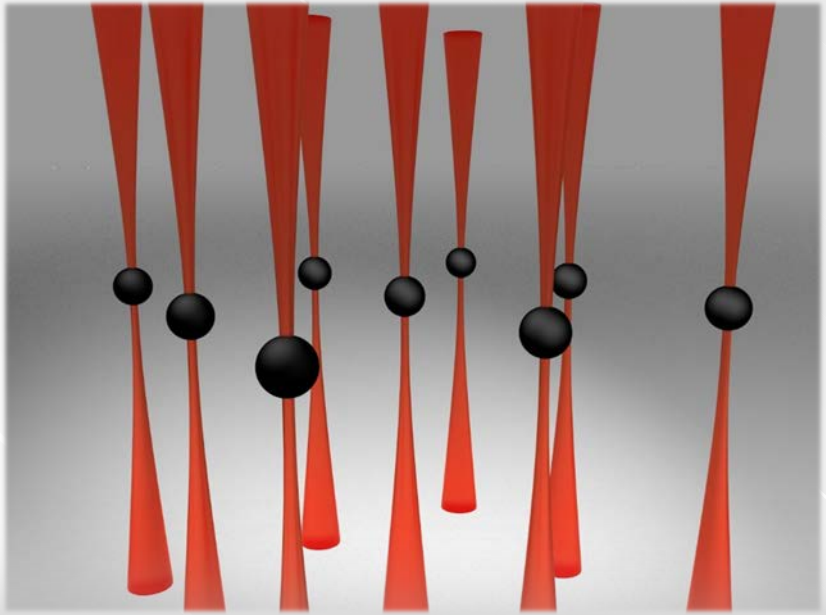
Quantum Brown Bag:
The Hamburg Quantum Computing initiative
& developping a quantum computer based on neutral atoms

Henning Moritz



GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

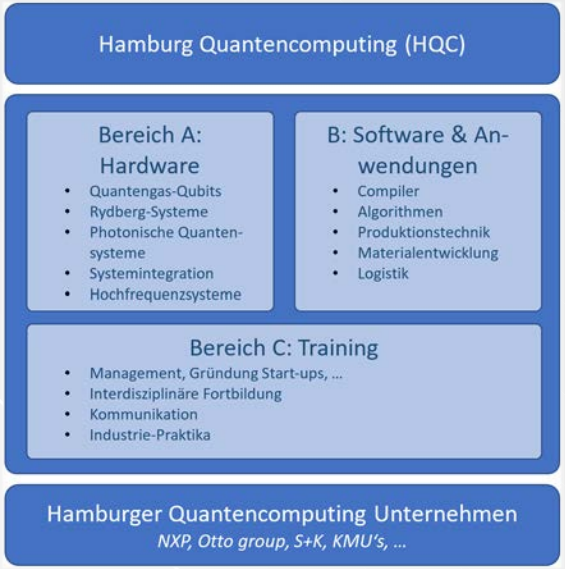
co-financed by the
EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)

Hamburg Quantum Computing (HQC) project

Funded by the European regional development fund (**ERDF**) with 7 Mio. €

And Hamburg‘s ministry of Science, Research, Equalities and Districts (**BWFGB**) with 10.5 Mio. €

Joint endeavor of the **University and the Technical University of Hamburg**



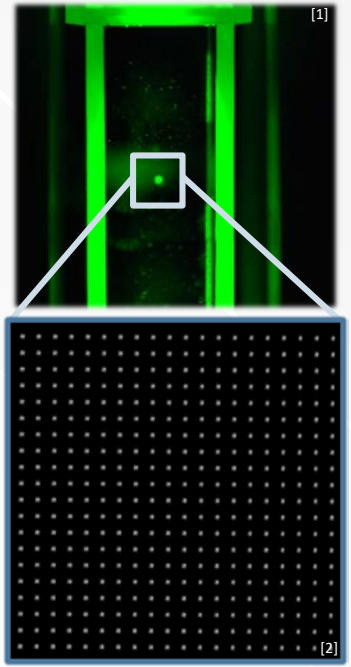
Goals:

