Introduction
(Lecture of the Quantum Information class of the Master in Quantum Science and Technology)

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Outline

1 **Introduction**
  - Motivation to study quantum information science

What is quantum information?

Interdisciplinary field based on

- Quantum mechanics (typically nonrelativistic)

    - Schrödinger equation, published in 1926

    - John von Neumann, E. P. Wigner

- Quantum optics,
    - Nobel Prize in Physics 1964, Charles Hard Townes, Nicolay Gennadiyevich Basov and Aleksandr Mikhailovich Prokhorov "for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the **maser-laser principle**"

    - Nobel Prize in Physics 2001, Eric A. Cornell, Wolfgang Ketterle and Carl E. Wieman "for the achievement of **Bose-Einstein condensation** in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates"

What is quantum information? II

- Quantum optics (continued)

  - The Nobel Prize in Physics 2005 was divided, one half awarded to Roy J. Glauber "for his contribution to the quantum **theory of optical coherence**", the other half jointly to John L. Hall and Theodor W. Hänsch "for their contributions to the development of **laser-based precision spectroscopy**, including the optical frequency comb technique. (Photodetection and the statistics of light, coherent states)"

  - The Nobel Prize in Physics 2012 was awarded jointly to Serge Haroche and David J. Wineland "for ground-breaking experimental methods that enable measuring and **manipulation of individual quantum systems**." (cavities, trapped cold ions)

  - The Nobel Prize in Physics 2022 was awarded jointly to Alain Aspect, John F. Clauser and Anton Zeilinger "for experiments with **entangled photons**, establishing the violation of **Bell inequalities** and pioneering quantum information science." (experiments with photons)

What is quantum information? III

- Computer science

  - Computational complexity theory, analysis of algorithms and computability theory.

- Unlike many areas of physics, it has a constructive side.

- Very often the goal is to create quantum states of very many particles experimentally, or to make a quantum computer.

- The theory is trying to help this development.

Subfields of quantum information science

- Theory of nonlocality, Bell inequalities, 1964

- Theory of quantum entanglement, Werner, 1989

- Quantum metrology (measuring some quantity using a quantum system), many experiments from 2000

- Quantum computer, quantum algorithms (factoring primes, Shor, 1994 and search, Grover, 1996)

- Quantum communication, quantum cryptography, BB84 (1984)

- Quantum error correction (three-qubit bit flip code, Asher Peres in 1985; Shor code 1995)

- Quantum simulation (one can simulate so large quantum systems that could not fit into a classical computer)