COM-309

Introduction to quantum information processing

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Cursus	Sem.	Type
Communication systems	BA5	Opt.
Computer science	BA5	Opt.
Minor in Quantum Science and Engineering	H	Opt.
Quantum Science and Engineering	MA1, MA3	Opt.

Language of teaching	English
Credits	5
Session	Winter
Semester	Fall
Exam	Written
Workload	150h
Weeks	14
Hours	**4 weekly**
Courses	3 weekly
Exercises	1 weekly
Number of positions	

Summary

Information is processed in physical devices. In the quantum regime the concept of classical bit is replaced by the quantum bit. We introduce quantum principles, and then quantum communications, key distribution, quantum entropy, and spin dynamics. No prior knowledge of quantum physics is required.

Content

Introduction a la mecanique quantique des systemes discrets.
- Interference experiments: double slit, Mach-Zehnder, polarization of photons experiments.
- Complex numbers, linear algebra recap, tensor product
- Quantum principles: states, unitary evolution, measurement, composite systems
- Notion of quantum bits, entanglement, no-cloning
- Bloch sphere

Cryptographie, Communications et Corrélations
- Secret key generation: BB84 and B92 protocols
- Entanglement: EPR pairs
- Bell/CSCH inequalityl. Ekert protocol for a secret key generation
- Teleportaion, dense coding, distillation.

Density matrices and Von Neumann entropy
- mixed states and entropy
- bipartite systems and entanglement entropy
- non-signalling and teleportation revisited
- basic inequalities of quantum information theory and comparison to classical

Spin and its dynamics
- Stern-Gerlach experiment, spin 1/2
- Dynamics of spin in magnetic fields, Rabi oscillations
- Heisenberg hamiltonian
- Manipulations of the spin and elementary quantum gates
- Introduction to the Jaynes-Cummings Model (time permitting)

Keywords

Polarization, spin, measurement, quantum bit, entanglement, key distribution, teleportaion, dense coding, Von Neumann entropy, spin dynamics.

Learning Prerequisites

Required courses

Linear algebra, basic probability

Important concepts to start the course

Vectors, matrices, eigenvalues, eigenvectors, projectors, inner product, algebraic manipulation of complex numbers, discrete probability distribution.

Learning Outcomes

By the end of the course, the student must be able to:

- Describe principles of quantum physics
- Illustrate quantum bits with photon polarization and spin
- Explain basic communication protocols like key distribution, dense coding, teleportation
- Describe how to manipulate qubits with magnetic fields
- Define quantum entropies and list basic properties
- Use IBM Q NISQ devices
- Use Qiskit and/or Pennylane and NISQ devices

Teaching methods

Ex cathedra lectures, exercise session, practical implementationns on simulators (qiskit, pennylane, qbraid)

Expected student activities

Participation in class, homeworks, hands-on exercises on simulators.

Assessment methods

- midterm
- miniproject
- Final written exam

Supervision

Office hours	No
Assistant.e.s	Yes
Forum	Yes
Others	Assistants are in exercise session

Resources

Virtual desktop infrastructure (VDI)

No

Bibliography

David Mermin, *Quantum computer science, An introduction, Cambridge university press 2000.* Written for computer science students with no knowledge of physics.
Michel Le Bellac, *A short introduction to quantum information and quantum computation, Cambridge University Press*. A pedagogic book with an elementary introduction to the physics of the subject.
Neil Gershenfeld. *The physics of information technology. Cambridge University Press.* On basic information technologies useful in computer science, classical communications and quantum aspects.

Ressources en bibliothèque

- Find the references at the Library

Notes/Handbook

Yes, on web site

Prerequisite for

Classes in Quantum Science and Engineering