Master and bachelor programs in quantum technologies

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Possible paths

Alternative 1

1. Keep present study direction under the Physics and Astronomy (PA) BSc program called
   - **Quantum technology**, but increase number of students
2. Similarly, keep existing study direction under the Physics master of Science program
   - **Quantum Science and Quantum Technology**, but increase number of students
3. And do the same for the CS program with the study direction
   - **Quantum Information Science and Technology**, but increase number of students

Second alternative

Alternative 2

1. Keep present study direction under the Physics and Astronomy (PA) BSc program called
   - **Quantum technology**, but increase number of students
2. Create a new master of science program called
   - **Quantum Science and Technology** (or something similar)

This will have as a consequence that one may eventually drop the study directions in the CS and Physics MSc programs (see below).

Third alternative

Alternative 3

1. New bachelor program
   - **Quantum Science and Technology** (or something similar)
2. Create a new master of science program called
   - **Quantum Science and Technology** (or something similar)

This will have as a consequence that one may eventually drop the study directions in the CS and Physics MSc programs (see below).

Alternative 2: New master of science program

Quantum Science and Technology, as a multidisciplinary program much along the same lines as the CS program

Collaboration with four possible departments

- Department of Chemistry (quantum chemistry and Hylleräs center, Simen Kvaal and Thomas B. Pedersen, plus several PDs and PhDs)
- Department of Informatics (cryptography, cyber security, Audun Jøsang and Mavroeidis, Vasileios, plus PDs and PhDs)
- Department of Mathematics (quantum information theory, operator algebra group, Alexander Muller-Hermes, Nadia S. Larsen, Eric Bedos and Sergiy Neshveyev plus several PhDs and PDs)
- Department of Physics (theory and experiment, several professors, PDs and PhDs, largest activity)

The program is hosted by the department of Physics.

Core mission of the program

The master program provides advanced knowledge to develop cutting-edge theoretical and experimental research in quantum simulation, quantum computing, quantum sensors, quantum communications and purely formal theoretical aspects.
Various universities, research centres and companies may actively participate in teaching the master's degree.

Motivation and Vision

Quantum technologies represent a transformative frontier across computing, sensing, communication, and materials science. The proposed MSc program addresses the growing demand for researchers and professionals capable of integrating quantum physics, mathematics, informatics, and quantum chemistry into coherent technological and scientific applications.

Potential partners

The program will be anchored in foundational research and experimental efforts in the Oslo region, leveraging existing expertise at:

- University of Oslo
- Oslo Metropolitan University
- University of South-Eastern Norway
- Simula Research Laboratory (quantum algorithms and hybrid computing),
- SINTEF (quantum devices, sensors, and materials).

Program Objectives

The MSc in Quantum Science and Technology will:

1. Provide students with a deep understanding of the theoretical, mathematical, and computational foundations of quantum mechanics and information.
2. Train students in both experimental and computational methods applicable to quantum technologies.
3. Encourage interdisciplinary collaboration bridging physics, informatics, mathematics, and chemistry.
4. Prepare graduates for both academic research careers and emerging industrial roles in quantum computing, sensing, communication, and materials.

Program Structure

The program consists of:

- A **Basic core curriculum** (60 ECTS) establishing the interdisciplinary foundation.
  - A **specialization track** (30 ECTS) chosen from the study directions listed below.
  - A **Master's thesis** (30 ECTS) supervised by one or more partner institutions.
  - Or a **Master's thesis** (60 ECTS) supervised by one or more partner institutions.

Study Direction 1: Quantum Computing and Algorithms

Focus: Foundational and practical aspects of quantum computation, from physical qubits to high-level algorithms.
Content: Quantum gates, circuits, error correction, variational quantum algorithms (VQE, QAOA), quantum Fourier transform, and quantum machine learning.
Disciplinary integration:

- Physics: Quantum mechanics and hardware models.
- Mathematics: Linear algebra and optimization.
- Informatics: Quantum programming and algorithmic complexity.
- Quantum Chemistry: Electronic structure simulations using quantum algorithms.

Local relevance: Collaborations with Simula Research Laboratory and OsloMet
Career paths: Researcher, quantum software developer, academic or industrial scientist.

Study Direction 2: Quantum Materials and Quantum Simulations

Focus: Theoretical and computational study of materials with quantum properties.
Content: Many-body theory, DFT, ab-initio methods, tensor networks, and quantum Monte Carlo.
Disciplinary integration:

- Physics: Condensed matter and many-body systems.
- Mathematics: Numerical methods.
- Informatics: Simulation algorithms.
- Quantum Chemistry: Correlation and electronic structure.