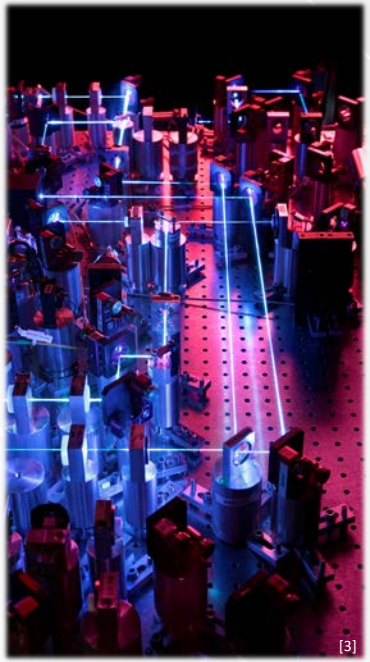
- Interdisciplinary **research** for the development and use of quantum computing, in the fields of
  - Quantum physics, microsystems & high frequency technology, computer science
- **Education** of next generation of quantum scientists
- To **strengthen Hamburg‘s quantum ecosystem**

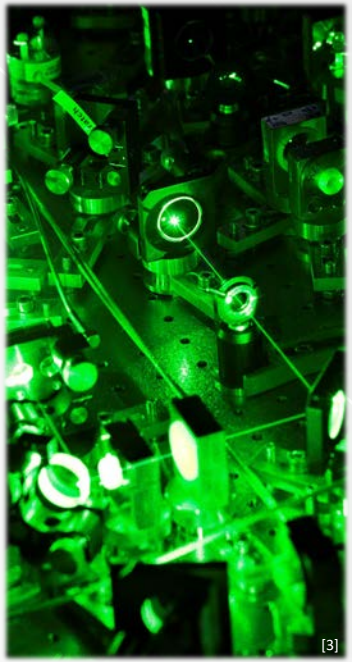
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

co-financed by the
EU (ERDF) and Hamburg‘s Ministry of Science, Research, Equalities and Districts (BWFGB)

Neutral-atom Quantum Computers


[1]
[2]


[3]


[3]

Advantages of neutral atoms

- Scalability
- Excellent level of control
- Natural qubit choice

highly-promising candidate for quantum advantage

Latest developments

- 4 BMBF funded projects, e.g. Rymax
- 5 hardware startups

PASQAL

planqc

atom computing

QuEra

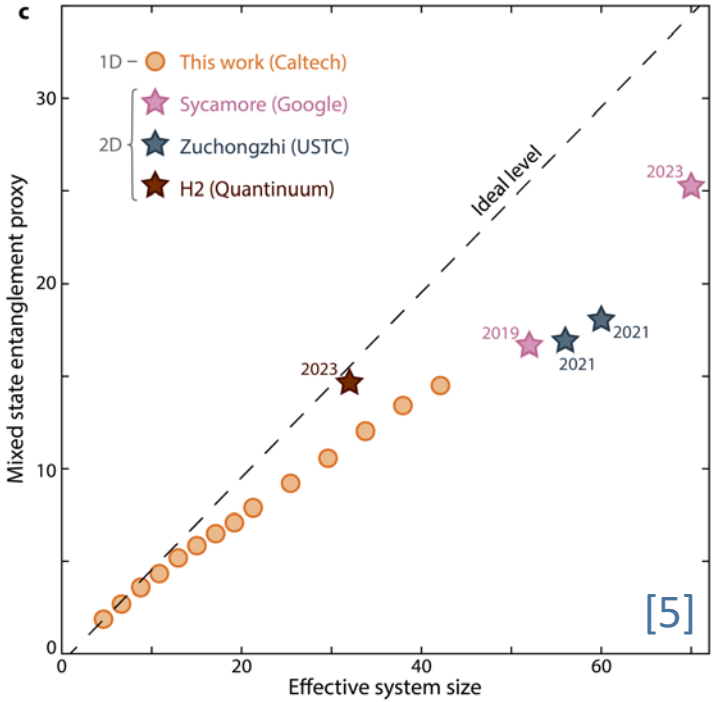
Infleqtion

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

[1] © UHH – S. Dörscher
[2] RPTU Kaiserslautern-Landau
[3] UHH, CUI, Peter Garten

co-financed by the
EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)

Recent advances in quantum computing in 2023



[5]

Neutral Atom QC

- reached the same gate fidelities as SC qubits and trapped ions
- State-of-the-art work still done in small academic groups

