

QUANT-400

Introduction to quantum science and technology

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Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	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

A broad view of the diverse aspects of the field is provided: quantum physics, communication, quantum computation, simulation of physical systems, physics of qubit platforms, hardware technologies. Students will grasp the field as a whole and better orient themselves on specialized topics.

Content**Introduction (2 weeks):**

- Overview of the frontiers of quantum science, technology and applications.
- Introduction to qubits, quantum states, measurements, evolution. Axiomatic formulation.
- Illustration with two level systems, Bloch sphere, Spin, its manipulation in magnetic fields. Heisenberg and spin Hamiltonians, elementary gates. Coherence times.

Communication, information and computation (5 weeks)

- Quantum communication: QKD, dense coding, teleportation.
- Circuit model of computation.
- Introduction to algorithms
- Quantum simulation of physical systems (e.g. VQE, hybrid quantum-classical approaches)

Physics of qubit platforms (3 weeks):

- Introduction to qubit platforms
- superconducting qubits
- trapped ions, spin qubits (time permitting)

Hardware technologies and applications (4 weeks):

- Single electron transistors (SET) and fabrication technologies
- Single electron memories (SEM)
- Hybrid CMOS-SET for analog and sensing functions at cryogenic temperatures
- The quantum stack, Quantum-classical interfaces
- From fidelity to electronic circuit specifications
- Cryogenic electronics to control quantum systems

Keywords

quantum bit, qubit, quantum information, quantum computation, algorithms, spin, quantum sensing, metrology, NISQ devices, cryogenic electronics, quantum-classical interface.

Learning Prerequisites

Required courses

- Linear Algebra
- Elementary physics classes

Learning Outcomes

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

- Describe various frontier topics in quantum science and technology.
- Illustrate quantum principles for simple systems
- Recognize quantum computation models
- Explain the simplest primitive communication protocols
- Present current hardware technologies and their applications
- Design electronics for quantum systems

Teaching methods

- Ex-cathedra lectures
- Exercices session

Assessment methods

- Written exam

Supervision

Assistants	Yes
Forum	Yes

Resources

Bibliography

- The physics of information technology / Gershenfeld
- Quantum computation and quantum information / Nielsen and Chuang
- Quantum computer science: an introduction /Mermin
- Bharti, K., et al., 2022. Noisy intermediate-scale quantum algorithms. Rev. Mod. Phys. 94, 015004.

Ressources en bibliothèque

- [Quantum computation and quantum information / Nielsen and Chuang](#)
- [The physics of information technology / Gershenfeld](#)
- [Quantum computer science: an introduction /Mermin](#)
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Prerequisite for

