectrum magnetic communication, with possible application in ultra-compact radio receivers for communication underwater and underground. Finally, we demonstrate dc and rf sensing beyond the shot noise limit, using squeezed light to reduce the optical quantum noise (optical shot noise) in the hOPM, and demonstrate a sensitivity improvement consistent with the amount of squeezing available.

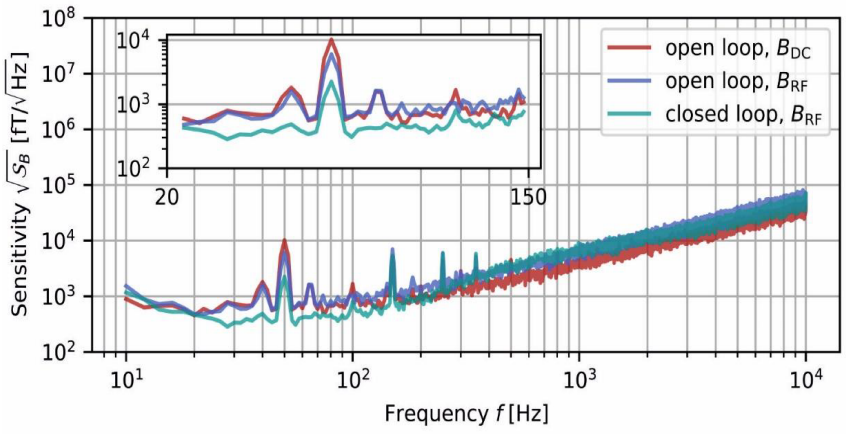

Figure 1. Sensitivity of the magnetometer for rf and dc operation with open or closed feedback loop probed with coherent light.

[1] D. Budker and M. Romalis, Nature Physics 3, 227 (2007).
[2] M. Szczykulska, T. Baumgratz, and A. Datta, Advances in Physics: X 1, 621 (2016).
[3] M. Lipka, A. Sierant. C. Troullinou, M. W.Mitchell, Physical Review Applied 21.3 (2024): 034054.