

Parametric resonance magnetometer based on elliptically polarized light yielding three-axis measurements with isotropic sensitivity

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Our team develops optically pumped magnetometers (OPM) based on metastable helium-4. This sensitive species has the advantage of working at any temperature, needing no heating nor cooling. We have made proof-of-concept recordings of both cardiography [1] and encephalography [2] with magnetometers where parametric resonances were excited by one or two radio-frequency (RF) fields. These alignment-based parametric resonance magnetometers (PRM) allow a vector measurement of the three components of the magnetic field [3]. However, such configuration yields a worse sensitivity for component parallel to the light polarization. Three-axis measurement with isotropic sensitivity is desirable for geophysics and medical applications such as magnetoencephalography. We present a new PRM configuration based on optical pumping of a spin-1 state (helium-4 2^3S_1 state) using elliptically polarized light. This allows exciting both an orientation (along the light propagation direction) and an alignment (along the major axis of the polarization ellipse) using a single pump/probe beam. Unlike the usual orientation- or alignment-based PRM configuration, we apply two RF fields along the pumping directions (see Fig. 1). Thanks to the interplay of both alignment and orientation with the RF fields, at an optimal light ellipticity and RF fields amplitudes, it is possible to obtain isotropic sensitivity. Compared to alignment-based helium-4 PRMs [3], the sensitivity is degraded by a factor 2 on the well-resolved axes, but improved by a factor 11 on the third axis (see Fig. 1). With the recent improvement of the sensitivity of helium-4 PRM down to $50 \text{ fT}/\sqrt{\text{Hz}}$, we expect this new configuration to reach vector three-axial measurements with an isotropic sensitivity of $100 \text{ fT}/\sqrt{\text{Hz}}$.

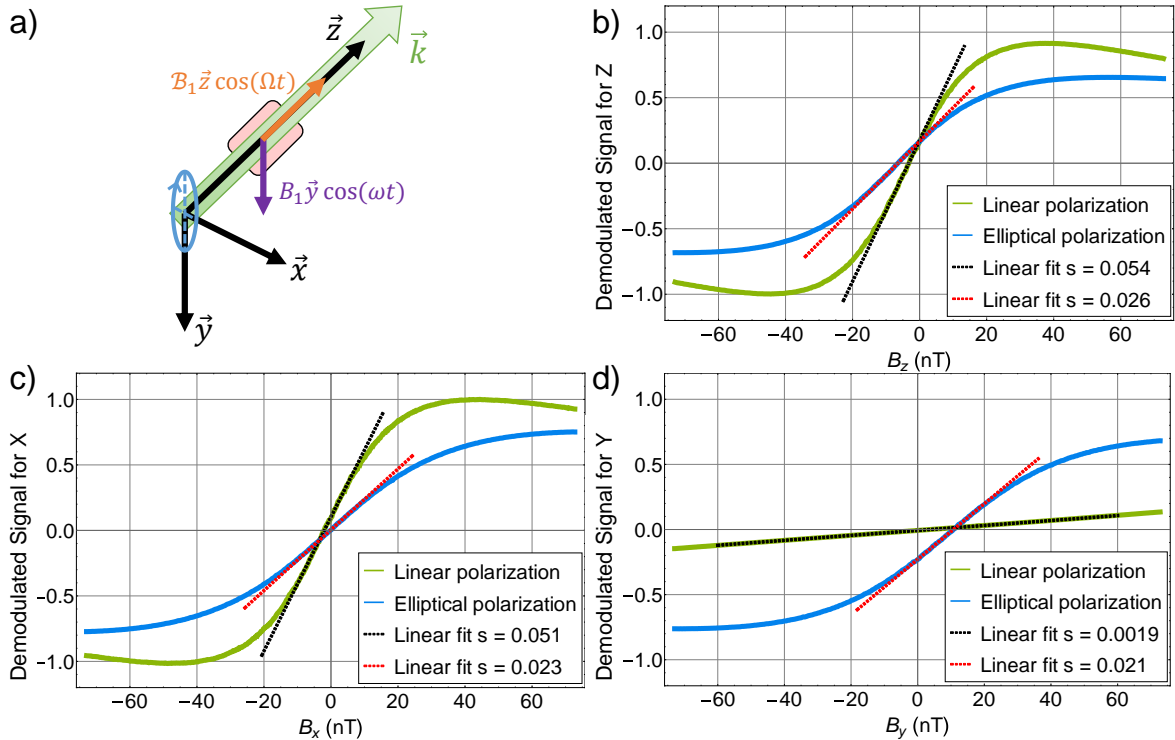


Figure 1 : a) Schematic sketch of the PRM based on elliptically-polarized light (b,c,d) Open-loop response signals of the PRM with respect to the three components of the magnetic field. All resonances amplitudes are normalized with the maximum value among the six resonances.

References

- [1] S. Morales *et al.*, *Phys. Med. Biol.*, vol. 62, n° 18, p. 7267-7279, 2017, doi: 10.1088/1361-6560/aa6459.
- [2] E. Labyt *et al.*, *IEEE Trans. Med. Imaging*, vol. 38, n° 1, p. 90, 2019, doi: 10.1109/TMI.2018.2856367.
- [3] F. Beato *et al.*, *Phys. Rev. A*, vol. 98, n° 5, 2018, doi: 10.1103/PhysRevA.98.053431.