MAR09-2009-020578

Abstract for an Invited Paper
for the MAR09 Meeting of
the American Physical Society

Can multi-particle systems be too entangled to be useful for quantum computation?

JENS EISERT, Blackett Laboratory, Imperial College London

In the context of “quantum information meets many-particle physics”, we pose the question of the role of entanglement in the quantum computational power of many-particle quantum systems (1). It is often argued that entanglement is at the root of the speedup for quantum compared to classical computation, and that one needs sufficient entanglement for this speedup to be manifest. In measurement-based quantum computing, the need for a highly entangled initial state is particularly obvious. In this work we show that, remarkably, quantum states can be too entangled - in the sense of having a too large geometric entanglement - to be useful for the purpose of computation. What is more, we can prove that this phenomenon occurs for the dramatic majority of all states: the fraction of pure states on n qubits not subject to the problem is smaller than e^{-n^2}. Our results show that computational universality is actually a rare property in quantum states. For the proof we make use of a link between the “quantum probabilistic method” and ideas on quantum many-body systems. This work stresses a new aspect of the question concerning the role entanglement plays for quantum computational speed-ups. We will also investigate a new classification of primitives from projected entangled pair states (PEPS) that can be used in order to systematically construct new models for measurement-based computation (2,3). In an outlook, I will - if time allows - mention other recent group activities related to quantum information and many-particle physics, including dynamical area laws and relaxation statements (4,5).

(1) “Most quantum states are too entangled to be useful as computational resources”, Phys. Rev. Lett., in press (2009)
(2) “Quantum computational webs”, arXiv:0810.2542
(3) “Novel schemes for measurement-based quantum computation”, Phys. Rev. Lett. 98, 220503 (2007)
(4) “Exact relaxation in a class of nonequilibrium quantum lattice systems”, Phys. Rev. Lett. 100, 030602 (2008)
0[pt] (5) “Area laws for the entanglement entropy”, Rev. Mod. Phys., in press (2009).