Many-body physics with Bose-Einstein condensates in a double well potential

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In my PhD I will upgrade an existing apparatus at the Physics Departments producing Bose-Einstein condensates in a double well potential with the goal to observe several interesting many-body phenomena related to quantum entanglement. Performing a series of experiments using a small number of atoms, i.e. few hundreds, the effect of quantum fluctuations, that are usually of the order of $\sqrt{N}$, became observable. In addition to the fundamental importance of these experiments the acquired knowhow will contribute to identify new strategies for the production of atomic entangled states useful to offer quantum enhanced sensitivity to interferometric devices.

The first crucial points for the success of the project is the possibility to control the interaction strength with respect to the kinetic energy in the system in order to suppress or enhance the quantum fluctuations of the system squeezing or anti-squeezing the relative atom number of the condensate in the left and right modes of the double well potential. This is possible using a Bose-Einstein condensate of ^{39}K where the value of the scattering length can be tuned using a broad magnetic Feshbach resonance.

The second important point is to implement an imaging system with single atom resolution in samples of few hundred atoms. The development of this detection technique is the main experimental challenge of this PhD. I plan to exploit a fluorescence detection that consists in trapping the atoms in an optical molasses for several hundreds of ms an collecting the light with a low noise camera. The two spatial modes will be preserved well separated also during the detection using a repulsive potential light sheet [1].

In different series of experiments I plan to study the interaction induced collapse and revival of the coherence in the Josephson oscillations between two spatially separated Bose-Einstein condensates in different condition of tunneling between the two wells [2, 3]. These phenomena, that haven't been observed with a macroscopic number of atoms, are particularly important in the field of trapped atom interferometry because they open to the possibility of using condensates of interacting atoms in high precision measurements of forces and electromagnetic fields. Therefore, splitting adiabatically a condensate in presence of attractive or repulsive interactions, we plan to create quantum entangled states where fluctuations are significantly enhanced or reduced, like for example the "NOON" state, that represents a coherent superposition of N particles in the right mode with zero particles in left mode, and vice versa [4]. The production of strongly quantum entangled states is extremely important in the contest of quantum interferometry for the operation of interferometric sensors with sub shot noise sensitivity.

References

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