Geometric Calculation of Entanglement Entropy via AdS/CFT

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Quantum entanglement is very important to understand properties of quantum many-body systems which appear in various areas such as condensed matter physics, quantum information theory and quantum gravity. In particular, the entanglement entropy is a remarkable quantity to measure quantum entanglement. For example, the entanglement entropy is expected to play a role of an order parameter for quantum phase transitions.

Four years ago, Shinsei Ryu and I found a formula which calculates the entanglement entropy in quantum field theories as an area of a minimal area surface in a particular spacetime, which coincides with the anti de-Sitter (AdS) space when the field theory is scale invariant [1]. This offers us a geometric interpretation of quantum entanglement and a new simple calculation of entanglement entropy rather than the usual complicated quantum mechanical one. This result has been obtained from the idea called AdS/CFT correspondence (or holography), which was discovered in string theory. This holographic calculation of entanglement entropy has been developed recently as one of the applications of AdS/CFT to condensed matter physics (for a review refer to [2]).

In this talk, first I will introduce the AdS/CFT correspondence to condensed matter physicists. Then I will explain how we can calculate the entanglement entropy via AdS/CFT. Finally, I would like to mention that the entanglement entropy in time-dependent backgrounds such as quantum quenches are important to understand quantum properties of black holes and to resolve the black hole information paradox based on [3].

References

[1] S. Ryu and T. Takayanagi, "Holographic derivation of entanglement entropy from AdS/CFT," Phys. Rev. Lett. **96** (2006) 181602 [arXiv:hep-th/0603001]; "Aspects of holographic entanglement entropy," JHEP **0608** (2006) 045 [arXiv:hep-th/0605073].

[2] T. Nishioka, S. Ryu and T. Takayanagi, "Holographic Entanglement Entropy: An Overview," J. Phys. A **42** (2009) 504008 [arXiv:0905.0932 [hep-th]].

[3] T. Takayanagi and T. Ugajin, "Measuring Black Hole Formations by Entanglement Entropy via Coarse-Graining," arXiv:1008.3439 [hep-th].