Exponential optimization of quantum state preparation via adiabatic thermalization

Davide Cugini[1]
Davide Nigro[1]
Mattia Bruno[2]
Dario Gerace[1]

1)Dipartimento di Fisica, Università di Pavia, via Bassi 6, 27100 Pavia, Italy

2)Dipartimento di Fisica, Università di Milano Bicocca, Piazza della scienza 3, 20126 Milano, Italy

davide.cugini01@universitadipavia.it

The preparation of a given quantum state on a quantum computing register is a typically demanding operation, requiring a number of elementary gates that scales exponentially with the size of the problem. In view of performing quantum simulations of manybody models, this limitation might severely hinder the actual application of the noisy quantum processors that are currently available [1,2]. **We present an original method to prepare a generic quantum state exploiting the concept of adiabatic thermalization** [3]. In particular, we apply a procedure introduced in [4], and theoretically derive an exponential scaling law for the simulation error of the quantum state preparation as a function of the thermalization time. Here, the characteristic time dependence of such error on the thermalization process is explicitly formulated. We then design a preconditioning term that modifies the adiabatic preparation, reducing its characteristic time and hence giving an exponential advantage. We perform extensive numerical experiments to test our mathematical result on typical spin-models, such as the one- and two-dimensional Ising and Heisenberg Hamiltonians, confirming that the exponential bound is indeed realized and observing an exponential advantage for the preconditioned adiabatic processes. Our results provide a promising strategy to perform quantum simulations of manybody models via Trotter evolution on near term quantum processors.

References

[1] Y. Kim, et al., Nature, 618.7965 (2023) 500-505.
[2] F. Tacchino, et al., Advanced Quantum Technologies 3 (2020) 1900052.
[3] S. Jansen, M.-B. Ruskai, and R. Seiler, Journal of Mathematical Physics 48 (2007) 102111.
[4] G. Nenciu, Communications in mathematical physics 152 (1993) 479-496.

Figures

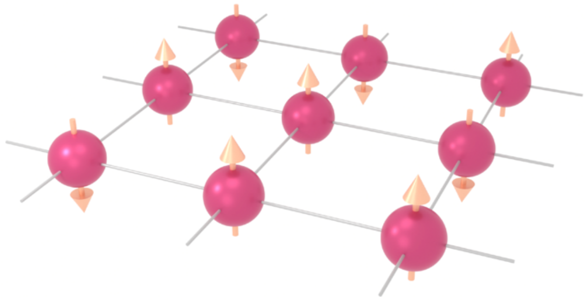

Figure 1: Lattice structure for 2D XZ Heisenberg model with periodic boundary conditions.

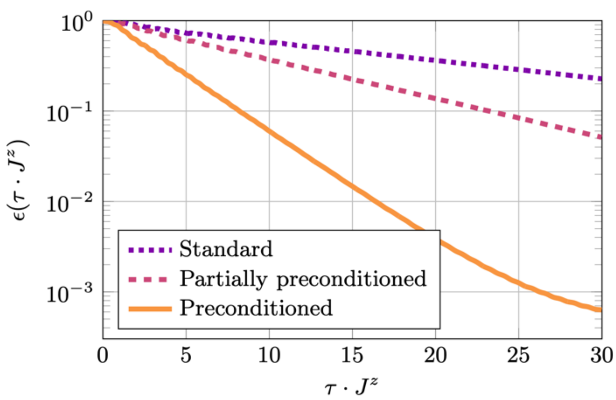

Figure 2: Dependence of the adiabatic thermalization error, plotted as a function of the thermalization time, for the ground state preparation of the 2D Heisenberg model with coupling constants $J^X = 5J^Z$.