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Next step to the quantum computer

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Physicists at the University of Bonn build quantum data memory

Physicists from the University of Bonn **have succeeded in taking a decisive step forward towards processing quantum information with neutral atoms**: in the latest issue of the 'Physical Review Letters' vol. 93 (2004) they describe how they managed to set up a quantum register experimentally. Their next aim is to construct a quantum gate in which two or more atoms interact with each other in a controlled way. By combining the register and gate there would then be all the basic components available for developing a quantum computer with neutral atoms.

Registers are the central memory of a computer. They consist of a series of elementary information cells which can each take one bit of information, i.e. a logical zero or one. In a register of eight bits' length, for example, a number between 0 and 255 can be stored – the 255 corresponds to a series of eight bits with the state of 1. In order to add two numbers three registers are normally required: two for the two addends and one more for the result.

'For our registers we use neutral atoms,' Dominik Schrader of the Bonn Institute of Applied Physics adds. An atom is a microscopic quantum system and can therefore store quantum information. In analogy with the 'bit' this is thus known as a 'qubit'. In addition to the classic information states of zero and one, qubits can also take up an arbitrary number of intermediate states, what are known as quantum mechanical superposition states.

Dominik Schrader has built the register together with Dr. Arno Rauschenbeutel in Professor Dieter Meschede's team. In their experiment the physicists first decelerated caesium atoms so that they were scarcely moving. Five of these 'cool' atoms were then loaded onto a laser beam, a stationary light wave consisting of many peaks and troughs – roughly comparable to a piece of corrugated cardboard. The atoms were 'trapped' inside the troughs and remained stationary, which the team was able to check with a highly sensitive digital camera.

With the aid of an additional laser the researchers then initialised the quantum register, i.e. they 'wrote' zeros on all the qubits. 'We were then able to store the quantum information desired in each qubit by using microwave radiation,' Dominik Schrader explains. So as to be able to manipulate the qubits individually and selectively, the physicists generated a localised magnetic field. 'Depending on the local strength of the magnetic field, the qubits only react to microwave radiation of a very specific frequency. By varying the microwave radiation we were thus able to write the qubits desired.' The resolution of this addressing technique is about two thousandths of a millimetre – over a length of one millimetre, therefore, several hundred qubits could be stored.

In order to check whether the register really had stored the information desired, the researchers bombarded the chain of atoms with laser light which only interacts with qubits in status 0. The laser photons shot these 0 atoms off the carrier beam, but left the 1 atoms unaffected. On the camera image only the atoms with a state of 1 were subsequently visible.

In their next step the physicists will now attempt to set up a quantum gate, in which two or more qubits of the register interact with each other in a controlled way. 'We hope to get there in two years,' Dominik Schrader says. 'Mind you, in a field like this you repeatedly come across difficulties which you would not previously have anticipated.' He is thus cagey in making a prediction about when a 'quantum computer' worthy of the name will begin to operate. However, it would probably have abilities which would make traditional computers look pretty puny – e.g. when factorising large numbers, where today's computers soon come up against their limitations.

Source: University of Bonn