Building 3-D atomic structures atom by atom using lasers

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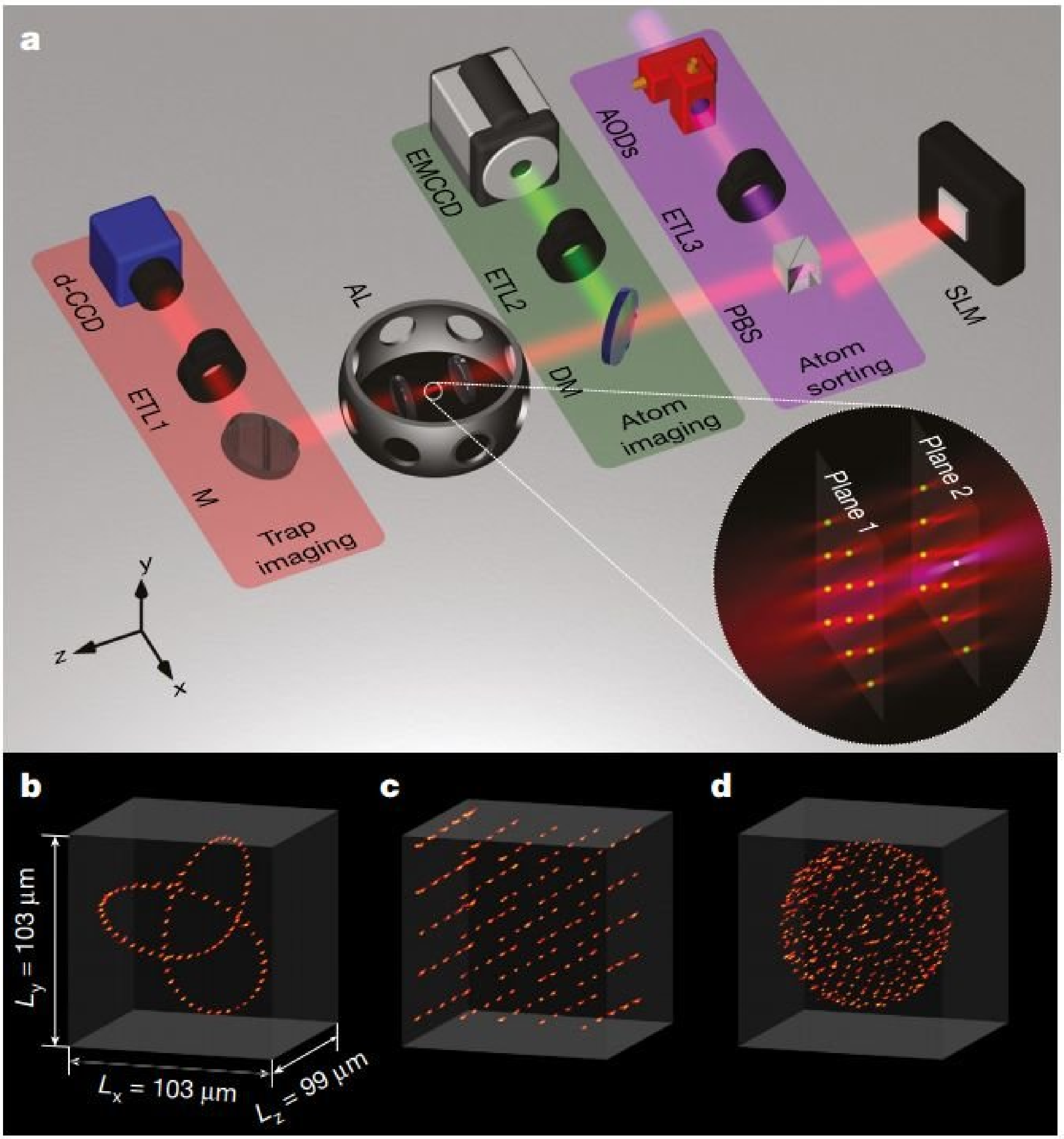

Experimental setup and trap images. Credit: *Nature* (2018). DOI: 10.1038/s41586-018-0450-2

A team of researchers at Centre National de la Recherche Scientifique (CNRS) in France has developed a technique for arranging cold atoms into useful 3-D arrayed structures. In their paper published in the journal *Nature*, the group describes their technique and the ways the structures could be useful.

As work toward the development of a functional quantum computer continues, groups of scientists have worked on technologies required for the development of such a machine. One such requirement is the development of atomic structures—if atoms are to serve as qubits, they must be arranged in precise and useful ways that allow for interactions between one another. Most envision such arrangements to consist of 3-D arrayed structures. In this new effort, the researchers report on a technique they have developed to build 3-D atomic structures in arrayed shapes likely to be needed for quantum computer applications.

The technique involves building microtraps using spatially modulated light. Such traps and other instruments use the energy in light to move single neutral atoms around in desired ways and then to hold them in place. To build a desired structure, the group moved a small mass of rubidium atoms into a trap that filled it up just halfway. Doing so situated the atoms in random spots inside the trap. They then activated deflectors that used both sound and light to serve as tweezers that they used to move the atoms in the trap in desired ways. After that, they used the tweezers to grab single atoms outside of the trap and placed them into desired spots inside the trap. The end result was a 3-D structure in a desired shape.

The researchers note that their technique allows for creating 3-D structures in a variety of shapes, all of which are precisely ordered. Notably, the results are free of defects because each atom is placed individually into the structure. To prove the effectiveness of their technique, the researchers bathed a structure they had built with light and studied the result with a CCD camera—it was able to highlight the fluorescence of the rubidium atoms showing their locations within the microtrap.

More information: Daniel Barredo et al. Synthetic three-dimensional atomic structures assembled atom by atom, *Nature* (2018). DOI: 10.1038/s41586-018-0450-2

Abstract
A great challenge in current quantum science and technology research is to realize artificial systems of a large number of individually controlled quantum bits for applications in quantum computing and quantum simulation. Many experimental platforms are being explored, including solid-state systems, such as superconducting circuits1 or quantum dots2, and atomic, molecular and optical systems, such as photons, trapped ions or neutral atoms3,4,5,6,7. The latter offer inherently identical qubits that are well decoupled from the environment and could provide synthetic structures scalable to hundreds of qubits or more8. Quantum-gas microscopes9 allow the realization of two-dimensional regular lattices of hundreds of atoms, and large, fully loaded arrays of about 50 microtraps (or 'optical tweezers') with individual control are already available in one10 and two11 dimensions. Ultimately, however, accessing the third dimension while keeping single-atom control will be required, both for scaling to large numbers and for extending the range of models amenable to quantum simulation. Here we report the assembly of defect-free, arbitrarily shaped three-dimensional arrays, containing up to 72 single

atoms. We use holographic methods and fast, programmable moving tweezers to arrange—atom by atom and plane by plane—initially disordered arrays into target structures of almost any geometry. These results present the prospect of quantum simulation with tens of qubits arbitrarily arranged in space and show that realizing systems of hundreds of individually controlled qubits is within reach using current technology.