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OSM7.3 Polarimetric Magnetic Field Sensors Based on Yttrium Iron Garnet

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Polarimetric Faraday-effect magnetic field sensors based on ferrimagnetic materials, such as yttrium iron garnet[1,2] (YIG), offer much greater sensitivities than conventional sensors based on diamagnetic materials, such as glass. On the other hand, the magnetic nature of ferrimagnetic materials produces sensor design problems quite distinct from those associated with sensors employing diamagnetic sensing elements. Nevertheless, if properly designed, totally passive magnetic field sensors exhibiting high sensitivity and good directional response may be constructed from YIG.

The sensitivity of a ferrimagnetic sensor (in terms of rotation angle per applied field) is given by Θ^F_{sat} / H_{sat}, where Θ^F_{sat} is the saturation Faraday rotation and H_{sat} is the saturation magnetic field. The quantity Θ^F_{sat} is given by the product of Kundt's constant K (for YIG, K = 220 °/cm at 1.3 μm) and the sample length. H_{sat} is given by the product of the material's saturation magnetization M_{sat} and the sample's demagnetization factor N_D, which is solely a function of the sample's length-to-width ratio. Thus, the sensitivity of ferrimagnetic sensors is dependent on the sensor geometry and can therefore be tailored for specific applications.

Experimentally, three cylindrical YIG samples of the same diameter (5.0 mm) and varying length (1.0, 3.0, and 5.7 mm) have been evaluated. The frequency response as well as the response linearity and directionality have been characterized and will be reported. Sensors based on YIG should be considered in applications of magnetometry requiring moderate to high sensitivity, large dynamic range, and compact size.

For the sample of 3.0 mm length, the sensitivity at 1.3 μm is approximately 800°/T (14 rad/T). Using a 1.3 μm laser diode with 0.4 mW power, we obtained a minimum detectable field of 30 nT/$\sqrt{Hz}$ at a modulation frequency of 80 Hz. The corresponding shot-noise limit was calculated to be approximately 5 nT/$\sqrt{Hz}$. Further optimization of the sensor design and increased laser power should improve the sensitivity substantially.

References

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