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Towards an Optical Magnetic Gradiometer Using Laser-Written Vapor Cells

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We present a compact optical magnetic gradiometer based on laser-written vapor cells (LWVCs) with a dual-chamber design, aimed at high-sensitivity detection of magnetic field gradients. This system is built around an optically pumped magnetometer (OPM), which enables precise measurements of magnetic variations while rejecting common-mode noise—an essential feature for operation in unshielded environments.

The vapor cells are fabricated using the FLICE method (Femtosecond Laser Irradiation followed by Chemical Etching), which allows for full 3D control of the internal microstructure. This technique makes it possible to create highly compact and integrable vapor cells with carefully designed geometries. In our design, each sensing chamber is 3 mm long and 1.5 mm wide, connected via microchannels that allow controlled vapor flow.

To evaluate the system, we begin with a single-channel configuration to measure absolute magnetic sensitivity and then transition to a dual-chamber setup for gradient field detection. The measurement relies on detecting the Free Induction Decay (FID) signal—an oscillatory, time-dependent response of the atomic ensemble after optical pumping. By analyzing the FID signal from each chamber, we extract the local magnetic field and compute their difference to determine the gradient. Two readout schemes are employed: one based on optical rotation and another using phase shift detection in a Mach-Zehnder interferometer configuration.

With its high spatial resolution, integrability, and sensitivity, this gradiometer is a promising step toward miniaturized quantum sensors suitable for applications ranging from biomedical diagnostics to environmental monitoring.

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