

Introduction

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

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- 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,
 - Photodetection and the statistics of light, coherent states, etc., George Sudarshan, Roy J. Glauber, and Leonard Mandel, 1950's, 1960's



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."
 - 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**."
 - 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."

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)