ENTANGLEMENT AND ULTRACOLD ATOM INTERFEROMETRY

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Performing measurements is the key for our understanding of Nature: thanks to increasingly accurate measurements we have been able to investigate more outlying and fundamental phenomena. Interferometry has revealed to be one among the most precise techniques in metrology. In a interferometer, two (light or matter) waves undergo a phase shift that generates observable interference effects: the aim of interferometry is measuring these effects in order to estimate the phase shift with the smallest possible uncertainty. Entanglement can be exploited to enhance the interferometric sensitivity [1].

In a linear interferometer, such as the SU(2) Mach-Zehnder one, beating the shot-noise phase uncertainty requires feeding the interferometer with *usefully entangled states*, that are states in which quantum correlations between particles are recognized by Fisher information [2]. However, noise and decoherence restrict the creation and use of such input states. Conversely, in a nonlinear interferometer, such as the SU(1,1) scheme suggested in optical context [3], it is possible to overcome the classical limitation in sensitivity even with a nonentangled probe state in input, because multipartite entanglement is created *inside* the interferometer by means of nonlinear interactions.

Interferometry with ultracold trapped atoms has come to the fore in the last decade because of its potential in ultraprecise measurements. In this respect, we are exploring two different directions. On the one hand, we have studied the possibility to design a nonlinear three-mode interferometer using a spinor Bose-Einstein condensate, which exploits entanglement generated by spin-mixing atom-atom interactions [4] to perform sub-shot-noise phase estimation with respect to the finite resources in input (i.e. the average number of particles in the condensate). Experimental imperfections due to particle losses and finite detection efficiency have also been taken into account [5]. Preliminary experimental results have been carried out in Heidelberg at Kirchhoff Institut für Physik [6]. On the other hand, we are trying to quantify the effect of thermal fluctuations on multiparticle entanglement for applications to an atomic two-mode linear interferometer. Such a device has been implemented at LENS in Quantum Interferometry group, using a BEC confined in a double-well potential. This system has revealed to be precious even for studying quantum critical phenomena at finite temperature, symmetry breaking, metastability and hysteresis [7]. Our work aims to theoretically disclose features for first-order and second-order quantum phase transitions in a similar system from the point of view of information theory.

Riferimenti bibliografici

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