Simulated adiabatic cooling protocols for systems with and without topological excitations

Anne Matthies[1]
Achim Rosch[1], Mark Rudner[2] and Erez Berg[3]

[1]*University of Cologne, 50937 Cologne, Germany*
[2]*University of Washington, Seattle, WA 98195-1560, US,*
[3]*Weizmann Institute of Science, Rehovot, 76100, Israel*

anne.matthies@uni-koeln.de

Preparing the ground state of a many-body Hamiltonian on a quantum device is of central importance, both for quantum simulations of molecules and materials [1], and for a variety of quantum information task [2]. Such a Hamiltonian can be simulated physically by tuning the interaction in e.g. a cold atom system. On a quantum computer the Hamiltonian can also realized in a digital manner. Different approaches to ground state preparation have been proposed, including variational quantum simulation [3], adiabatic evolution [4] and, more recently, also simulated cooling [5,6].

We propose a simple, robust protocol to prepare a low-energy state of an arbitrary Hamiltonian on a quantum computer. The protocol is inspired by the "adiabatic demagnetization" technique, used to cool solid state systems to extremely low temperatures. The adiabatic cooling protocol is demonstrated via an application to the transverse field Ising model (see Fig.1). We use half of the qubits to model the system and the other half as a bath. Each bath spin is coupled to a system spin. In a strong magnetic field, the bath spins are prepared in the polarized ground state. By an adiabatic downward sweep of the magnetic field (see Fig. 2), we change the energy of the bath spins and allow for resonant processes that transfer entropy from the system to the bath qubits. After each cycle, the bath is reset to the ground state. We find that the performance of the algorithm in the presence of a finite error rate depends on the nature of the excitations of the system; systems whose excitations are non-local (topological) objects are more difficult to cool. Finally, we explore ways to partially mitigate this problem.

References

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Figures

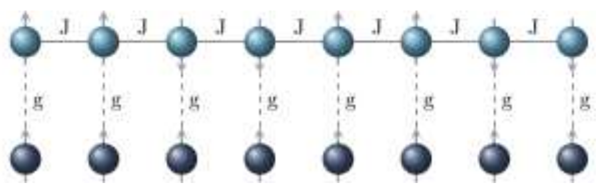

Figure 1: Model: System spins (light blue) are coupled to each other by coupling J. Each bath spin (dark blue) can be coupled to one system spin by coupling g. In the beginning of each cycle the bath is fully polarized.

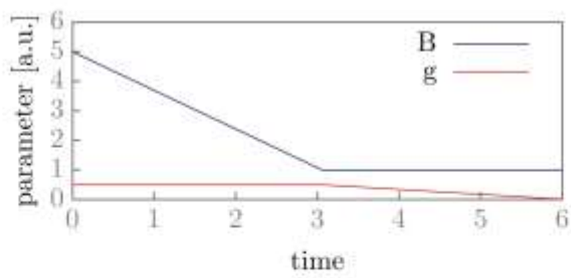

Figure 2: Adiabatic sweep: The magnetic field B of the bath spins is adiabatically decreased in each cycle. Afterwards the coupling g between system and bath slowly switched off.