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

On (1)

Off (0)

Quantum bit

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

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

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

Bold – Compulsory course
II. QT - Research @ RWTH
Electron spin qubits

1 or ↑:  

0 or ↓:  

Electron trap

“state sensor”

Semiconductor

Gold

500 nm

Gold
Electron spin qubits

Long-term goal:
Quantum computer with millions of qubits

Current status:
Systems with single or few qubits

Temperature = 0.1 K

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

* Forschungszentrum Jülich