BOUNDARY THEORIES OF TWO-DIMENSIONAL TENSOR NETWORK STATES NEAR THE AKLT POINT

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The edges of strongly correlated quantum many-body systems are known to possess interesting properties, which are related to the properties of the bulk material. For example, the low energy behaviour of two-dimensional quantum Hall systems can be described in terms of chiral modes which are localized at the edge of the system. Here this so called bulk-boundary correspondence is studied in the setting of projected entangled-pair states (PEPS) [1], a class of two-dimensional tensor network states which describe gapped quantum systems.

Using the tensor network formalism, the low energy Hilbert space of the bulk Hamiltonian can be identified with the entanglement degrees of freedom at the boundary of the system [2]. This allows to define a Hermitian operator acting on the boundary and which can be interpreted as the boundary Hamiltonian in the lowest order. The boundary Hamiltonian contains information about the low energy properties of the bulk Hamiltonian, and the behaviour of the boundary Hamiltonian can be investigated when the parameters of the bulk Hamiltonian are varied.

Here these boundary theories are studied numerically using the PEPS representation of the AKLT state [3], the valence bond ground state of interacting integer spins in two dimensions. The strengths of the interaction terms appearing in the boundary Hamiltonian are investigated when the AKLT Hamiltonian is perturbed by various interaction terms in the bulk. The boundary Hamiltonian is shown to be quasi-local with the range of interactions decreasing exponentially, and for large systems it consists of nearest-neighbour and next-nearest-neighbour interactions:

$$H_B \approx \eta_1 \sum_i \mathbf{S}_i \cdot \mathbf{S}_{i+1} + \eta_2 \sum_i \mathbf{S}_i \cdot \mathbf{S}_{i+2}$$

A local magnetic field in the bulk induces a local field also at the boundary. Using the PEPS structure, it can be shown that all local symmetries in the bulk are also inherited by the boundary Hamiltonian.

An interesting question is whether the low energy physics, described by the boundary Hamiltonian H_B, bears some relation to the entanglement spectrum of the bulk ground state. This connection, known as the Li-Haldane conjecture [4], suggests an intimate relation between the boundary Hamiltonian and the entanglement Hamiltonian derived from the entanglement spectrum of tensor network states [5].

References

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