

ML4Q Platforms for Quantum Technologies course 2025

24 – 28 March 2024

Overview

Date	Topic	Lecturer	Location
Mon 24.03.	Introduction to Quantum Information and Algorithms	Markus Müller	FZJ
Tue 25.03.	Quantum algorithms and Entanglement theory & Out of equilibrium open quantum systems	Andrea Nava	Düsseldorf
Wed 26.03.	Quantum optics for quantum computing with ultracold atoms and semiconductors	Andrea Bergschneider & Nina Stiesdal	Bonn
Thu 27.03.	Superconducting and semiconductor qubits	Rami Barends, Seyed Akbar Jafari, Vincent Mourik	Aachen
Fri 28.03.	Basics of topological quantum computation & Basics of quantum circuits	Erwann Bocquillon & Xhek Turkeshi	Cologne

The exact schedule will be slightly different for each day, but usually classes will start around 10:00 and finish around 17:00 and there will be a lunch break.

The presentations for the graded assessment are planned for the week of 7–11 April. Exact dates will be provided soon.

Content Overview

Day 1, 24.03.2025 (FZJ)

On this day students will get a brief hands-on introduction to quantum information and quantum circuits. We will discuss ingredients of quantum algorithms, and in particular Grover's quantum search algorithm. Furthermore, we will introduce basic theoretical concepts and recent experimental breakthroughs in quantum error correction, which will be crucial to protect future scalable quantum computers against noise. In addition, a joint lunch, lab tours and discussions with other quantum technology research groups at Forschungszentrum Jülich are planned.

Cluster of Excellence
Matter and Light for Quantum Computing (ML4Q)

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Day 2, 25.03.2025 (Düsseldorf)

During the second day we will join (for two lectures) the 'Spring R(h)ein Quantum School', where students will be introduced to the concept of quantum algorithms and entanglement theory. In addition, the concepts of topological phase transitions and Mpemba effect in open quantum systems will be discussed.

Day 3, 26.03.2025 (Bonn)

During this day, we explore ways to interface photons with quantized matter for the realization of tailored qubits. We will give a basic introduction to light-matter coupling on the example of the two-level system. We will use this formalism to treat specific realistic quantum systems and discuss how to reach sizable coupling between single photons and those systems, for instance by using cavities or collective effects. After that, we will give an overview on ML4Q projects done in Bonn followed by lab tours and a Meet & Greet poster session with the Bonn PhD students.

Day 4, 27.03.2025 (Aachen)

In the morning session we will have two lectures on superconducting qubits and spin qubits. The afternoon session will consist in two lab tours to showcase how the above two types of qubits are produced in the lab.

Day 5, 28.06. 2025 (Cologne)

The aim of this day is to introduce students to two notions of quantum computation. First, we will discuss quantum circuits, sampling and understand how one can accurately define and benchmark quantum advantage, with case studies on recent articles.

Second, we'll describe basics of topological quantum computation, and present experimental efforts aiming at realising it. In addition there will be a poster session and lab tours from ML4Q groups.

