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Single-Beam Vector Atomic Magnetometer for Wide-Range Magnetic Field Measurements with Simultaneous Triaxial Modulation

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In practical applications such as earthquake early warning, environmental magnetic field compensation, and geomagnetic navigation, magnetic sensors are typically required to measure both the magnitude and direction of the magnetic field[1]. Consequently, high-sensitivity vector atomic magnetometers have become an important research focus[2]. Although various schemes have been developed, limitations in sensitivity, dynamic range, and system complexity continue to restrict their practical deployment.
In this work, we present a high dynamic range vector atomic magnetometer based on nonlinear magneto-optical rotation (NMOR) with triaxial magnetic field modulation. A phase-locked loop (PLL) tracks the resonance frequency of atomic multipole moments to measure the magnetic field magnitude, while directional information is extracted through secondary demodulation of optical rotation signals under three-axis magnetic filed modulation. Our magnetometer achieves a modulus sensitivity of 500 fT/Hz$^{1/2}$, a polar angle sensitivity of 0.29 mrad/Hz$^{1/2}$, and an azimuthal angle sensitivity of 0.94 mrad/Hz$^{1/2}$, enabling real-time measurement of dynamically varying vector magnetic fields.

Figure 1: Measurement results of the vector NMOR atomic magnetometer.

Reference

[1] S. J. Ingleby,C. O'dwyer, P. F. Griffin, et al. Phys. Rev. Appl. 10(3), 034035 (2018).
[2] X. Meng, Y. Zhang, X. Zhang, et al. Nat. Commun. 14(1), 6105 (2023).

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