Development of a compact OPM module with one-beam optical gradiometer configuration for magnetic noise reduction

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We have been studying and developing ultra-high-sensitivity optically pumped magnetometers (OPMs) since 2006. In 2015, we reported a compact and portable potassium OPM module with a pump-probe arrangement [1], however, its sensitivity was limited mainly by environmental magnetic noise. To reduce the noise and improve the signal-to-noise ratio as well, we proposed a concept of optical gradiometer configuration [2], in which the difference of the magnetometer at two distinct areas inside a glass cell was obtained directly via the magneto-optical rotation via one probe beam. In this study, to realize it to be a practical magnetic sensor based on the same concept, we fabricated an OPM module of $30 \times 30 \times 120$ mm^3 with one probe beam optical gradiometer. The glass cell installed in the OPM module has a volume of $10 \times 3 \times 45$ mm^3, and contained K vapors for the highest sensitivity. In the OPM module, a pump beam from a fiber are split into two to irradiate the sense and reference areas, which are 30 mm apart. A probe beam passes through a sensing area, then, is lead to a reference area before detected by a polarimeter. In this configuration, the environmental noise is cancelled out. According to a feasibility study, it was found that the environmental noise was reduced sufficiently compared to a conventional OPM module, which did not have a reference area. The compact OPM module with one-beam optical gradiometer configuration could be a practical ultra-high-sensitivity magnetic sensor for biomagnetic measurements such as MEG without a heavy magnetic shield.

[1] K. Kamada, D. Sato, Y. Ito, H. Natsukawa, K. Okano, N. Mizutani and T. Kobayashi, Human MEG measurements with a newly developed compact module of high-sensitivity atomic magnetometer, JJAP **54**, 026601 (2015).
[2] K. Kamada, Y. Ito, S. Ichihara, N. Mizutani and T. Kobayashi, Noise reduction and signal-to-noise ratio improvement of atomic magnetometers with optical gradiometer configurations, Opt. Express **23**(5), 6976-6987 (2015).