

Reservoir-controlled quantum materials

Teacher: **Cristiano Ciuti**, Professor, Université Paris Cité, Laboratoire MPQ (CNRS-UMR 7162)

ECTS: 3

Language : English

Exam : Written exam (exercises & questions related to course and articles given in advance)

General Motivation

In recent years, new concepts related to the coupling of quantum many-body systems to tailored reservoirs are providing elegant ways to modify the electronic, optical and mechanical properties of quantum materials in condensed matter, atomic, optical and quantum circuit platforms. Moreover, reservoir-based approaches are emerging in the context of machine learning and quantum information. This M2 course and its tutorials will provide in a pedagogical way the fundamental concepts for the reservoir-control of quantum systems and show the most recent developments, applications and experimental realizations. The interdisciplinary and self-contained character of this class should resonate with students belonging to the tracks of Condensed Matter, Quantum Physics, and Theoretical Physics.

Part 1: Reservoir-induced dynamics

- Conceptual challenges and general motivations
- Fundamental theoretical framework: master equations
- Methods: elimination of reservoir degrees of freedom and effective dynamics
- Illustrative applications to different systems

Part 2: Cavity-controlled electronic transport

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

Chapter 3: Reservoir-computing and machine learning

- Concepts of machine learning
- Deep neural networks, reservoir-computing, kernel machines
- Overview of recent experiments

Part 4: Many-body bosonic systems controlled by quantum impurities

- Multimode cavity and circuit QED
- Coupling of a single (artificial) atom to a many-mode bosonic system
- Fine spectral structure and many-body localization
- Overview of recent experiments