Precision measurements, entanglement and squeezing with continuous-variable systems

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The Fisher information quantifies the sensitivity of a quantum state with respect to changes of a parameter and defines the precision limits for applications in interferometry and sensing. Most of the research on quantum metrology has focussed on discrete-variable systems [1]. Well controlled continuous-variable quantum systems are available through homodyne techniques in photonic systems, or by the motion of harmonically trapped particles. A precise understanding of such systems is crucial for applications as force and displacement sensing.

We present upper limits for the sensitivity of separable states which can be applied to continuous-variable systems [2], leading to an experimentally usable witness for entanglement in a multi-mode displacement sensor. In this talk, we discuss both the theoretical background and the analysis of experimentally generated Gaussian continuous-variable quantum states in photonic systems with homodyne measurements.

Moments up to second order provide sufficient information on Gaussian quantum states. Generally, the information available from these moments can be used to define lower bounds on the quantum Fisher information, determined by the covariance matrix [3]. The bounds have a natural interpretation in terms of squeezing, in analogy to spin squeezing coefficients known from discrete variable systems [4, 3]. We show that the lower bounds obtained from continuous-variable squeezing coefficients [3] are saturated by all pure and mixed Gaussian states.

Finally, we explore quantum enhancements of the precision for displacement sensing with a single mode. We discuss how a phase-insensitive precision measurement of the displacement amplitude can be realized using Fock states [5, 6], presenting both theoretical results and an experimental realization with a trapped ion.

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