Fiber-coupled laser-written vapor cells for optical magnetometry

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Abstract: We present a fiber-coupled laser-written vapor cell (FC-LWVC) prototype for compact, high-sensitivity optical magnetometry, demonstrating the feasibility of integrating micro-optical components within all-glass chips.

Optically pumped magnetometers (OPMs) enable highly sensitive magnetic field measurements and are widely used in biomedical diagnostics, remote sensing, infrastructure monitoring, and environmental applications [1]. The development of portable quantum sensors has driven research toward compact and robust atomic vapor cells fabricated on wafer-level platforms [2]. Femtosecond laser irradiation followed by chemical etching (FLICE) provides a powerful method to fabricate all-glass laser-written vapor cells (LWVCs) for atomic quantum sensing of electromagnetic fields [3].

In this work, we present a fiber-coupled laser-written vapor cell (FC-LWVC) fabricated by FLICE, followed by integration of micro-optical components. The vapor cell consists of a sensing chamber (3 mm × 1.5 mm) and a reservoir chamber (1.5 mm diameter) connected by 0.2 mm microchannels for alkali-metal-vapor transport. The sensing chamber is directly bonded to GRIN lenses, and ferruled 780HP fibers are attached to the input and output facets using UV-curing epoxy, achieving 63% fiber-to-fiber optical transmission. The cell is filled with N_2 buffer gas and activated using a high-power CW laser following the procedure described in [4]. Based on relaxation-rate analysis [5], the optimal N_2 number density is estimated to be 0.99 amg. The optical quality of the LWVC and the buffer gas pressure are characterized using single-pass absorption spectroscopy.

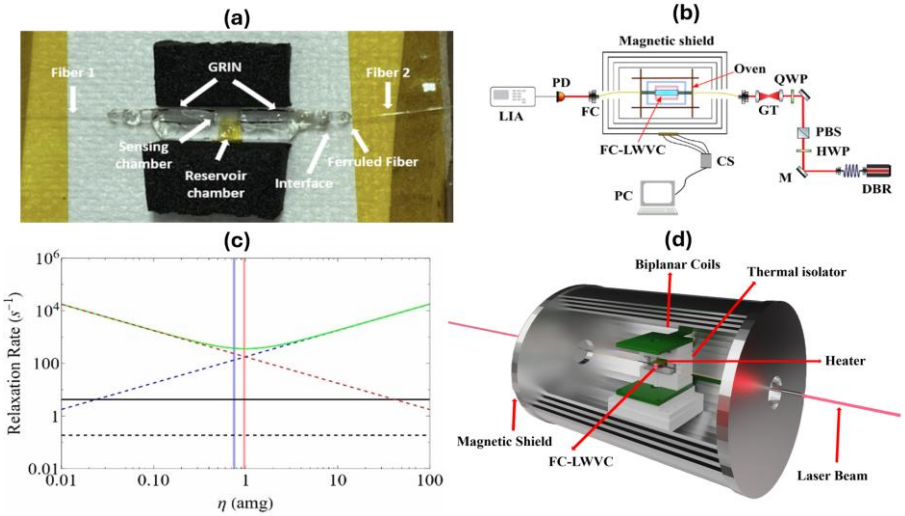

Fig. 1 a) FC-LWVC prototype; b) Experimental schematic of ZFR-OPM; c) Total collisional relaxation rate in a laser written vapor cell as a function of N_2 number density for Cs^{133}. Contributions fro Cs–Cs spin-exchange collisions (black solid line), Cs–buffer-gas collisions (blue dashed line), and Cs–Cs spin-destruction collisions (black dashed line) are shown; d) Three-dimensional diagram of the LWVC in the magnetic shield.

Zero-field resonance (ZFR) magnetometry is implemented using a single circularly polarized resonant beam. The FC-LWVC is housed in a ceramic oven and heated via a flexible PCB-based resistive heater. Experiments are conducted in a magnetically shielded environment, with controlled magnetic fields applied along orthogonal axes to cancel residual ambient fields. Previous LWVC studies demonstrated pT-level sensitivity with smaller cells in free-space configurations [4,5]. The fiber-integrated configuration enhances robustness and alignment stability, while the all-glass structure is poised to provide superior hermeticity to high-pressure compared with conventional MEMS vapor cells.

References

[1] D. Budker and M. Romalis," Optical magnetometry," Nature physics **3**, 227–234 (2007).

[2] Y. Li, D. B. Sohn, M. T Hummon, S. Schima, and J. Kitching," Wafer-scale fabrication of evacuated alkali vapor cells," Optics Letters **49**, 4963–4966 (2024).

[3] J. Kitching, J. P. Shaffer, and D. Budker, "Atom-based quantum sensing of electromagnetic fields," Optica 12, 2008–2023 (2025).

[4] V. G. Lucivero, A. Zanoni, G. Corrielli, R. Osellame, and M. W. Mitchell, "Laser-written vapor cells for chip-scale atomic sensing and spectroscopy," Opt. Express **30**, 27149-27163 (2022).

[5] A. Zanoni, K. Mouloudakis, M. C. D. Tayler, G. Corrielli, R. Osellame, M. W. Mitchell, V.G. Lucivero, "Picotesla optically pumped magnetometer using a laser-written vapor cell with sub-mm cross section," J. Appl. Phys **136**, 144401 (2024).