Strapdown Quantum Inertial Measurement Unit

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Since their first demonstration in the early 1990s, atom interferometers have proven to be excellent absolute inertial sensors—having been exploited as ultra-high sensitivity instruments for fundamental tests of physics and as state-of-the-art atomic gravimeters. As a result, they have been proposed as next generation sensors for inertial navigation. However, most atom-based inertial measurements are one-dimensional, meaning they can measure only a single axis of rotation or acceleration at a time. Up to now, gyrostabilized vertical atom interferometry for gravity surveys has been demonstrated by ONERA [1]. Various groups have made encouraging progress in the domain of multi-axis inertial sensing with cold atoms [2–4], but none have yet demonstrated a robust, motion compatible platform, capable of measuring the full acceleration vector without reconfiguring their instrument.

Here, we present the first hybrid three-axis accelerometer exploiting the quantum advantage to measure the full acceleration vector by combining three orthogonal atom interferometer measurements with a classical navigation-grade accelerometer triad. Our atom interferometer is installed on a rotating platform which allows us to operate in almost any orientation, while evaluating the long term stability, performing a full calibration and estimating the bias of the quantum triad. Its ultra-low bias permits tracking the acceleration vector over long timescales—yielding a 50-fold improvement in stability ($6 \times 10^{-8}\ g$) over our classical accelerometers. We record the acceleration vector at a high data rate (1 kHz), with absolute magnitude accuracy below 10 μg, and pointing accuracy of 4 μrad.

When it actually comes to moving the cold atom sensor, rotation has been so far the main showstopper. We present a full hybridization of classical and quantum sensors, including gyroscopes, mechanical accelerometers and an atom interferometer to perform the first quantum measurement of the acceleration along a rotating axis, for an arbitrary angle and in presence of vibrations. A conjoint real-time contrast/phase correction led to fringes reconstruction with a contrast around 35% and a signal to noise ratio around 6, for an interrogation time T = 10 ms and rotations rates up to 150 mrad/s.

The latter integration of classical gyroscopes to our multiaxis atom accelerometer is an additional step to complete a full inertial measurement unit (IMU) including an *in situ* atomic recalibration. This strapdown strategy enables to reach the full potential of quantum accelerometers and highlights their potential as future inertial navigation units. It also opens new perspectives for gravity mapping or mineral exploration.

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