Trapping and Quantum Computing

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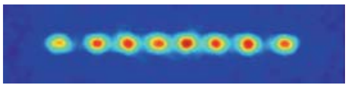
Important applications for our scientific laser systems are atom and ion trapping. Utilizing lasers, atoms and ions are trapped and cooled in ultra-high vacuum. In ion traps, the ions are held in predefined positions by the potential of alternating electromagnetic fields. Employing tunable lasers for "sideband cooling", the ions are slowed down to the lowest motional quantum state of the trap potential. If the ions can be transferred into a superposition of two electronic states, they might act as "qubits" in a quantum computer. Making use of both the Coulomb interaction between ions and control over their motional quantum states, these qubits can be entangled to perform all required quantum-logical operations. Trapped, cold ions have thus become a model system for future quantum computers.

Ion trap in ultra-high vacuum.



8 ions in a linear trap.

In this type of experiments, our lasers perform a variety of tasks such as cooling, repumping, photoionization, addressing and processing of qubits and their states. Reliability, narrow linewidths, tunability and sufficient power are key requirements for these lasers.

Recently, the group of Prof. Rainer Blatt at the University of Innsbruck was able to demonstrate the first qubyte — a system of 8 qubits. Strings of eight $^{40}Ca^{+}$ ions were trapped in a linear Paul trap. Superpositions of the $S_{1/2}$ ground state and the metastable $D_{5/2}$ state of the Ca^{+} ions represent the qubits. Each ion qubit in the linear string is individually addressed by a series of tightly focused laser pulses. Since the ions are separated by only 5 µm, they sense each other via their repulsive electrostatic interaction, permitting information transfer from ion to ion. After preparing an entangled state with a series of laser pulses, the quantum state is read out with a CCD camera using state selective fluorescence.

Four TOPTICA laser systems are used in this set-up.