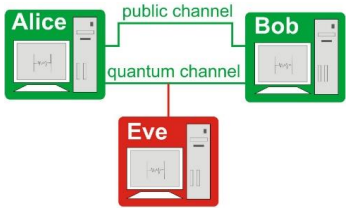
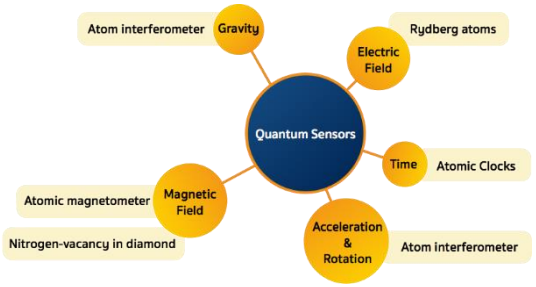
Quantum Technology (QT)

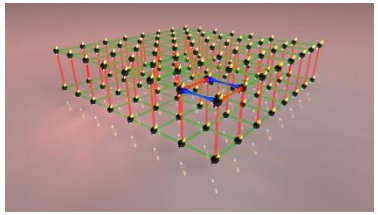
What is Quantum Technology (QT)?

Quantum technology is a novel field of physics and engineering, which exploits ***quantum entanglement, quantum superposition and quantum tunneling***, for practical applications such as;

- quantum communication (or cryptography),
- quantum computing,
- quantum sensors (or metrology), and
- quantum simulation.

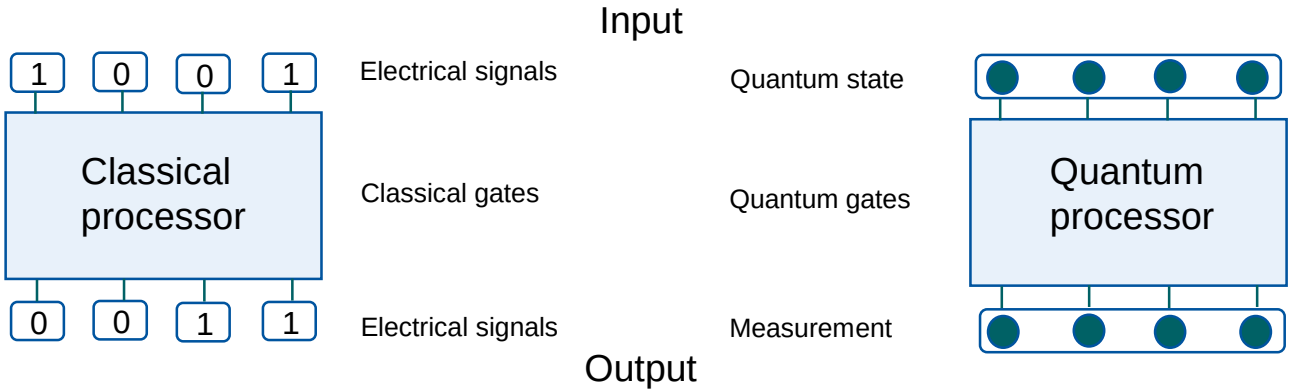






Quantum Computing

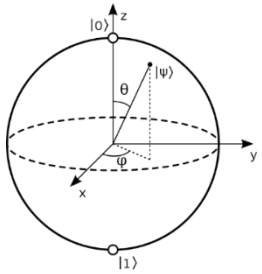
What is the difference between classical and quantum computer?



In quantum computers, the logical operations are carried out using the quantum bit (*qubit*) state $|\Psi\rangle$, which is the *superposition* of the basis states $|0\rangle$ and $|1\rangle$.

