Entanglement at finite temperatures in mesoscopic conductors

P. Samuelsson

Division of Mathematical Physics, Department of Physics, Lund University, SB̈ox 118, SE - 221 00 Lund Sweden

We present a theory for entanglement generation, characterization and detection in mesoscopic conductors at finite temperatures [1]. The motivation for our work is provided by the recent experiment of Neder *et al*, [2], realizing the two particle interferometer proposed by Samuelsson, Sukhorukov, and Buttiker [3]. We show that at finite temperatures both the expression for the entangled state as well as schemes for entanglement detection based on low frequency current correlations need to be reconsidered. The two main reasons for this are i) electronic reservoirs acting as detectors emit quasiparticles back towards the mesoscopic source, modifying the state emitted from the source, ii) a completely filled Fermi sea, acting as a vacuum for emitted quasiparticles, does not exist at finite temperatures, making the entire concept of quasiparticle entanglement nontrivial. Taking as a starting point available experimental quantities, average currents and zero frequency current correlations, we show that the physically accessible quantity is the two-particle density matrix reduced from the full many body state emitted by the source. A discussion of the properties of the reduced density matrix, focusing on the entanglement, is provided. An expression for the entanglement in terms of the concurrence for an arbitrary conductor at finite temperature is presented. Moreover, we present finite temperature schemes for entanglement detection, a Bell inequality and Quantum State Tomography, formulated in terms of low frequency current correlators [1]. It is argued that a unambiguous demonstration of entanglement is within reach in the system of Neder *et al* [2]. We also compare our approach to existing finite temperature works based on energy resolved entanglement and wavefunction projection.

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[2] I. Neder, N. Ofek, Y. Chung, M. Heiblum, D. Mahalu, V. Umansky, Nature 448, 333 (2007).
[3] P. Samuelsson, E. Sukhorukov, and M. Buttiker, Phys. Rev. Lett. 92, 026805 (2004).