PHYS-744

# Advanced Topics in Quantum Sciences and Technologies

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| Cursus | Sem. | Type |
|---|---|---|
| Physics | | Opt. |

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|---|---|
| Language of teaching | English |
| Credits | 4 |
| Session | |
| Exam | Oral presentation |
| Workload | 120h |
| **Hours** | **72** |
| Lecture | 48 |
| Exercises | 24 |
| **Number of positions** | |

## Frequency

Every 2 years

## Remark

Next time: Fall 2024

## Summary

This course provides an in-depth treatment of the latest experimental and theoretical topics in quantum sciences and technologies, including for example quantum sensing, quantum optics, cold atoms, theory of quantum measurements and open dissipative quantum systems, etc.

## Content

**Topics for Fall 2022**
**"Quantum sensing and metrology" by Dr. Mayeul Chipaux**

1. Sensing using individual or ensemble of quantum objects: photons, ions or atoms, superconducting devices, point defects in solids...
2. Sensitivity up to the standard quantum limit: coherence, shot noise, quantum projection noise...
3. Sensitivity up to the Heisenberg limit: entanglement, Fisher information, squeezing...

Specific examples based on Nitrogen-Vacancy centers in diamond will illustrate the concepts.

**"Quantum Information Processing with trapped ions" by Prof. Cornelius Hempel, PSI**

1. Basic concepts of how to use trapped ions for quantum computing
2. State of the art examples and the road to scale up to fault tolerant machines

**"Quantum mechanics of superconducting circuits" by Prof. Vladimir Manucharyan**

1. Circuit quantization and periodic table of superconducting artificial atoms (qubits)
2. Quantum computing with superconducting qubits
3. Extreme coupling regimes of QED and many-body simulations.

**"Quantum Neural Networks" by Prof. Zoé Holmes**

1. introduction to quantum neural networks (QNNs) and some of their potential uses
2. What makes a 'good' QNN? Expressibility and the barrier to trainability posed by barren plateaus

Organizers: Ch. Galland & J.-Ph. Brantut

## Keywords

Quantum Science, Quantum Technology, Quantum sensing, Quantum Optics; Quantum simulation; Quantum measurement; Open systems; Cold atoms; Cavity optomechanics; Single photon detection

## Learning Prerequisites

### Required courses
Required : Quantum Optics I and II

### Recommended courses
Recommended : Statistical Physics IV

### Important concepts to start the course
strong background in classical mechanics and electromagnetism, knowledge of quantum mechanics

## Learning Outcomes
By the end of the course, the student must be able to:
- Describe current research in the field of quantum science and technology
- Formulate the challenges in experimental quantum science
- Use theoretical tools to describe real quantum systems

## Teaching methods
Lectures with student's participation and hands-on activities.

## Expected student activities
Actively participate to all lectures by asking questions. Deliver a final presentation on modern research topic.

## Assessment methods
Each student will be presenting one of the proposed papers during a final symposium.

## Resources
### Notes/Handbook
Advanced Topics in Quantum Sciences and Technologies is a graduate-level lecture series dedicated to PhD and Master students already possessing a background in quantum mechanics and quantum optics.

### Moodle Link
- https://go.epfl.ch/PHYS-744