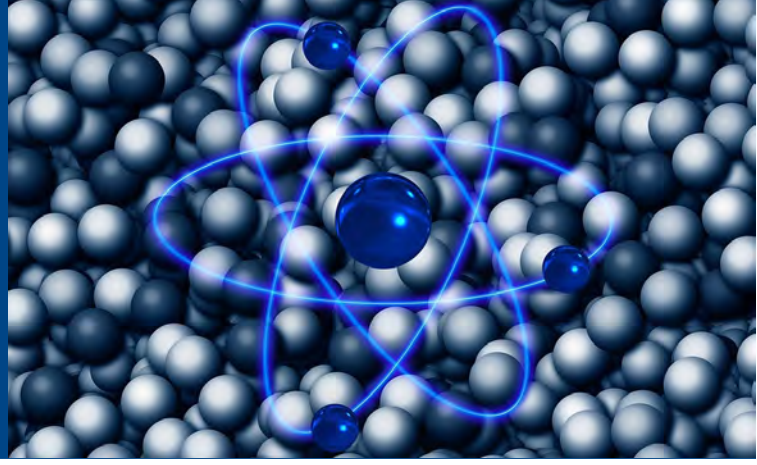
Lecture series on *Quantum Engineering* at University Paris-Saclay



Optical and Electrical Quantum Engineering

Tuesday 7, 14, 21, and 28 March 2017 from 9:00 to 12:30
Balmer room at Laboratoire Aimé Cotton*

Attendance is free but registration is *mandatory* (by email to Laurent Sanchez-Palencia, lsp@cpht.polytechnique.fr)

The IQUPS** network organizes a series of introductory lectures on Quantum Engineering. They are open to Master students, PhD students, Post-docs, and researchers. The first series will combine on each Tuesday morning of March 2017 one course of Optical Quantum Engineering (OQE) and one course of Electrical Quantum Engineering (EQE).

Program : 09:00 – 09:15 : welcome breakfast
09:15 – 10:45 : lecture on OQE or EQE
10:45 – 11:00 : coffee break
11:00 – 12:30 : lecture on EQE or OQE

The ensemble of the two courses is eligible as « complément de formation initiale » for students from the Ecole Doctorale Ondes et Matière (EDOM) and the Ecole Doctorale Physique en Ile-de-France (EDPIF).

Optical quantum engineering, from fundamentals to applications

Philippe GRANGIER (Laboratoire Charles Fabry, IOGS, Palaiseau)

In this course we will start from basic quantum mechanics and introduce progressively qubits, entanglement, and Bell's inequalities; some details will be given about « Aspect's experiments » realized in the 1980's at Institut d'Optique, as well as on the recent « loophole free Bell tests » realized in 2015. In the second part we will point out the links between entanglement, quantum measurement, and quantum gates, and illustrate these ideas using some simple examples. In the third and fourth parts these ideas will be applied to quantum optics experiments with Gaussian and non Gaussian states, quantum cryptography, and possible future quantum networks.

Lecture 1 (7 March, 9:15-10:45) : Qubits, entanglement and Bell’s inequalities.
Lecture 2 (14 March,11:00-12:30) : Entanglement in a Quantum Measurement Process : from QND measurements to quantum gates.
Lecture 3 (21 March, 9:15-10:45) : Quantum optics with discrete and continuous variables
Lecture 4 (28 March, 11:00-12:30) : Quantum cryptography and optical quantum networks

Electrical quantum engineering with superconducting circuits

Patrice BERTET and Reinier HEERES (Service de Physique de l’Etat Condensé, CEA-Saclay)

The research field of quantum state engineering with electrical superconducting circuits was born from fundamental questionings about the possibility of observing macroscopic quantum phenomena. This led to the experimental demonstration, 15 years ago, that the quantum state of an electrical circuit can be manipulated and read-out. Superconducting circuits based on Josephson junctions can thus behave as genuine artificial two-level atoms, which can be used as quantum bits. Compared to real atoms, these superconducting qubits are macroscopic in size, leading to large electrical or magnetic dipole, which facilitates their coupling to other circuits. Superconducting qubits can in particular be strongly coupled to superconducting resonators. This coupled qubit-resonator system is described by the Jaynes-Cummings model, which also describes the coupling of real atoms to high-quality-factor resonators in Cavity Quantum Electrodynamics (QED). The circuit version (called by analogy to atomic physics « Circuit QED ») offers an architecture for quantum information processing since it enables qubit readout and multi-qubit entanglement and gates. Recent experiments have demonstrated the operation of elementary quantum processors based on up to 10 qubits. In addition, it is possible to couple superconducting circuits and resonators to other quantum systems such as spins or mechanical resonators, forming so-called Hybrid Quantum Devices.

Lecture 1 (7 March, 11:00-12:30; P. Bertet) : Introduction to superconducting circuits and qubits
Lecture 2 (14 March, 9:15-10:45; R. Heeres) : Circuit QED : qubit state readout, and resonator quantum state engineering
Lecture 3 (21 March, 11:00-12:30; P. Bertet) : Multi-qubit quantum state engineering and quantum gates
Lecture 4 (28 March, 9:15-10:45; P. Bertet): Introduction to Hybrid Quantum Devices

* Instructions to come can be found on the website of Laboratoire Aimé Cotton (http://www.lac.u-psud.fr)
** Ingénierie Quantique à l’Université Paris-Saclay