The Hebrew University of Jerusalem

Syllabus

Quantum information methods for many body physics - 77697

Last update 23-04-2020

HU Credits: 3

Degree/Cycle: 2nd degree (Master)

Responsible Department: Physics

Academic year: 0

Semester: 2nd Semester

Teaching Languages: English and Hebrew

Campus: E. Safra

Course/Module Coordinator: Erez Zohar

Coordinator Email: erez.zohar@mail.huji.ac.il

Coordinator Office Hours:

Teaching Staff:
Dr. Erez Zohar

Course/Module description:
Quantum Many Body Physics is a very challenging research field, that requires the development of new computation methods, for handling strong interaction and non-pertubative models. The course will introduce two modern approaches to many-body physics and quantum field theory, rooted in quantum information theory: one is quantum simulation – mapping one quantum system to another one which is controllable in the laboratory, and tensor networks, which allow one to perform efficient calculations for physically relevant many body quantum states. The course will include examples from both condensed matter and particle physics (prior knowledge with the demonstrated models is not required).

Course/Module aims:
To introduce modern research methods in quantum many body physics and field theory, based on quantum information, along understanding the relevant features of this field; to implement these methods to example models from particle and condensed matter physics.

Learning outcomes - On successful completion of this module, students should be able to:
1. To match a quantum system to a quantum simulator, to map between the two and to plan the control and measurement of the simulator enabling to study the system.
2. To design and construct symmetric MPS and PEPS suitable for a physical model and to study their properties using the MPS and PEPS toolbox.

Attendance requirements(%):

Teaching arrangement and method of instruction:

Course/Module Content:
1. Introduction: review of second quantization of bosons and fermions; Symmetries (global and local), conserved quantities, constraints; Demonstrating system (that will be useful in the next section): ultracold atoms in optical lattice and Hubbard models

2. Hamiltonians on demand - quantum simulators: Motivation; Analog simulation, imposing symmetries, theory of effective Hamiltonians, state preparation, adiabatic evolution; Digital simulation, the Trotter-Suzuki approximation of time evolution, tailoring many body interactions from two-body interactions with ancillas.
3. States on demand - tensor network states: Non interacting Hamiltonians, Gaussian states; Local interacting Hamiltonians and entanglement area law; Motivation for tensor networks as physically relevant states, a brief overview of tensor network constructions (PEPS, MPS, MERA, ...) ; PEPS (Projected Entangled Pair States) and their 1d version, MPS (Matrix Product States): structure and construction, basic properties, imposing symmetries on demand, parent Hamiltonians and analytical properties; Fermionic PEPS

Required Reading:
Notes and references to scientific literature will be given during the course.

Additional Reading Material:

Course/Module evaluation:
End of year written/oral examination 0 %
Presentation 0 %
Participation in Tutorials 0 %
Project work 100 %
Assignments 0 %
Reports 0 %
Research project 0 %
Quizzes 0 %
Other 0 %

Additional information: