Progress Towards Quantum-Enhanced Atomic Gravimetry

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Atom interferometry currently provides state-of-the art sensitivity for measurements of gravity. However, shot-noise inherently limits the sensitivity and bandwidth. Recently, there has been tremendous interest in using quantum entanglement to reduce shot-noise, improving the capability of these devices. While entanglement-enhanced sensitivities have been demonstrated in proof-of-principle atom interferometers, none of these interferometers has been capable of measuring gravity, or any inertial quantity [1].

We propose and theoretically model a scheme capable of generating entanglement which is compatible with high-precision atomic gravimeters. Through detailed numerical simulation, we demonstrate that our scheme produces spin-squeezed states with variances up to 14 dB below the SNL, and that absolute gravimetry measurement sensitivities between two and five times below the SNL are achievable with BECs between 10^4 and 10^6 in atom number [2]. Our scheme is robust to phase diffusion, imperfect atom counting, and shot-to-shot variations in atom number and laser intensity. Our proposal is immediately achievable in current laboratories, since it needs only a small modification to existing state-of-the-art experiments and does not require additional guiding potentials or optical cavities. We also show how this scheme can be improved further by adding a 'kick' to the atoms to increase the effective spin-squeezing interactions while also minimising phase diffusion, and also explore how this scheme can be used in conjunction with quantum non-demolition (QND) measurements.

[1] S. Szigeti, O. Hosten, S. Haine, Appl. Phys. Lett. **118**, 140501 (2021).

[2] S. Szigeti, S. Nolan, J. Close, S. Haine, Phys. Rev. Lett. **125**, 100402 (2020).