Applying Tensor Network Techniques to Lattice Gauge Theories

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Abstract:

The term Tensor Network States (TNS) encloses a number of families that represent different ansatzes for the efficient description of the state of a quantum many-body system. The first of these families, Matrix Product States (MPS), lies at the basis of Density Matrix Renormalization Group methods, which have become the most precise tool for the study of one dimensional quantum many-body systems. Their natural generalization to two or higher dimensions, the Projected Entanglement Pair States (PEPS) are good candidates to describe the physics of higher dimensional lattices.

In the last years, the advancement has been remarkable both in the techniques to work with these families, specially for two and higher dimensional systems, and in the theoretical understanding of their fundamental properties. Quantum information tools have been deciding in this development.

Tensor Network Techniques reveal themselves as very promising tools for the non-perturbative study of lattice Hamiltonians. Specially suited to the study of equilibrium properties of local Hamiltonians, they can also be applied to non-local interactions and to dynamical problems.

Lattice Gauge Theories, in their Hamiltonian version, offer a challenging scenario for these techniques. While the dimensions and sizes of the systems amenable to TNS studies are still far from those achievable by LGT computations, Tensor Networks can be readily used for problems which more standard techniques cannot easily tackle, such as the presence of a chemical potential, or out-of-equilibrium dynamics.

As a proof of the feasibility of these methods, we have explored the performance of MPS techniques in the case of the Schwinger model, a widely used testbench for lattice techniques. Using MPS, we are able to determine the ground state and the mass gaps of the model away from any perturbative regime. These methods allow us also to study the effect of a chemical potential term and of non-zero temperature in the phase diagram.