Spin locking in unshielded, self-oscillating, atomic magnetic gradiometer

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Atomic magnetometers are highly sensitive devices, able to reach sub $\mathrm{fT}\sqrt{\mathrm{Hz}}$ sensitivities at fields smaller than microtesla [1]. Applications are numerous, ranging from searches for exotic physics [2], to exploring the geomagnetic field [3] as well as the magnetic field of the human brain [4].
This sensitivity however, requires the magnetometers to be operated in a shielded environment at very low fields. If operated at the earth's magnetic field, these magnetometers suffer from lower sensitivity due to the nonlinear Zeeman effect causing splitting and lineshape asymmetries [5]. This is also an important source of the so-called "heading error" [6] in scalar atomic magnetometers, which is effectively the dependence of the sensor's reading to its orientation relative to the magnetic field.
We propose a self-oscillating magnetometer in gradiometer configuration based on the nonlinear magneto-optical rotation in two Rb paraffin coated cells. We use intensity modulated pump light to cause dichroism or birefringence in our vapor. We then measure the oscillation of the polarization rotation of an unmodulated probe light caused by the pump. We apply a radio-frequency field to force the spins to precess around it, in order to suppress the broadening produced by the nonlinear Zeeman effect, a mechanism called "spin-locking" [7].Our setup is mounted on a 3D rotation mechanism, allowing the sensor to be positioned in different directions compared to the earth's magnetic field and thus investigating how the nonlinear Zeeman suppression affects the heading error. With this magnetometer we aspire to build a robust, cheap, sensitive and portable device for measuring sub-picotesla magnetic fields from the human brain with high sensitivity, in an unshielded environment.

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