Atom Interferometry with Spin Squeezed States

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Atom interferometers [1] are wonderful tools for precise measurements of electromagnetic interactions [2] and intertial forces [3]. In a typical Mach-Zehnder type atom interferometer, the atomic wavepacket is splitted, redirected and recombined through the interaction with three laser pulses. As a result, the relative phase of the two paths, carrying the physical signal, is converted into a population difference that can then be detected.
The sensitivity of these devices scales with the momentum imparted on the atoms by the laser beams, with the interferometer duration and with our ability to correctly readout the phase.
While significant effort has been done in increasing imparted momentum and duration [4], the problem of reducing the phase error in readout has not yet been addressed in the context of atom interferometry. Atom interferometers with uncorrelated particles can operate at most at the Standard Quantum Limit, in which the phase error scales as the inverse square root of atom number. A different and more favorable scaling with atom number can be achieved by generating entangled states and specifically Spin Squeezed States, where the Standard Quantum Limit can be overcome [5].
Two schemes for the generation of such states have been demonstrated experimentally so far that can meet the requirements of atom interferometry experiments and that are based on the enhanced interaction of the atoms and the photons circulating in an optical cavity. Firstly, the generation of squeezed states by the nonlinear interaction induced by feedback in the cavity [6] and secondly the nondestructive collective measurement which leaves the atomic ensemble in a spin squeezed state [7].
This technology is currently well suited for atomic clocks where the atoms remain trapped inside the cavity mode volume. For the case of atom interferometers we will develop schemes that allow the atoms to be released in free space and subsequently detected. We will also design schemes that can merge an atom interferometer inside an optical cavity, therefore realizing a constant coupling between the cavity photons and the atoms.
Based on the recent progress in the generation of these non classical states, we hope to prove that the performance of atom interferometers can be greatly increased by this novel technology.

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