The Abdus Salam
International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

Workshop on
NEW TRENDS IN QUANTUM DYNAMICS AND ENTANGLEMENT
21 - 25 February 2011

Heisenberg-limited Sensitivity with Decoherence-enchanced Measurements

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Abstract:

One of the most promising spin-offs of quantum information theory for science is the idea of using quantum information processing in order to increase the sensitivity of precision measurements.

The major goal of these "Quantum-Enhanced Measurements" (QEM) is to achieve the Heisenberg limit (HL) - a sensitivity that scales as the inverse of the number of quantum resources N. This would represent a major improvement over the standard quantum limit (SQL) with its typical inverse square root of N behavior. However, despite about 30 years of efforts, the SQL has been surpassed only by very few experiments so far, and only for small values of N. Indeed, the standard protocols of QEM require highly entangled states that are typically very prone to decoherence, and are therefore unlikely to scale up to the large numbers of N required before QEM can compete with classical precision measurements.

In this talk I show that, under certain conditions, decoherence itself can be used as a signal that allows one to achieve the Heisenberg limit with an initial product state. After exploring the effect at the example of the measurement of the length of a cavity with the help of superradiance, I put this new type of "decoherence-enhanced measurements" into a broader context, and present a general theory that shows the feasibility of a much larger class of precision measurements that can achieve the HL without using entanglement.