Quantum Entanglement in Many-body Physics (L16)

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The theory of quantum entanglement provides a new language for describing correlations in quantum many-body systems, thé central problem in theoretical physics. One of the big challenges is to develop the grammar and semantics of that new language. This course will provide an introduction to this novel but striving field of research which spans a wide array of fields such as quantum computation, condensed matter physics, quantum field theory and quantum chemistry.

The course will cover a selection of topics including:

- Introduction to the theory of entanglement
- The relevant physical corner of Hilbert space
- Lieb-Robinson bounds and the spreading of entanglement
- Area laws of the entanglement entropy
- Quantum tensor networks
- Entanglement-based Variational methods for strongly correlated systems
- Topological quantum order and entanglement patterns
- Notions of entanglement in condensed matter physics, quantum field theory and quantum chemistry.

Prerequisites

It will be assumed that you have taken an advanced quantum mechanics course, similar to Part II Principles of Quantum Mechanics. Familiarity with quantum computation (e.g., from Part II and Part III Quantum Information and Computation) will be beneficial.

Literature

1. B Zeng, X Chen, DL Zhou, XG Wen, *Quantum information meets quantum matter*, Springer.
2. R. Horodecki, P. Horodecki, M. Horodecki, K. Horodecki, *Quantum entanglement*, Reviews of modern physics, 17;81(2):865 (2009).
3. M.B. Hastings, *Locality in Quantum Systems*, https://arxiv.org/abs/1008.5137
4. J.I. Cirac, D. Perez-Garcia, N. Schuch, F. Verstraete, *Matrix product states and projected entangled pair states: Concepts, symmetries, theorems*, Reviews of Modern Physics 93 (4), 045003 (2021).

Additional support

Three examples sheets will be provided and three associated examples classes will be given. There will be a one-hour revision class in the Easter Term.