Quantum Effects in the Charging of a Quantum Battery

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Quantum Thermodynamics is a relatively new research field that considers effects of quantum physics in the exchange of energy between different physical systems. Relatively because such considerations date back to the analysis of the build up of the intensity of laser fields in the 1960's. More recently, though, the development of quantum information theory has brought a whole new perspective to the field which has seen an abrupt growth in diversity and interests. Subjects such as the role of quantum effects in the establishment of the second law of thermodynamics, thermalization out of unitary evolutions, the quantum version of classical fluctuation theorems, relations between informational and thermodynamical entropies, optimization of energy expense in quantum circuits and the limits, differences and advantages of thermodynamic cycles with quantum work fluids and the charging of quantum batteries are just a few examples of themes that have attracted the attention of different communities in the last few years. As it was the case in the early development of the field of quantum information, quantum thermodynamics has also allowed to revisit some well established ideas and protocols in search for new advantages allowed by a fresh perspective and by looking at them from a different angle.

In this work, we analyze two quantum thermodynamical protocols where the specific interaction with selected subspaces of a quantized finite dimensional system are exploited to improve the performance over some of their previous versions. In the first one, we show how the vacuum of a quantized field can be exploited to improve the optical pumping of a quantum battery [1]. There are different ways to optically pump energy into a finite dimension quantum system but they all essentially rely on an external energy source that excites a higher transitory energy level of the system works as an intermediate state to eventually transfer the energy to a final metastable target state. These protocols are ultimately limited by the temperature of the environment to which the system is coupled. Here we show that by replacing one of the energy transitions of the system with a selective interaction with a quantized field [2,3] we are able to improve the overall energy transference by exploiting the vacuum of such field.

The second protocol describes how the selective interaction with the symmetric and the antisymmetric subspaces of interacting qubits allows one to use thermal fields to charge a quantum battery and to store more steady state entanglement in the system than previous proposals [4,5].

References

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