Mobile quantum gravity sensor with unprecedented stability

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Gravimetric atom interferometer GAIN

The gravimetric atom interferometer GAIN is a mobile sensor that uses atom interferometry based on stimulated Raman transitions to measure Earth’s gravity. It’s performance has been tested against other state-of-the-art gravimeters in two comparison campaigns. To our knowledge, GAIN’s long-term stability of 0.5 nm/s² is the best value of an absolute gravimeter published in literature.

Atom interferometry

Mach-Zehnder sequence of Raman pulses (T = 260 ms)
Local laser phase φ impinged onto atoms connects interferometer phase with gravity:

\[ \Delta \Phi = -4 \alpha g \cdot 7^2 \Phi = 2 \cdot \Phi_1 + \Phi_2 \]

Interferometer phase is encoded in population of states:

\[ P_{F=2} = \frac{1}{2} \left[ 1 + e^{-\delta \Phi} \right] \]

Fluorescence detection

• Detection pulses with intermediate repumper light
• Fluorescence light collected on photomultiplier tube.

Stability

• Allan deviation of residuals indicate white noise stability of 5×10⁻¹¹ Δg/nm/s²

Accuracy

• GAIN’s gravity value slightly higher than reference/FG-5. Bias during both campaigns:
  - GAIN 1st campaign: Wettzell, 2013: (32 ± 39) nm/s²
  - GAIN 2nd campaign: Onsala, 2015: (32 ± 39) nm/s²

• Developed method to calculate effect of Raman wavefront distortions [2], still limiting contribution
• Systematic error budget as of 2016-02:

Goal:

• Interferometry with two clouds in different vertical positions for gravity gradiometry [4]
• Applications of gravimeters include underground and resource exploration, navigation, and determination of the Newton’s constant G [5].

Progress at HUB:

• Increased loading rate by juggling technique [6]
• Simultaneous interference fringes of both clouds
• Suppression of common-mode noise in the differential signal
• Differential phase can be extracted from ellipse fit even when a fringe fit fails

References