Entanglement Spectra of Two-dimensional Quantum Systems

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Study on entanglement has been attracted attention in wide area of science. Entanglement entropy can characterize nature of strongly correlated quantum systems. For instance, the relationship between size dependence of entanglement entropy and existence of energy gap is well established. The saturated value of entanglement entropy in the thermodynamic limit becomes logarithm of number of edge states for one-dimensional gapped systems, whereas the entanglement entropy logarithmically diverges for one-dimensional critical systems and the coefficient is decided by the central charge. On the other hand, entanglement properties of two-dimensional quantum systems have little investigated because of intractableness of computation. We considered the entanglement properties of the following two models since these systems are tractable by knowledge of statistical physics.

(i) Two-dimensional Valence-Bond-Solid (VBS) state[1,2]

We proposed calculation method by Monte Carlo method to obtain reduced density matrix of VBS state when we divide total system into two symmetric subsystems. By using the method, we obtained size dependence of entanglement entropy and entanglement spectrum for square lattice and hexagonal lattice. The "low-energy" structure of entanglement spectrum for square lattice is similar with the energy dispersion of one-dimensional antiferromagnetic Heisenberg chain. To consider more clearly, we defined new quantity which is called *nested entanglement entropy* to calculate the central charge of the holographic system. We found the central charge is nearly $c = 1$ which is the central charge of one-dimensional antiferromagnetic Heisenberg chain.

(ii) Two-dimensional quantum lattice gas model with excluded volume effect[3]

We studied entanglement properties of the quantum lattice gas model with excluded volume effect on square ladder and triangle ladder. We found that the holographic system for square ladder and that for triangle ladder, respectively, can be described by two-dimensional Ising model and two-dimensional three-state Potts model.

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