Classical bit

Quantum bit

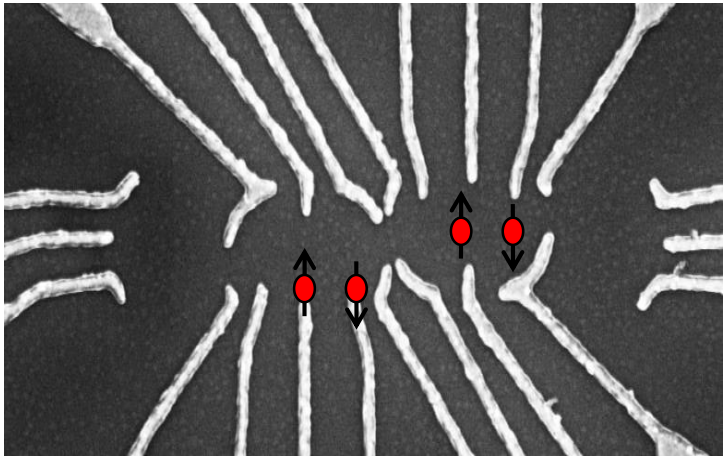


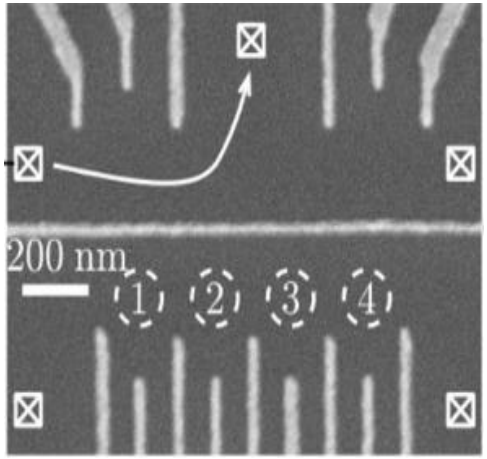
$$|\Psi\rangle = a\,|0\rangle + b\,|1\rangle = \bullet$$
$$|a|^2 + |b|^2 = 1$$

What are different types of qubit?

