Ultrasensitive ferromagnetic needle gyroscope for tests of fundamental physics

Derek F. Jackson Kimball[1], Yehuda B. Band[2], Dmitry Budker[3,4], Pavel Fadeev[3], Alexander O. Sushkov[5], Tao Wang[4]

[1] California State University – East Bay, Hayward, California, USA
[2] Department of Chemistry, Department of Physics, Department of Electro-Optics, and the Ilse Katz Center for Nano-Science, Ben-Gurion University, Beer-Sheva, Israel
[3] Helmholtz Institute Mainz, Johannes Gutenberg University, Mainz, Germany
[4] Department of Physics, University of California at Berkeley, Berkeley, California, USA
[5] Boston University, Boston, Massachusetts, USA

Under conditions where the angular momentum of a ferromagnetic needle is dominated by intrinsic spin, an applied torque is predicted to cause gyroscopic precession of the needle [1]. If the needle can be sufficiently isolated from the environment, a measurement of the precession can yield sensitivity to torques far beyond that of other systems, such as atomic magnetometers and gyroscopes [1,2]. The high sensitivity is a result of rapid averaging of quantum noise without a random walk of the ferromagnetic needle gyroscope's net spin [1]. A key enabling technology for a ferromagnetic-needle-based gyroscope and torque sensor is a method of near frictionless suspension. One approach is to levitate a ferromagnetic needle above a superconductor. With this goal in mind, we have experimentally investigated the dynamics of a micron-scale ferromagnetic particle levitated above a superconducting niobium surface [3]. A ferromagnetic needle gyroscope may be of particular interest for precision measurements testing fundamental physics [4]. For example, a ferromagnetic needle gyroscope in a satellite orbiting Earth could be used for a new experimental test at the intersection between general relativity and quantum mechanics: measurement of gravitational frame dragging [5,6], a fundamentally relativistic effect, with intrinsic spin, a fundamentally quantum phenomenon.

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