Conditional dynamics of optomechanical back-action evading measurements

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Since early works in gravitational wave detection it has been known that the precision attainable in a continuous measurement of the position of a harmonic oscillator is fundamentally limited. The limit, known as the standard quantum limit, is quantum- mechanical in nature. Besides being of fundamental interest, the existence of the standard quantum limit has become of practical relevance for ultra-sensitive measurements. Indeed, current experiments in cavity optomechanics have entered a regime where the dominant noise source comes from the quantum measurement backaction.

A strategy to elude the standard quantum limit is to restrict the measurement to a single quadrature of motion, which realizes a so-called backaction-evading (BAE) measurement. BAE measurements of mechanical motion can in principle achieve arbitrarily small uncertainties, which can be accessed via the conditional dynamics.

In this talk (1) I will provide an exact description of the conditional dynamics of an optomechanical system subjected to a BAE measurement. I will discuss the case of both continuous (two-tone) and stroboscopic BAE measurements. Results are simple and yet very informative, e.g. the existence of an optimal sensitivity (in terms of the system's parameters), which was not known so far. Unlike previous descriptions based on the adiabatic approximation, quantum features induced by the measurement on the whole optomechanical system can be accessed, e.g. conditional entanglement. (2) I will show how the presence of spurious terms in the interaction (so-called counter-rotating terms) usually considered detrimental, can favour the appearance of robust quantum features, such as conditional cavity squeezing and entanglement. (3) I will finally discuss how to extend BAE measurements (continuous and stroboscopic) to multi-mode optomechanical systems. This offers a strategy to efficiently entangle mechanical motion and study the multipartite entanglement structure induced by the measurement on an optomechanical system.