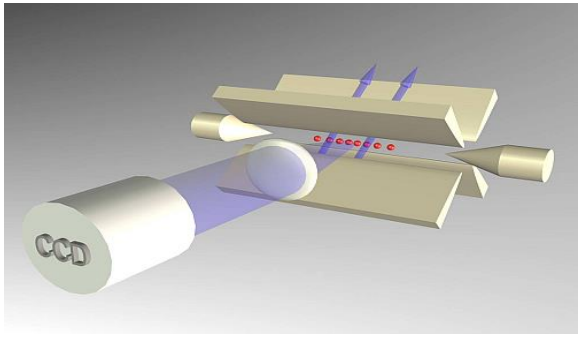
Types of qubits

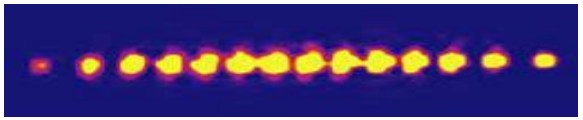
Electron spin qubits



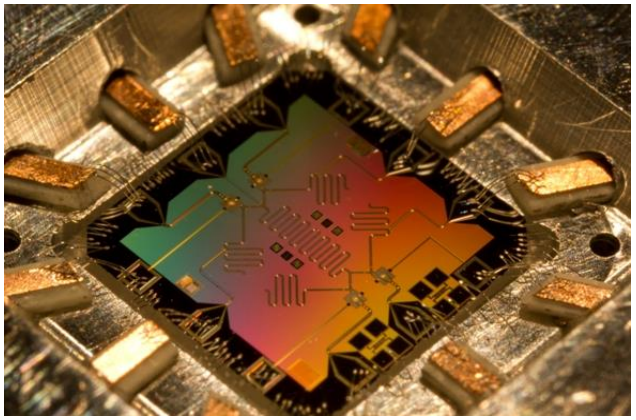


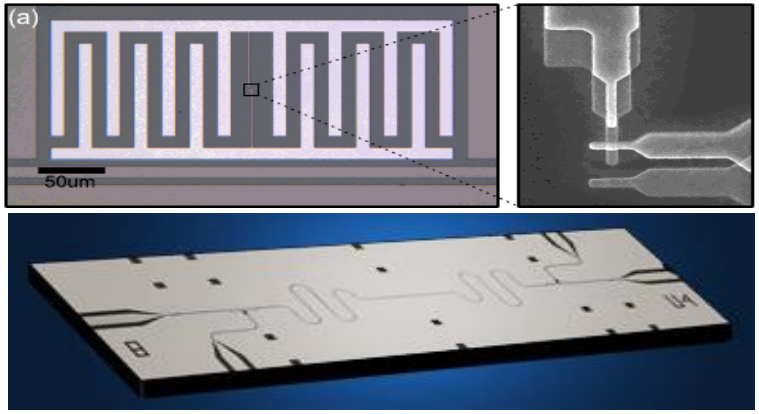
Trapped Ions

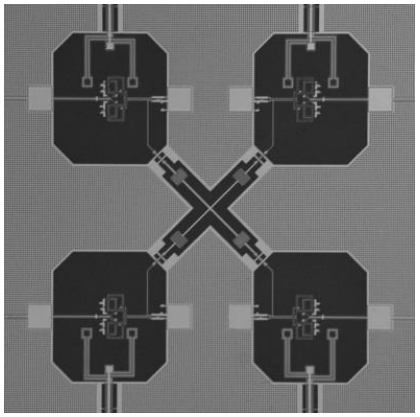




Superconducting Qubits







I. QT – Teaching @ RWTH

Quantum Technology (QT) study track @RWTH

M.Sc. in Physics, new regular study track starting from winter semester (WS) 2019/2020.

M.Sc. in Electrical Engineering, Information Technology and Computer Engineering, part of study track Micro- and Nanoelectronics (MINA).

Curriculum – QT

Department of Physics	Faculty of Electrical Engineering and Information Technology
Winter semester (Total 30 ECTS)	Winter semester (Total 32 ECTS)
Condensed matter physics I or **Quantum theory of condensed matter I** or **Theoretical solid state physics** – **10 ECTS**	**Compound Semiconductors and Optical Components** and **High Frequency Electronics** and **Solid state technology** and **VLSI-Design for Digital Signal Processing - Fundamentals** – **16 ECTS**
Hardware platform for QT – 5 ECTS NEW	**Hardware platform for QT** – **4 ECTS** NEW
	Quantum Mechanics for Electrical Engineers – **4 ECTS** NEW
Elective courses[1] – 15 ECTS	Elective courses[2] – 8 ECTS
Summer semester (Total 30 ECTS)	Summer semester (Total 32 ECTS)
Quantum Information – **10 ECTS**	**Quantum Information** – **8 ECTS**
Lab course quantum technology – 5 ECTS NEW	**Lab course quantum technology – 4 ECTS** NEW
Elective courses[1] – 15 ECTS	Elective courses[2] – 20 ECTS
Winter semester (Total 30 ECTS)	Winter semester (Total 26 ECTS)
Master's seminar and practical – **30 ECTS**	**Master's internship** – **22 ECTS**
	Elective courses[2] – 4 ECTS
Summer semester (Total 30 ECTS)	Summer semester (Total 30 ECTS)
Master's thesis and colloquium – **30 ECTS**	**Master's thesis and colloquium** – **30 ECTS**

[1] Physics and [2] Electrical Engineering
Bold – Compulsory course

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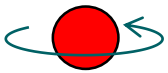
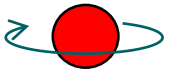
II. QT - Research @ RWTH

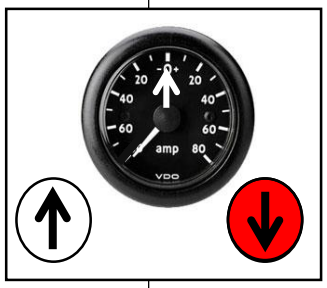
Electron spin qubits

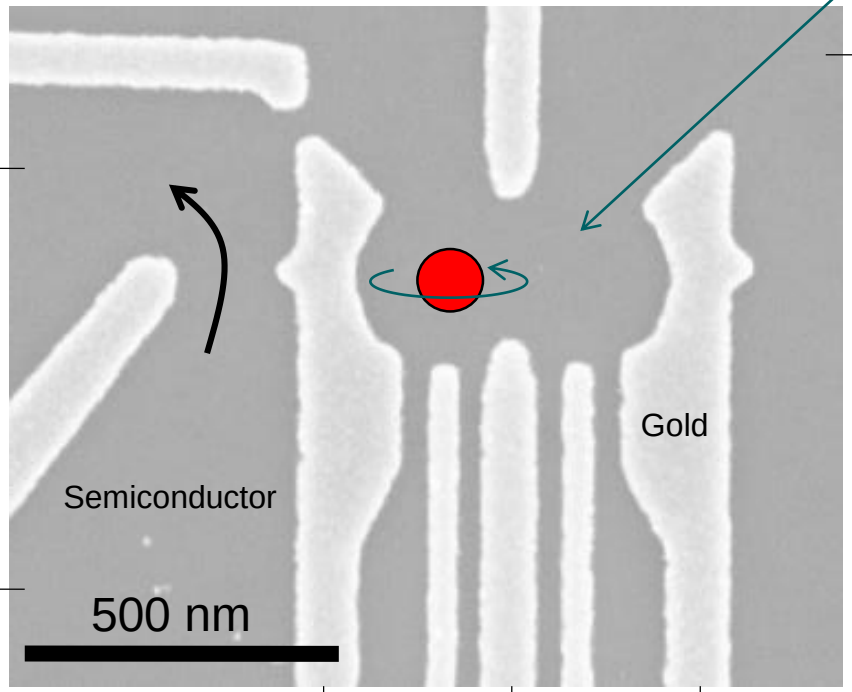
1 or ↑: 

