Considerations for a caesium magnetometer array for the n2EDM experiment

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The n2EDM experiment

The apparatus consists of two identical chambers, where the spins of ultra cold neutrons (UCN) precess in the following configuration of electric and magnetic fields, with frequencies $\omega_{n,11}$ and $\omega_{n,12}$. A neutron electric dipole moment

$$d_n = \frac{\hbar}{4E} (\omega_{n,11} - \omega_{n,12})$$

may then provide insight into the baryon asymmetry of the universe, as a source of CP violation, and into new physics [2].

Solution to $d_{false}^{Hg-n}$

An array of caesium magnetometers (CsM) with an optimised geometry allows the calculation of the magnetic field gradients $G_{l,m}$ [4] and of

$$d_{false}^{Hg-n} = \frac{\hbar \gamma n \gamma H}{2 c^2} \sum_{l=1}^{\infty} G_{l,m=0} \rho n_{l,m=0}$$

with the goal of

$$\Delta d_{false}^{Hg-n} \leq 4 \times 10^{-29} \text{ e} \cdot \text{cm}.$$ 

This is based on the assumption that

$$\sum_{l=1}^{\infty} G_{l,m=0} \rho n_{l,m=0} = \langle xB_x + yB_y \rangle.$$ 

Magnetic contaminants

The inevitable contamination of magnetic dipoles (e.g. magnetisable dust, screws, etc.) in the n2EDM experiment dictates that

$$-\frac{\hbar \gamma n \gamma H}{2 c^2} (x B_x + y B_y) = \frac{\hbar \gamma n \gamma H}{2 c^2} \sum_{l=1}^{\infty} G_{l,m=0} \rho n_{l,m=0}$$

Why $^{133}$Cs?

- Saturated vapour at room temperature
- Well resolved hyperfine levels
- No need for buffer gas
- 30 ms T2 time assured by anti-relaxation coating

Problem

A mercury comagnetometer (HgM), samples the same volume as the UCN. Its reading compensates the effect of $B$ fluctuations on $\omega_{n,11}$ and $\omega_{n,12}$... but...

this correction leads to a systematic shift of Eq. 1 by $d_{false}^{Hg-n}$ (Eq. 3) [3,4], since

$$\langle \vec{B} \rangle - \langle |\vec{B}| \rangle = \frac{\omega_{n,H}}{\gamma_H} \frac{\omega_n}{\gamma_n} \neq 0$$

Expected performance of CsM array

Amplitude at PD

The chosen sensor measures $|\vec{B}|$ and is of Bell-Bloom type [5,6]. Amplitude modulated and linearly polarised light resonant on the appropriate electronic transition during the pumping regime leads to the precession of the aligned spin ensemble. A typical signal recorded by a photodiode (PD) looks like:

References