Local relevance: SMN and Hylleraas Centre for Quantum Molecular Sciences.
Career paths: Computational physicist, materials modeler, simulation scientist.

Study Direction 3: Quantum Information and Communication

Focus: Theoretical and experimental foundations of quantum information science and secure communication.
Content: Entanglement, teleportation, quantum Shannon theory, quantum networks, and repeaters.
Disciplinary integration:

- Physics: Photonic and spin-based quantum systems.
- Mathematics: Information theory and group theory.
- Informatics: Communication protocols and cryptographic architectures.
- Quantum Chemistry: Photon–matter interactions.

Local relevance: University of Oslo and SINTEF Microsystems and Nanotechnology.
Career paths: Quantum cryptography specialist, communication researcher, network engineer.

Study Direction 4: Quantum Sensing and Metrology

Focus: Quantum-enhanced precision measurement and detection technologies.
Content: Quantum Cramér–Rao bound, entangled sensing, NV centers, superconducting sensors, quantum control.
Disciplinary integration:

- Physics: Quantum optics and solid-state physics.
- Mathematics: Estimation theory and signal processing.
- Informatics: Bayesian inference and data analysis.
- Quantum Chemistry: Defects and spin–orbit coupling.

Local relevance: SMN at UiO and SINTEF sensor technologies, Justervesenet, FFI.
Career paths: Quantum instrumentation engineer, metrology researcher, applied physicist.

Study Direction 5: Quantum Control and Quantum Engineering

Focus: Quantum device design, control, and scalability.
Content: Control theory, decoherence, noise modeling, hardware platforms, cryogenics.
Disciplinary integration:

- Physics: Experimental quantum systems and control.
- Mathematics: Control theory and dynamical systems.
- Informatics: Optimization and control systems.
- Quantum Chemistry: Interface materials and decoherence modeling.

Local relevance: UiO, SINTEF and other?
Career paths: Experimental physicist, quantum engineer, cryogenic systems designer.

Study Direction 6: Quantum Machine Learning

Focus: Quantum algorithms for artificial intelligence and data-driven discovery.
Content: Quantum neural networks, quantum generative models, hybrid quantum-classical algorithms.
Disciplinary integration:

- Physics: Variational algorithms and circuit design.
- Mathematics: Statistics and optimization.
- Informatics: Machine learning and AI frameworks.
- Quantum Chemistry: Data-driven molecular prediction.

Local relevance: SimulaMet, NBIM, DNB?
Career paths: Quantum ML researcher, AI engineer, data scientist in R&D.

Summary Table of Study Directions

Study Direction	Focus	Key Disciplines	Local Rele
Quantum Computing & Algorithms	Algorithms and theory	Physics, Math, Informatics, Chemistry	UiO, Simu
Quantum Materials & Simulations	Quantum materials and modeling	Physics, Math, Chemistry, Informatics	SMN, Hyll
Quantum Information & Communication	Secure communication, entanglement	Physics, Math, Informatics	UiO, SINT
Quantum Sensing & Metrology	Precision measurement	Physics, Math, Chemistry, Informatics	UiO, SINT
Quantum Control & Engineering	Hardware and control systems	Physics, Math, Informatics	SINTEF
Quantum Machine Learning	AI and hybrid quantum computing	Physics, Math, Informatics	Simula

Or fewer study directions

- Quantum information and communication
- Quantum Computing
- Quantum Sensing and Metrology
- Quantum machine learning

or iterations thereof.

Existing and new courses that can be used, all 10 ECTS

- FYS3415/4415 Quantum Computing Fundamentals
- MAT3420 Quantum Computing Fundamentals
- MAT4430 Quantum information theory
- FYS4480 Many-body physics
- FYS5419 Quantum Computing and Quantum Machine Learning
- FYS5429 Advanced Machine Learning
- FYS-MENA4111 Quantum Mechanical Modelling of Nanomaterials
- FYS4411: Computational Physics 2, Monte Carlo methods
- FYS4170: Quantum field theory
- FYS4110: Modern quantum mechanics

To be developed?

Quantum Mechanics for Quantum Technologies

Mathematics for Quantum Science

Programming for Quantum Simulations

Quantum Information Theory and Algorithms

Quantum Hardware

Quantum Sensors and Metrology

Cryptography and cybersecurity