Quest for quantum coherence and second quantum revolution

ECTS credits
5 credits

Semester
Fall

In brief

Course langage: English

Presentation

Prerequisites

Basics of quantum mechanics

Learning objectives

(Learning outcomes)

This course reflects recent developments of quantum technologies which belong to what is nowadays called the second quantum revolution (the first quantum revolution corresponding to the ``heroic'' years of development of the quantum theory (1900-1930) as has been outlined in the ECM first year lessons of introduction to the quantum theory (alpha program)).

This second revolution began, roughly, in the 80's, with the development of new protocols of communication (like e.g. quantum cryptography) and new quantum algorithms, in parallel with the developement of new technologies which enabled to prepare-and control the evolution of-quantum entangled systems.

In february 202, the president Macron announced the onset of the Plan Quantique in France, complementary to the so-called European Quantum Flagship. These inititiatives aim at developing new quantum technologies (like e.g. quantum computers, quantum networks of safe communication and so on) which are likely to reach in the coming years supremacy compared to their classical counterparts.

In this framework, decoherence constitutes a very serious problem, which limits the development of all these new technologies.

Quest for quantum coherence and second quantum revolution

The goal of this course is

1 to familiarize the student with the concept of quantum decoherence through a combination of magistral courses (12 hours) and supervised exercises (8 hours);

2 to also devote time (10 hours) to bibliographic works realized in autonomy, in small groups, about the most recent developments of the Plan Quantique (quantum simulators, quantum algorithms, quantum communication and so on).

Description of the programme

The first part, about decoherence, aims at properly defining quantum (de)coherence which will be made possible thanks to the introduction of new conceptual tools such as e.g. entanglement, density operator, and reduced density operators of an entangled system.

The complementarity between coherence and entanglement will be put into evidence, and its conceptual implications will be emphasised in relation with the Bohr-Einstein controversy about wave-particle duality and the Wheeler delayed-choice paradox.

The role of decoherence at the macroscopic scale will be outlined, and the theory of open quantum systems in interaction with the environment will be sketched. This formalism will be illustrated by a presentation of the experimental measure of decoherence in a lossy QED cavity realized at the beginning of our century by the team of Serge Haroche (nobel prize 2012).

The second part, about recent developements in the framework of the plan quantique will consist of a bibliographic work, to be defined in collaboration with the students.

Generic central skills and knowledge targeted in the discipline

– C1 Innovation scientifique et technique :

The student will learn new formalisms (reduced density operators, open quantum systems) which provide a faithful description of quantum systems interacting with their environment. He/she is expected to develop new conceptual skills (to compute the biorthogonal decomposition of a two qubit system for instance) and to be able to make use of these new formalisms in order to solve simple problems, similar to those treated during the supervised exercices.

– C2 Maîtrise de la complexité et des systèmes.

An open quantum system is by nature a complex system, due to the impossibility to perfectly simulate the environment, be it by numerical or analytic methods. The concepts presented in the first part of this course represents a sophisticated and elegant way to tackle this intrinsical complexity. This can only contribute to broaden the scientific culture of the student, a prerequisite for dealing with complexx situations.

-C5 vision stratégique

In the second part of the lesson (bibliographic research) it is expected that the student will explore a scientific research field in full development (cfr the Plan Quantique) which will bring him unavoidably to develop his strategical vision.

How knowledge is tested

–CC1 written 65 % for decoherence and open systems dynamics (written evaluation)

– CC2 oral 35 % for the bibliographic work (an oral presentation to all students of the course will also provide an opportunity to develop soft skills related to this type of work).

Bibliography

-poly for the 1st part (delivered by the teacher).

-various types of scientific documents (papers, tutos and so on) will be provided by the teacher and/or selected by the student for what concerns the second part, to be defined in function of the task.

Teaching team

Thomas Durt plus guests to be announced and to be confirmed

Sustainable Development Goal

Quality education

Total des heures	**30h**
AU	30h

Useful info

Name responsible for EU

Lead Instructor

Thomas Durt

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