Quantum information

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In 2007 ACQAO has developed new, unambiguous approaches to test for the fundamental quantum concepts of: position measurement[1], Einstein-Podolsky-Rosen (EPR)[2], and Bell[3], correlations. These new approaches, meriting a high impact Physical Review Letter, can be used for developing novel types of sensors or other quantum technologies.

Center of mass measurements

We have developed a concrete approach to treat the quantum limits to center of mass measurements[1]. We show that, for the same density an N-particle fermionic cluster can be measured with up to N times lower variance than a bosonic cluster of quantum particles. This indicates that ultra-cold Fermi gases may be useful as gravity or magnetic sensors, due to the strongly correlated nature of the fermions.

Signatures of macroscopic EPR entanglement

In fundamental quantum physics, macroscopic entanglement is a new and untested area of physics. This work will lead to novel EPR experiments [2, 3], taking into account inefficient detctors and macroscopic particle numbers of interest in quantum-atom optics. These new quantum limits and unambiguous EPR entanglement measures are within reach of current generation and detector technologies in quantum-atom optics. They also have many potential applications in areas of new technology.

Continuous variable tests of Bell's theorem

The original Bell inequality, and all of its generalizations, have so far been applicable only to the case of discrete or binned observables. We have developed the first continuous variable *correlation* tests of Bell inequality[3]. Violation of these new inequalities is predicted for multiparticle quantum states, the GHZ states, generated using multiple parametric down conversion. This gives potential for the efficiency loop-hole to be closed for Bell's theorem, because of the high efficiencies possible for quadrature phase amplitude detection. The detection efficiencies required are practical even for very large particle numbers n, for which *the discrepancy between the quantum and classical result actually increases.*

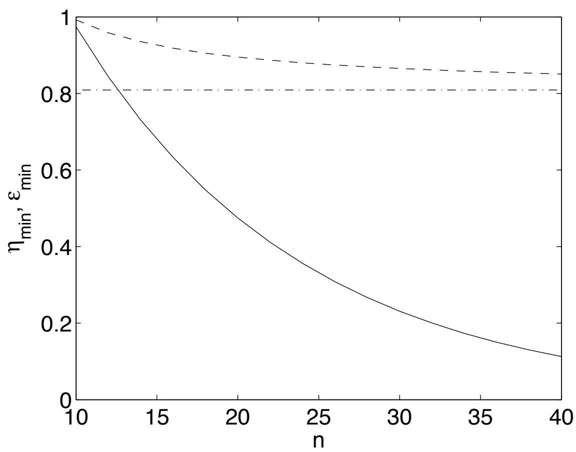

Figure on left: Minimum state preparation fidelity ϵ_{min} for ideal detectors (solid line), and minimum detection efficiency η_{min} for ideal state preparation (dashed line) required for violation of the continuous variable Bell inequality as a function of the number n of modes/sites present. The asymptotic value of η_{min} is the dash-dotted line, $\eta = 0.8$.

References

[1] T. Vaughan, P.D. Drummond, G. Leuchs, Phys. Rev. A **75**, 033617 (2007)
[2] E.G. Cavalcanti and M.D. Reid, J. Mod Optics **54** , 2373 (2007)
[3] E.G. Cavalcanti, C. Foster, M.D. Reid and P.D. Drummond, Phys. Rev. Lett. **99**, 210405 (2007)