Summary of the Quantum Science and Engineering Degree Programme

Class of the CdS	LM44 (Mathematical-Physical Modelling for Engineering)
Department of Reference	Dep. of Physics and Astronomy (DFA) Dep. of Information Engineering (DEI)
Language(s) of delivery	ENGLISH
Degree Course Venue	University of Padova

Motivation

Quantum technologies are among the most advanced and promising frontiers in modern science and engineering. Grounded in quantum mechanics principles such as superposition and entanglement, they offer the potential for transformative applications across various sectors. Over recent decades, progress in understanding and manipulating quantum systems has led to the rise of quantum computing, communications, and sensing, core pillars of the 2017 Quantum Flagship, a major initiative aimed at transitioning these technologies from research labs to industry. This momentum continues, as demonstrated by the 2021 founding of the European Quantum Industry Consortium (QuIC), the largest quantum-focused association in Europe, which aims to build a strong and vibrant quantum ecosystem. The University of Padua is at the forefront of this rapidly expanding sector. The Department of Information Engineering (**DEI)** has already various courses and research activities on this topic with a focus on the field of quantum communications, while the Department of Physics and Astronomy (**DFA**) won the Department of Excellence project with a coordinating role in the field of quantum computing by acting as a spoke co-leader in the Italian National Center for HPC, Big Data, and Quantum Computing (ICSC Foundation), and hosting the Quantum Computing and Simulation Center (QCSC), which is dedicated to developing a general-purpose quantum computer at the University. Both departments play leading roles in major European quantum research projects and collaborate closely to leverage their complementary expertise through the **Padua Quantum Technologies Research Center (QTech)**, an interdepartmental center established in 2020 to drive innovation and research in quantum science and technology.

Building on their complementary expertise in quantum communications and in quantum computing and simulation, and in response to rapid scientific advances and the growing demand for professionals in the quantum technology sector, the DEI and DFA propose the establishment of a Master's Degree in **Quantum Science and Engineering (LM-44)**—a comprehensive academic program designed to provide thorough training in this emerging field. The complementary contributions from the departments of Chemistry and Mathematics will complete the framework in an organic way.

Learning objectives

The Master's Degree in **Quantum Science and Engineering** offers a multidisciplinary curriculum designed to equip graduates with the skills needed to apply quantum technologies in industry and research. Students gain expertise in advanced mathematics, quantum physics, precision electronics, and quantum information, supported by both theoretical study and hands-on laboratory experience.

The main purpose of the course is to train highly qualified professionals, able to:

1. Design and develop quantum communication systems, contributing to the creation of ultra-secure and high-efficiency communication networks.

2. Apply quantum computing principles to solve complex problems in various fields, from optimization to simulation of molecular systems.

3. Collaborate in multidisciplinary teams, acting as a bridge between experts from different disciplines thanks to their transversal training.

4. Integrate quantum technologies into existing engineering systems, improving their performance and opening up new application possibilities.

5. Develop next-generation quantum sensors, with applications ranging from precision medicine to space exploration.

Employment opportunities

The training program in **Quantum Technologies**, covering quantum computing, quantum simulation and quantum communication, offers students numerous career opportunities in a fast-growing and innovative field.

The most immediate job prospects lie with companies developing hardware and software for quantum computing and communications. While the number of such companies is still limited globally, employment potential is significant, given the involvement of major multinationals, many of which are joining the European Quantum Industry Consortium (QuIC). Companies like IBM, Google, Microsoft, Intel, and Amazon have launched ambitious quantum development programs and are actively seeking qualified professionals.Another key sector is telecommunications, particularly in network infrastructure and security. Quantum communication and cryptography are reaching maturity, creating strong demand, both nationally and internationally, for experts in these areas.

Graduates can pursue roles in R&D or operational divisions as **Quantum Engineers**, **Quantum Communication Specialists**, **Quantum Software Developers**, **Quantum Cryptography Experts**, **Quantum Research Scientists**, or **Quantum Systems Analysts**.

Further employment opportunities exist in the **secondary market** for quantum technologies: industries that, while not developing quantum hardware or software, apply quantum solutions to optimize processes, products, or services. This is similar to the widespread use of classical computing. Sectors include finance (e.g., portfolio optimization, risk analysis, algorithmic trading), pharmaceuticals and chemistry (e.g., drug discovery, molecular simulation), logistics (e.g., route and supply chain optimization), and energy and transport networks (e.g., power grid optimization, battery design, crash test simulations).

Additionally, a smaller but important share of graduates may enter **academic and research institutions**, both in Italy and abroad, to contribute to the development and application of quantum technologies. These roles range from specialized technologists to research scientists, with further growth expected in the medium to long term.

List of Mandatory Course:

- Quantum Information&Computing or Microelectronics
- Numerical method for quantum technologies
- Quantum Optics and Lasers
- Semiconductor Nanostructures

Optional courses:

- Quantum Cryptography and Security
- Quantum Communication Lab (LABORATORIO)
- Introduction to Tensor Network Methods
- Quantum Information With Atoms And Photons
- Quantum Methods For Ict
- Quantum Open System And Control
- Quantum Algorithm
- Advanced Quantum Physics
- Introduction To Superconducting Qubits
- Ion Traps laboratory
- Quantum Simulations
- Programmable Hardware Devices

- Nanoelectronics
- Nanofabrication
- Selected Topic In Quantum Science
- Theory Of Strongly Correlated Systems
- Digital Electronics
- Fundamentals Of Nanoscience
- Advances photonics
- Fiber optics
- Optoelectronics And Photovoltaic Devices
- Nanophotonics and metasurfaces