“Quantum metrology frontiers with cold atoms”

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The prospect of using quantum entanglement to improve the precision of atomic and optical sensors has been a topic of discussion for more than two decades. Experiments aimed at achieving this objective have shown significant improvements in the last half a decade. In this talk I will focus on our recent experiments that highlight the developments in the field. The first part of the talk will describe the generation of 20dB spin-squeezed states of half a million \(^{87}\text{Rb}\) atoms via an optical cavity-based measurement. Practically, this level of squeezing enables a 100-fold reduction in averaging time or a 100-fold reduction in atom numbers to achieve a given sensing precision. This work also demonstrates an atomic clock operating 10 dB beyond the classical limit. Some of the states prepared possess in excess of 680 atom entanglement. The second part of the talk will describe a more recent experiment where we demonstrated metrology beyond the classical limit without ever making a measurement below the classical limit. We achieve this using a method we call ‘quantum state magnification’. Here, cavity-aided collective interactions between atoms ‘magnify’ signals together with quantum noise to easily measurable levels using fluorescence imaging. The method relaxes stringent detection requirements, and can also be implemented in physical platforms other than cold atom-cavity systems.