Phase Locked Atomic Interferometers for Gravity Gradiometry

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The ability to monitor and measure gravity accurately can reveal important and hidden structure in the world around us. Unlike current tools used in civil engineering, and geodesy, such as radar, gravity cannot be shielded. This passive measurement provides a large advantage over conventional devices as there is no signal to be absorbed, limiting range and resolution. Gravity gradiometry measures the spatial derivative of gravity. They operate by measuring gravity in two positions whilst connected by a rigid baseline. This presents some benefits over absolute gravimetry such as common-mode noise rejection and the ability to distinguish between linear acceleration and gravity.

Classical gravity gradiometers are currently the only practical devices of this species [1]. These require inertial test masses which are susceptible to manufacture tolerances. Quantum gravity gradiometers aim to solve these issues by using atoms, whose masses are precisely known, as inertial test masses. Atomic interferometry can then increase the sensitivity of measurements beyond the limits of a classical device [2]. Quantum gravity gradiometers function by creating two cold atom ensembles and measuring their acceleration with Raman beams acting as a 'ruler'. As such the Raman beams must be phase coherent between the two ensembles. This is achieved by line of sight which limits geometry. Furthermore, a vacuum chamber which can accommodate suitable separation and drop times are required. This makes quantum gradiometers bulky and heavy; impractical for applications outside of the lab.

We propose a different approach to quantum gravity gradiometers in aims to increase portability and practicability. The two atom ensembles will be separated into two vacuum chambers, reducing bulk and increasing portability. These chambers will then be linked with optical fibre which will also behave as a phase stabilisation mechanism for the Raman beams. Following a technique that has been shown to transfer phase instability of 5×10^{-15} at 1 s over 86 km of fibre [3]. This novel approach provides flexibility of geometry, giving us the ability to freely translate the atom ensembles relative to each other. This shows scope for full tensor gradiometry. Our approach also enables investigation into the largely unexplored regime between fully correlated and uncorrelated gravimeters.

References

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