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Accuracy before sensitivity: Magnetically-silent vector magnetometer as a new tool for nEDM search

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For many years the central focus of atomic magnetometer development has been towards an increase in sensitivity while the aspect of absolute accuracy in the field measurement has received less attention. Here we present measurements made with a novel atomic magnetometry scheme based on the detection of the free induction decay of a spin-oriented Cs vapour which, together with a three beam readout, yields an accurate and sensitive determination of the three components of the magnetic field at the sensor's location.

Summary

The precision measurement and control of magnetic fields in nEDM experiments is a major prerequisite for controlling systematic errors. Over the past decade, the Fribourg atomic physics group has contributed to this task by two generations of laser-pumped atomic magnetometers (LPM). We are currently working on a third generation of LPMs that shall overcome major identified limitations of the methods deployed in the past. Our previous generation of Mx magnetometers has demonstrated a remarkable sensitivity and robustness in vacuum and high electric field environment. The weakest point of Mx-magnetometers based on phase-locked loops is their lack of absolute accuracy: in order to yield identical readings of a 1 microT field with 10 fT precision, the internal phases of two nominally identical sensors have to be adjusted with a precision of better than 5 microrad, which is rendered impractical, if not impossible, by both mechanical construction and electrical signal treatment considerations. Moreover, the currently deployed Mx-technique magnetometers require a weak oscillating magnetic field to be applied to the sensor to drive the resonance condition. Stray fields from one sensor influence its neighbors, yielding sensor cross talk, another potential source for systematic readout errors.

Here we propose a magnetometer scheme based on the free induction decay (FID) of a spin-oriented Cs vapour. The feedback-free nature of the free precession makes it possible to measure the absolute value of the magnetic field.

We will present details our progress toward a magnetically silent (all-optical) vector magnetometer. Spin orientation is produced by optical pumping with amplitude-modulated light (Bell-Bloom pumping) in an anti-relaxation coated vacuum cell, followed by a recording of the resulting FID using light of significantly lower intensity. The direction and amplitude of the magnetic field are reconstructed by monitoring the transmitted light intensity of three nonparallel beams traversing the vapour cell. The sensitivity and the limitations of the method will be addressed. The pulsed mode of operation of such magnetometers reduces their sensitivity yet yields the benefits of a significantly increased accuracy and vector information, both features of primordial importance for nEDM experiments.

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