Quantum-Limited Nonlinear Metrology with Bose-Einstein Condensates

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Quantum nonlinear interferometry protocols using Bose-Einstein condensates (BECs) have recently been proposed as a novel platform for weak-signal detection. In particular, a two-mode BEC consisting of N atoms can be used to implement a nonlinear Ramsey interferometer that potentially operates near the limits established by quantum mechanics. Such protocol, when realized in highly elongated geometries, achieves detection sensitivities that scale better than the 1/N "Heisenberg limit" of linear metrology. In this talk, I will discuss the conditions for observing nonlinear-enhanced scalings in this system as well as several phenomena that get in the way of achieving the desired “super-Heisenberg” scaling. In particular, there are position-dependent phase shifts that need to be modeled precisely for an accurate description of the measurement signal. This brings into question the accuracy of the quasi-1D approximation, both spatially and temporally. By combining ideas form quantum information theory with perturbative techniques, we derive equations that optimally describe the BEC interference process in anisotropic confinements. This approach leads to an improved quasi-1D model which provides a considerably more refined account of the interference signal.