Atom 'noise' may help design quantum computers

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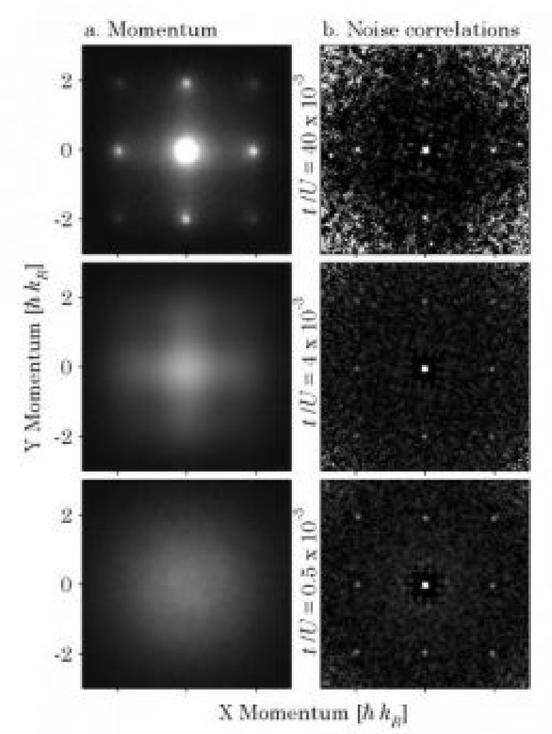

To make images of atom "noise," NIST physicists placed a Bose-Einstein condensate in an optical lattice made of intersecting laser beams, then turned the lattice off and imaged the expanding cloud of atoms. In the images on the left, lighter areas are the highest concentrations of atoms; darker areas are the lowest concentrations of atoms, dappled with noise. On the right are the processed noise images, revealing that the atoms are spaced evenly in the lattice. Credit: NIST

As if building a computer out of rubidium atoms and laser beams weren't difficult enough, scientists sometimes have to work as if blindfolded: The quirks of quantum physics can cause correlations between the atoms to fade from view at crucial times.

What to do? Focus on the noise patterns. Building on earlier work by other groups, physicists at the National Institute of Standards and Technology have found that images of "noise" in clouds of ultracold atoms trapped by lasers reveal hidden structural patterns, including spacing between atoms and cloud size.

The technique, described in the Feb. 23 issue of *Physical Review Letters*, was demonstrated in an experiment to partition about 170,000 atoms in an "optical lattice," produced by intersecting laser beams that are seen by the atoms as an array of energy wells arranged like an egg carton. By loading just one atom into each well, for example, scientists can create the initial state of a hypothetical quantum computer using neutral atoms to store and process information.

The atoms first are cooled to form a Bose-Einstein condensate (BEC), a unique form of matter in which all the atoms are in the same quantum state and completely indistinguishable. The optical lattice lasers then are slowly turned on and the BEC undergoes a transformation in which the atoms space out evenly in the lattice. More intense light creates deeper wells until each atom settles into its own lattice well. But during this transition, scientists lose their capability to see and measure key quantum correlations among the atoms.

Key structures are visible, however, in composite images of the noise patterns, which reveal not only atom spacing but also cloud size and how much of the BEC has undergone the transition.

In the NIST experiments, the BEC was placed in an optical lattice at various laser intensities. The lattice was turned off, and scientists took pictures of the expanding cloud of atoms after 20 to 30 milliseconds. To identify and enhance the noise signal, scientists looked for identical bumps and wiggles in the images and made composites of about 60 images by identifying and overlaying matching patterns. Lead author Ian Spielman likens the technique to listening to a noisy ballroom: While it may be impossible to hear specific conversations, correlations in noise can show where people (or atoms) are located in relation to each other, and the volume of noise can indicate the size of the ballroom (or atomic cloud), Spielman says.

Citation: I.B. Spielman, W.D. Phillips and J.V. Porto. 2007. The Mott insulator transition in a two dimensional atomic Bose gas. *Physical Review Letters*. Feb. 23.

Source: National Institute of Standards and Technology