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Quantum metrology with collective atomic spins

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Quantum metrology uses quantum features such as entanglement and squeezing to improve the sensitivity of quantum-limited measurements. Long established as a valuable technique in optical measurements such as gravitational-wave detection, quantum metrology is increasingly being applied to atomic instruments such as matter-wave interferometers, atomic clocks, and atomic magnetometers. Several of these new applications involve dual optical/atomic quantum systems, presenting both new challenges and new opportunities. I will describe an optical magnetometry system based on cold rubidium-87 in an optical trap, which achieves both shot-noise- and projection-noise-limited performance, allowing study of optical magnetometry in a fully-quantum regime [1,2]. The versatility of this system allows us to design both linear and non-linear atom- light couplings, and to apply dynamical decoupling and quantum non-demolition measurement, for application in quantum-enhanced magnetometry [3]. As an example, we have recently developed a method for generating metrologically-advantageous optical nonlinearities and performed the first interaction-based quantum-noise-limited measurements of atomic magnetisation [4]. With this technique we implement a non-linear metrology scheme proposed by Boixo et al. with the surprising feature of precision scaling better than the 1/N "Heisenberg limit" [5].

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