0 or ↓: 

Electron trap

“state sensor”





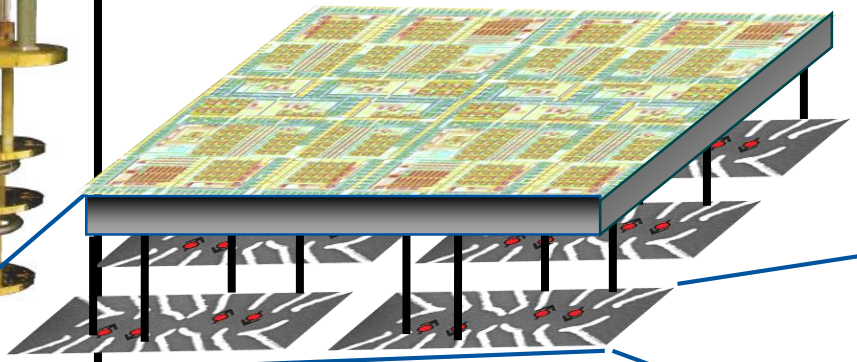
Electron spin qubits

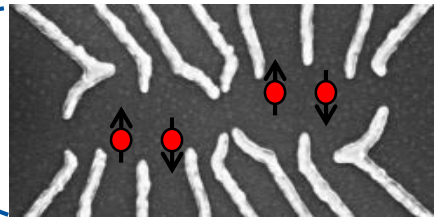
Dilution refrigerator

Temperature = 0.1 K

Long-term goal:
Quantum computer with millions of qubits

Current status:
Systems with single or few qubits





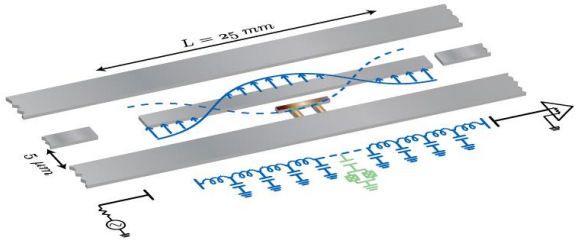
1 µm

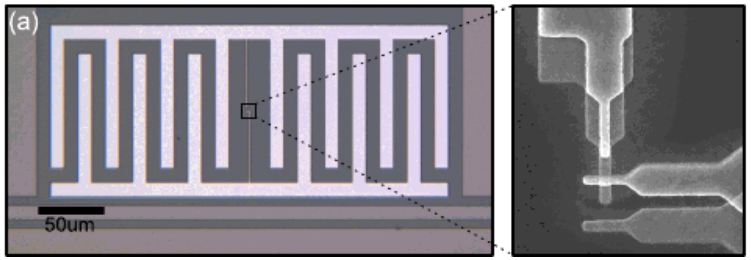
Superconducting qubits

- Effective quantum description (Hamiltonian) of a (non-dissipative) superconducting circuit. For e.g., Josephson-junction: a nonlinear inductor, breaking the degeneracy of energy level spacing, is a good candidate for the superconducting (flux, phase, transmon, ...) qubit.

- Qubits with long coherence times make possible:
  - error-correcting circuits
  - accurate measurements of decoherence mechanisms

- Goals:
  - understand physics of decoherence
  - find ways to limit decoherence
    ⇒ develop theoretical models and compare with experiments





Research groups

Experimental

Prof. Hendrik Bluhm

Prof. Thomas Schäpers

Prof. Beata Kardynal

Prof. Markus Ternes

PD Dr. Alexander Pawlis

Dr. Lars Schreiber

Theory

Prof. David DiVincenzo

Prof. Fabian Hassler

Prof. Barbara Terhal (FZJ*/ TU Delft)

Prof. Kristel Michelson

Dr. Gianluigi Catelani

Weblink

*** Forschungzentrum Jülich**

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