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Numerik auf Quantencomputern

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Quantum Computers

Bit - Qubit

Classical computer: smallest information unit: **bit**

- Logically expressed by values 0 and 1
- Physically realized by flow/non-flow of electrons through transistor
- follows to laws of classical physics

Quantum computer: smallest information unit: **qubit**

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Superconducting qubit

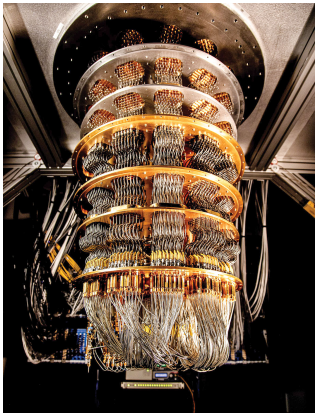

Figure: Quantum computer (Google)

- essentially electric circuits
- superconducting materials
  - no loss of electricity at low temp.
  - free flow of formed electron pairs
  - follows laws of quantum mechanics!
- ground state - lowest energy
- excited state (elect. in outer orbit) - higher energy
- manipulated via microwaves/magnetic flux pulses
- +: manufactured – scalable
- -: all are different – inherent errors

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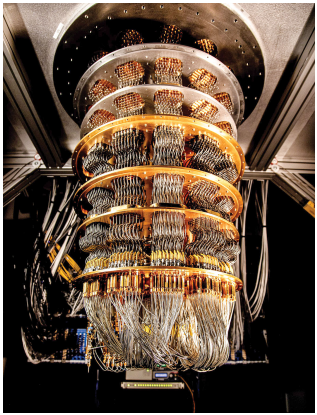

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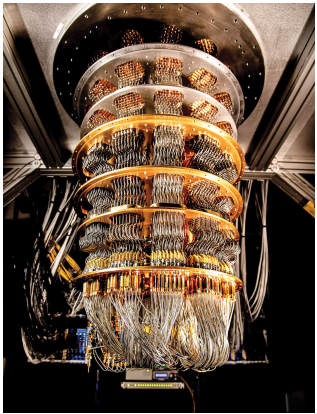

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Defect qubit

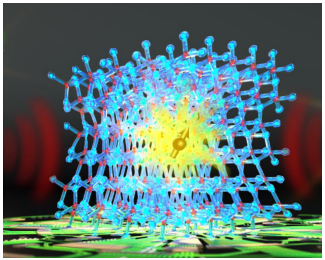

Figure: Al-nitride ion trap

Defect: space where atoms missing/misplaced in material structure

- e.g.: diamonds: replace carbon by nitrogen
- also aluminium nitride/silicon carbide
- traps electrons - gives access point to manipulate

History I - Quantum Mechanics

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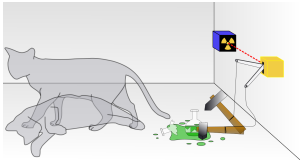

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1980 Paul Benioff: first model of a computer operating under laws of QM
- shown by a Schrödinger equation description of Turing machines

1985 David Deutsch: description for a quantum Turing machine
- introduced quantum gates for elementary operations

1992 Deutsch–Jozsa algorithm
- first quantum algorithm with exponential speedup

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- quantum algorithm for factorization in polynomial time

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- quantum annealer: only special comp. tasks, 84qubits then - 5000 now

2019 Google: quantum supremacy

- useless series of operations in 200s – supercomputer takes about 10,000 years
- IBM: 10000 years are rather 2.5days by optimization
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- access/control/initialization of qubits
- coherence time: time how long qubit can hold its state
  - superconducting qubit: $\sim 10^{-4}s$
  - Si-carbide defect qubit: $5s$
  - affected by noise
- information storage - copy of states impossible
  - solution: quantum entanglement – later
- all problems increase drastically with more qubits!
- employ error correcting codes
  - use logical qubits (something that keeps the information of a bit) – later

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