LEMAQUME

LEvitated MAgnets for QUantum MEtrology

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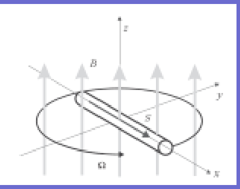
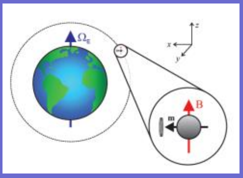
Objectives

- Develop novel torque and magnetic field sensors based on levitated hard ferromagnets or ferromagnet/diamond hybrids coupled to quantum devices (SQUIDs, NV centers, optics)
- Study the interplay between librational (classical) and gyroscopic (atom-like) dynamics
- Demonstrate torque-based magnetometry beyond the quantum Energy Resolution Limit (ERL)
- Demonstrate the potential as sensor by performing measurements relevant to fundamental physics (5th force – dark matter)
- Design and perform a proof-of-principle experiment with a ferromagnet in free-fall in the Hannover Einstein Elevator, in order to test feasibility of testing General Relativity frame dragging in space with a quantum sensor



A MICROMAGNET in a small B field should behave as a gyroscope (featuring Larmor precession), exactly as atoms do, provided that spin is the dominant angular momentum!

Ultrasensitive magnetometry beyond standard quantum limits is possible!
(both in gyroscopic or librational regime)

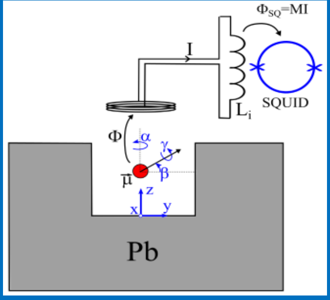


A ferromagnetic gyroscope in space can potentially detect the extremely slow precessional motion induced by Lense-Thirring effect (dragging from earth rotation)
Interplay between quantum & gravity! (⇒ no unique prediction)

Three experimental platforms

SUPERCONDUCTING TRAPS

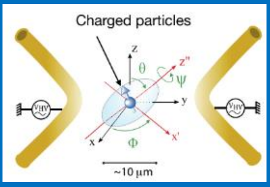
- Type I superconductors (Pb or Al)
- Hard micromagnets (1-1000 μm)
- Detection with SQUIDs
- Low temperature



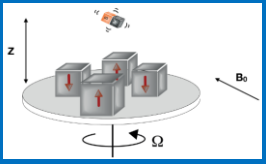
- Detect rotational modes
- Study libration/precession interplay
- Demonstrate magnetometry beyond ERL
- Perform 5th force measurements using spin actuators

CIRCUIT-BASED TRAPS

- Electrical Paul trap (rotating E)



- Magnetic Paul trap (rotating B)



- Attach to the magnet NV centers for sensing
- Observe precession dynamics
- Develop a quantum stabilized static chip-trap (Einstein-de Haas stabilization)
- Observe Barnett effect

FREE-FALL

- Launch hard micromagnets in free-fall in weak B
- Detect Larmor precession of the micromagnet during free-fall using either optics or SQUIDs
- Perform precision measurements, e.g 5th force, using spin actuators

EINSTEIN ELEVATOR – Hannover

Active "drop tower" for experiments in μg to 5g regime at high repetition rate

- Free-fall duration: 4 s
- High repetition rate: 100-300 day^{-1}
- Residual acceleration: 10^{-6} g

Consortium

- CNR-IFN Trento , IT (A. Vinante)
- CNRS Paris, FR (G. Hétet)
- Johannes Gutenberg Universitat Mainz, DE (D. Budker)
- Leibniz Universitat Hannover, D (E. Rasel)
- University of Ulm, D (M. Plenio)
- University of Latvia, LV (A. Cebers)
- Ben Gurion University, IL (R. Folman, Y. Band)

External Partners:
University of Southampton, UK (H. Ulbricht)
California State University, US (D. Jackson Kimball)
Boston University, US (A. Sushkov)

Organization

WP1: Superconducting traps
Vinante +
Ulbricht, Folman

WP2: Paul and circuit traps
Hétet + Folman

WP3: Free-fall
Budker, Rasel +
Folman, Sushkov, Kimball

WP4: theory and modeling
Plenio, Cebers, Band

More info: www.lemaqume.org