Phonon-mediated generation of quantum correlations between quantum dot qubits

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Quantum correlations play a crucial role in the understanding and possible implementation of any quantum computation algorithm. Unfortunately the influence of the environment is usually hostile to entanglement [2], which is the standard type of quantum correlations used for quantum computation.

It has been recently shown that a weaker type of quantum correlations, those which are measured by the quantum discord and which are sometimes present in separable (non-entangled) states, are also useful from the perspective of quantum computation [3]. Nevertheless while an interaction with the environment is also detrimental to the quantum discord, the latter is expected to be much more robust against the influence of environment compared to entanglement, and it may even be enhanced, under some special conditions.

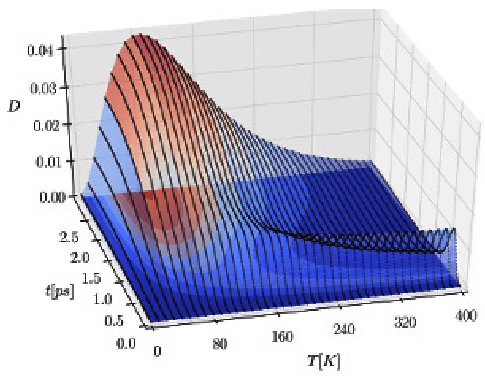

Figure 1: Exemplary time and temperature dependence of the rescaled discord for the initial equal superposition qubit state and thermal state of the environment.

In order to investigate the following idea, we study the generation of quantum correlations between two excitonic quantum dot qubits due to their interaction with the same phonon environment [1]. Such generation results from the fact that during the pure dephasing process at finite temperatures, each exciton becomes entangled with the phonon environment [4]. The extent to which the correlations are generated at different temperatures is a trade-off between the phonon effects being small at low temperatures, and small entanglement generation for a high - temperature environment.

During the study, we show that such an interaction will lead to the creation of finite quantum discord values between the two qubits, if the distance between them is small enough the environments cannot be treated as separate, and the temperature is modest. Because the phonon-induced dephasing of quantum states is partial [5], the generated discord is robust until the influence of other, slower decoherence mechanisms become dominant.

Finally we identify two most prominent features of the evolution during the generation of the quantum discord, their origin and parameter dependence (which are both different) and interpret them with the help of X-states whose quantum correlations are easier to quantify.

[1] J. Krzywda and K. Roszak *Sci. Rep.* **6**, 23753 2016. *ArXiv:1511.08434*
[2] T. Yu and J. H. Eberly, *Phys. Rev. Lett.* **93**; 140404, 2004.
[3] H. Olivier and W. Żurek *Phys. Rev. Lett.* **88**; 117901, 2001.
[4] K. Roszak and P. Machnikowski, *Phys. Rev. A* **73**, 022313 2006.
[5] K. Koszak and Ł. Cywiński, *Phys. Rev. A* **92**; 032310, 2015.