

Reservoir-controlled quantum materials

Resp. UE: Cristiano Ciuti (PR Université de Paris)

Teachers: Cristiano Ciuti (PR Université de Paris)

ECTS credits: 3

Language of instruction: English

Examination: written exam (questions on articles given in advance)

Description:

In recent years, new concepts related to the coupling of quantum manybody systems to judiciously tailored reservoirs and/or ancillary systems are providing elegant and effective ways to dramatically modify the electronic and optical properties of quantum materials in condensed matter, atomic and optical platforms. Moreover, reservoir-based approaches are also emerging in the context of artificial intelligence and quantum information. In particular, machine learning approaches can be applied to reservoir systems with random character in order to perform recognition of quantum states and quantum operations. This course and its tutorials will provide in a pedagogical way the fundamental concepts for reservoir-control of quantum systems and show the most recent and exciting developments, applications and experimental realizations. The interdisciplinary and self-contained character of this class should resonate with students belonging to the programs Condensed Matter, Quantum Physics, and Theoretical Physics.

Chapter 1: Introduction and Fundamentals (6h including tutorials)

- Conceptual challenges and general motivations
- Fundamental theoretical framework
- Methods: elimination of ancillary degrees of freedom and effective dynamics
- Methods: stochastic approaches, variational methods, low-entropy techniques
- Description of main experimental platforms

Chapter 2: Cavity-controlled electronic transport in disordered quantum materials (8h including tutorials)

- Cavity-mediated long-range electron hopping due to the exchange of virtual photons
- Cavity-mediated long-range electron-electron interactions
- Applications to disordered conductors
- Applications to 2D quantum Hall systems
- Overview of recent experiments

**Chapter 3: Manybody bosonic systems controlled by quantum impurities
(8h including tutorials)**

- Multimode cavity and circuit QED
- Coupling of a single (artificial) atom to a many-mode bosonic system
- Effective coupling between low and high-frequency photons
- Manybody quantum states of radiation mediated by the quantum impurity
- Overview of recent experiments

**Chapter 4: Neuromorphic systems and reservoir-computing
(6h including tutorials)**

- Classical versus quantum neural networks
- Noisy quantum computation
- Reservoir-computing and reservoir quantum computing
- Perspectives in the field