Isotopic shift of Xe nuclei precession frequencies caused by spatial inhomogeneity of optically oriented alkali atoms

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Introduction

The effect of the isotopic shift, or precession-frequency mismatch arising between ^{129}Xe and ^{131}Xe xenon-isotope nuclei in the presence of optically oriented alkali atoms (Cs or Rb) has been discovered recently [1], and it was shown that it drastically affects the characteristics of gyroscopic devices based on balanced schemes with spin-exchange pumping of xenon isotopes [2]. The first attempt to explain this effect was made in [3]; here we present our recent experimental results approving our theory.

Experimental

The experiment was carried out on a setup based on the standard scheme [1, 3] with a longitudinal (i.e., oriented parallel to the dc magnetic field) circularly polarized optical pumping beam and transverse linearly polarized detection beam. Besides, we have added a system of magnetic coils in anti-Helmholtz configuration for forming a magnetic field gradient along the optical pumping axis (z axis). The gas cell contained Cs vapor, nitrogen, and natural xenon (containing 26.4% ^{129}Xe, 21.2% ^{131}Xe). The measurements were carried out in a multilayer magnetic shield. The magnetic field was stabilized by the optically pumped quantum ^{85}Rb magnetometer. Comparing to [3], the gradient coils setup were modified, and two compensating coils were added in order to minimize the influence of the scattered cell gradient field on the ^{85}Rb magnetometer. The isotopic shift effect was measured at 45 – 95 ºC temperatures and the magnetic field gradient range of ±400 nT/cm.

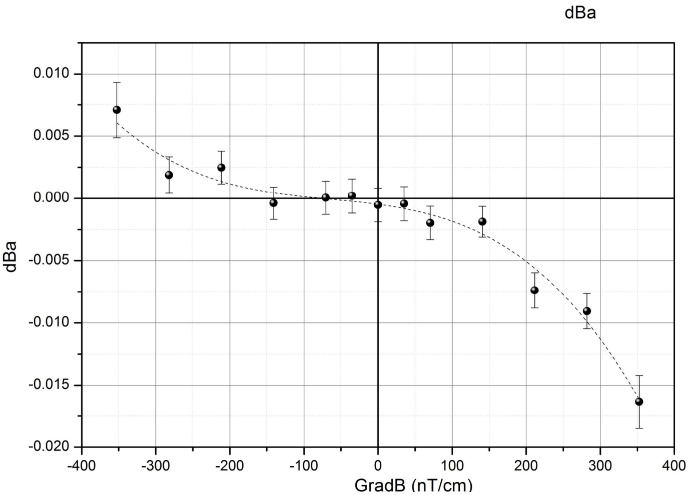

Figure 1. The dependence of isotopic shift on the external magnetic field gradient at T=85 ºC

Conclusion

We conclude that main part of isotopic shift (or the effect of precession frequency mismatch between ^{129}Xe and ^{131}Xe) is originated from peculiarities of Xe isotopes spin-exchange pumping and diffusion in the presence of non-uniform distribution of the optical pumped alkali atoms. Thus, we confirmed the isotopic shift dependence on the magnetic field gradient, and on the difference of the nuclear spins relaxation times. It is shown that the isotopic shift could be minimized by introducing the gradient of the external magnetic field, which compensates the gradient of the cell internal field. Isotopic shift could be as well eliminated by maintaining the cell at the temperature, providing the equal relaxation times of xenon isotopes.

References

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