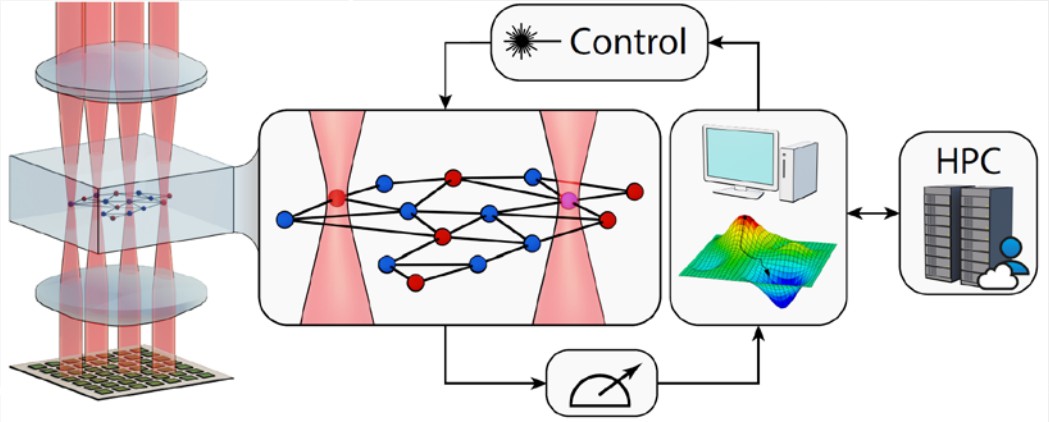
→ Highly-promising near-term QC platform

Bundesministerium für Bildung und Forschung

co-financed by the EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)

[1] Google Quantum AI, Nature **614**, 676–681 (2023)
[2] S. Moses et al., https://arxiv.org/pdf/2305.03828.pdf
[3] D. Bluvstein et al., Nature **604**, 451–456 (2022)
[4] S. Evered et al., https://arxiv.org/pdf/2304.05420.pdf
[5] A. Shaw et al., https://arxiv.org/pdf/2308.07914.pdf

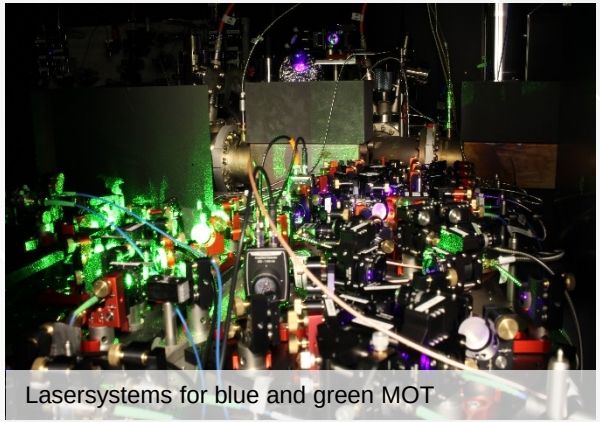
Overview



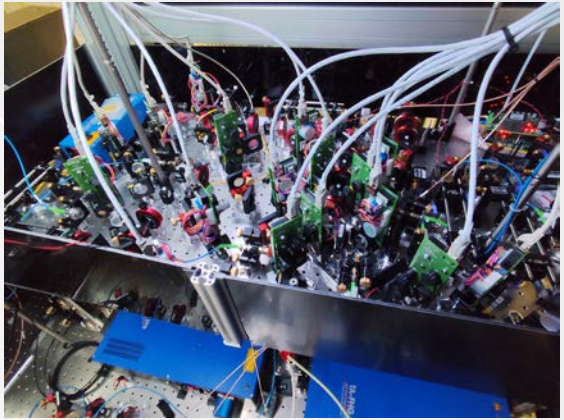
GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

co-financed by the
EU (ERDF) and Hamburg's
Ministry of Science, Research,
Equalities and Districts (BWFGB)

In the lab



Lasersystems for blue and green MOT



Hard work + many, many optical elements + colorful lasers + stainless steal + the almost absolute void with pressure < 1 x 10^{-11} mbar

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

co-financed by the
EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)

