World record: German supercomputer simulates quantum computer

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A quantum computer could provide an enormous improvement in the processing speed of existing computers. However, as yet they only exist in the laboratory in the form of small prototypes with a capacity of a few bits. They can now be explored in more detail, at least in simulations. The Jülich supercomputer JUGENE can now simulate the largest quantum computer system in the world with 42 bits.

"The computing power of a quantum computer grows exponentially with its size," says Prof. Dr. Kristel Michielsen from the Jülich Supercomputing Centre, Germany. "This is both an enormous opportunity for future applications and also a great challenge for simulations at the moment." If a quantum computer is expanded by just one single computer bit then its computing power is immediately doubled due to the laws of quantum mechanics on which it is based. The computing power of a classical computer only grows linearly with its components. Ten percent more transistors (in the ideal case) also only means ten percent more performance.

If you want to simulate a quantum computer using present computing power then you soon come up against limits. For a quantum computer with 42 computer bits you need machines like the Jülich supercomputer JUGENE, which is the fastest computer in Europe with almost 300,000 processors and a computing power of 10^{15} floating point operations per second. Shor's algorithm, a common test application for quantum computers, has been demonstrated on the 42-bit quantum computer, factorizing 15707 into 113x139. This is a number that is thousands of times larger than those factorized on quantum computers that have been experimentally realized in the past.

For the world record, the Jülich research team and the Computational Physics group of the University of Groningen in the Netherlands developed the simulation software to such a level that it can run efficiently on this large number of processors. "If so many processors have to work together then in the case of simple algorithms it can easily happen that processors are waiting for each other and thus performance is lost," says Michielsen. "Our software is optimized so that thousands of processors can work seamlessly together. It scales almost perfectly." Scaling is the term computer experts use to describe the property of software of converting more processors one-to-one into more power, that is to say faster results. Scalability will also play an increasingly important part in the multi-core processors of PCs.

On the basis of the simulation software that has now been developed, it will be possible to explore in detail the phenomena and dynamics of quantum-mechanical systems. Whereas today's laboratory prototypes have only reached a size of eight bits, simulation can be used to efficiently investigate the properties of larger systems. In particular, simulations make it possible to test the impact of external influences on the sensitive quantum system and to discover how to compensate for resulting errors, providing valuable findings for laboratory experiments.

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