Quantum-limited sensing

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Abstract

This proposal seeks to advance the state-of-knowledge for quantum-based sensors based on atom interferometry, including DoD relevant gyroscopes, accelerometers, gravity gradiometers, magnetometers and clocks.

Quantum entanglement is thought to provide performance gains for sensing, communication and computation applications. Despite prolific activity and substantial investment, quantum-entangled systems have not to date outperformed optimized, conventional systems. The proposed work will focus on developing quantum-entangled sensors which outperform non-entangled sensors. Since the current generation of precision atomic sensors (clocks, gyroscopes, accelerometers, and gravimeters) now perform near physical limits for a given atomic flux – due to the adverse influence of atom-atom interactions – quantum entanglement provides one of the few routes to improved sensor performance. In particular, we will bring our recent proof-of-concept demonstration of spin-squeezing in metrologically relevant clock systems to realistic sensor topologies. While there have been many recent proposals for next generation accelerometers and gyroscopes which have been based on novel quantum effects, few can achieve both the sensitivity, bias stability, dynamic range and scale factor stability – required for DoD applications – provided by free-space atom sensors. Quantum entanglement/metrology can improve performance of these sensors by, in principle, an additional factor of 1000x and realistically a factor of 10x to 100x, leading to sensors of unprecedented capability. This performance enhancement enables crucial trades for sensitivity, bandwidth and dynamic range.

The marriage of quantum metrology methods with next generation atom optics will lead to laboratory atom interference sensors of unprecedented sensitivity and capability. These sensors will be exploited for new precision tests of quantum mechanics and gravitational physics.