1.3.16 Quantum Optomechanics

Theoretical studies and huge technological progresses over the last decades made it possible to reach a considerable level of control over quantum states of matter in a large variety of physical systems, ranging from photons, electrons and atoms to bigger solid state systems such as quantum dots and superconducting circuits. This opened the possibility for novel tests of quantum mechanics and allowed, among other things, to take important steps forward in investigating the quantum regime of macroscopic objects. In this perspective, one of the main goals in today quantum science is controlling nano- and micromechanical oscillators at the quantum level. Quantum optomechanics [1,2], i.e. studying and engineering the radiation pressure interaction of light with mechanical systems, comes as a powerful and well-developed tool to do so.

Parametrically modulated optomechanical systems have been recently proposed as a simple and efficient setting for the quantum control of a micromechanical oscillator: relevant possibilities include the generation of squeezing in the oscillator position (or momentum) and the enhancement of entanglement between mechanical and radiation modes. In tIn Ref. [3] we further investigate this new modulation regime, considering an optomechanical system with one or more parameters being modulated over time. We first apply a sinusoidal modulation of the mechanical frequency and characterize the optimal regime in which the visibility of purely quantum effects is maximal. We then introduce a second modulation on the input laser intensity and analyze the interplay between the two. We find that an interference pattern shows up, so that different choices of the relative phase between the two modulations can either enhance or cancel the desired quantum effects.

In Ref. [4] instead we introduce and characterize two different measures which quantify the level of synchronization of interacting continuous variable quantum systems. The two measures allow to extend to the quantum domain the notions of complete and phase synchronization. The Heisenberg principle sets a universal bound to complete synchronization. The measure of phase synchronization is in principle unbounded, however in the absence of quantum resources (e.g. squeezing) the synchronization level is bounded below a certain threshold. We elucidate some interesting connections between entanglement and synchronization and, finally, discuss an application based on quantum opto-mechanical systems.

References

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1.3.17 Quantum Algorithms

Privacy is a major concern in many information trans- actions. A familiar example is provided by the transac- tions between web search engines and their users. On one hand, the user (say Alice) would typically prefer not to reveal to the server the item she is interested in (user privacy). On the other hand, the server (say Bob) would like not to disclose more information than that Alice has asked for (data privacy). User and data privacy are apparently in conflict: the most straightforward way to obtain user privacy is for Alice to have Bob send her the entire database, leading to no data privacy whatsoever. Conversely, techniques for guaranteeing the server's data privacy typically leave the user vulnerable. At the information theoretical level, this problem has been formalized by Gertner et al. as the Symmetrically-Private Information Retrieval (SPIR) [1]. This is a generalization of the Private Information Retrieval (PIR) problem [2] which deals with user privacy alone. (SPIR is closely related to oblivious transfer [3], in which Bob sends to Alice N bits, out of which Alice can access exactly one–which one, Bob doesn't know.) No efficient solutions in terms of communication complexity [4] are known for SPIR.

In a series of papers [5-7] we proposed a cheat sensitive quantum protocol to perform a private search on a classical database which is efficient in terms of communication complexity. It allows a user to retrieve an item from the server in possession of the database without revealing which item she retrieved: if the server tries to obtain information on the query, the person querying the database can find it out. Furthermore our protocol ensures perfect data privacy of the database, i.e. the information that the user can retrieve in a single queries is bounded and does not depend on the size of the database. With respect to the known (quantum and classical) strategies for private information retrieval, our protocol displays an exponential reduction both in communication complexity and in running-time computational complexity. In Ref. [7] the basic properties of the proposal was experimentally tested using a linear optical implementation.

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