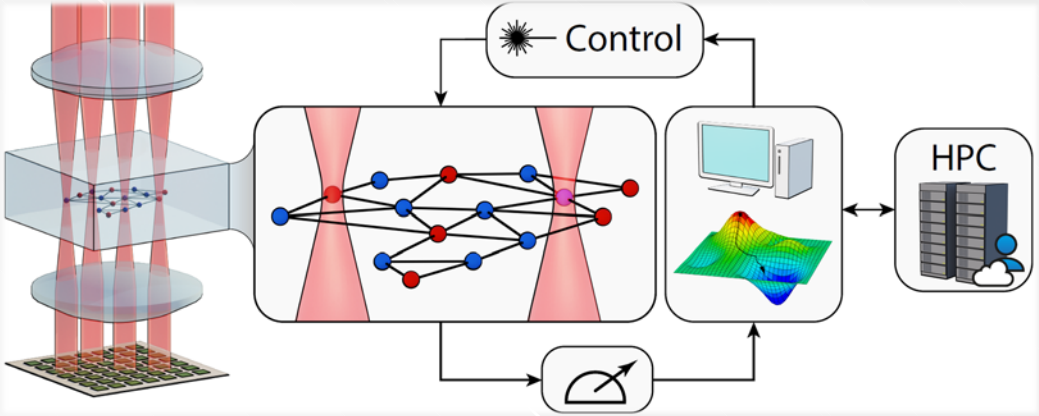
Steps to perform quantum computation

Load atoms into tweezers

Bring atoms to Rydberg states

Execute algorithm

Measure



GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

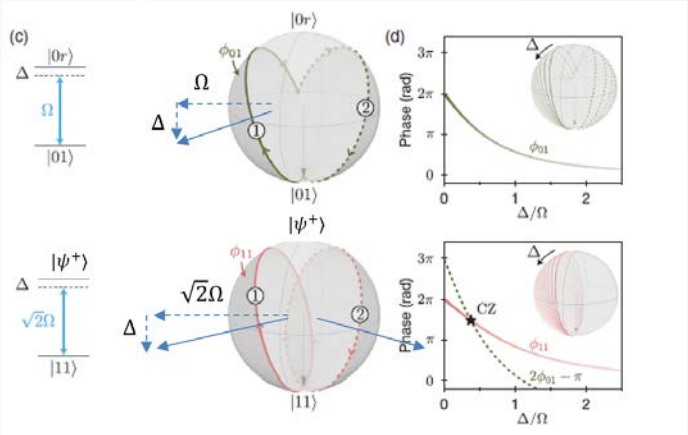
co-financed by the
EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)

Steps to perform quantum computation

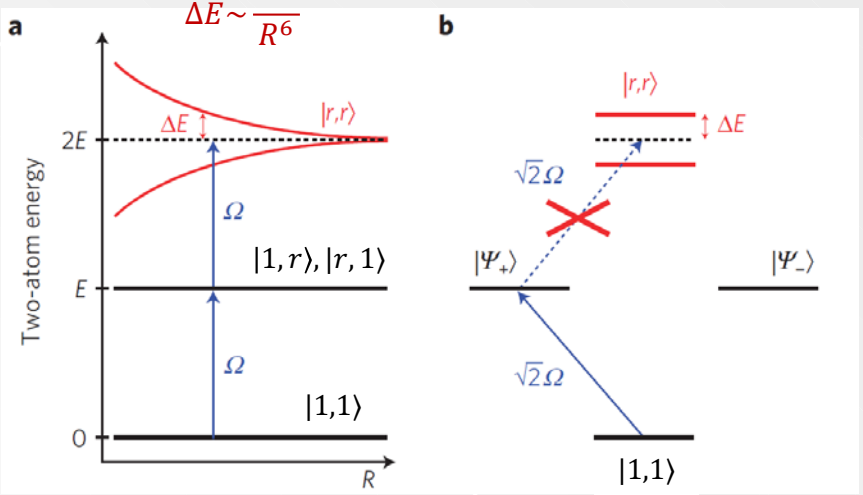
Atoms in Rydberg states
– large electronic cloud ⇒ large interaction between atoms
– Cannot excite both atoms simultaneously

$$\Delta E \sim \frac{n^{11}}{R^6}$$

Interaction gives conditionality for e.g. CNOT gates



[1] H. Levine PRL 123, 170503 (2019)



$$|\Psi_+\rangle = (|1,r\rangle + |r,1\rangle)/\sqrt{2}$$

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

co-financed by the
EU (ERDF) and Hamburg's Ministry of Science, Research, Equalities and Districts (BWFGB)