Quantum computing advance locates neutral atoms

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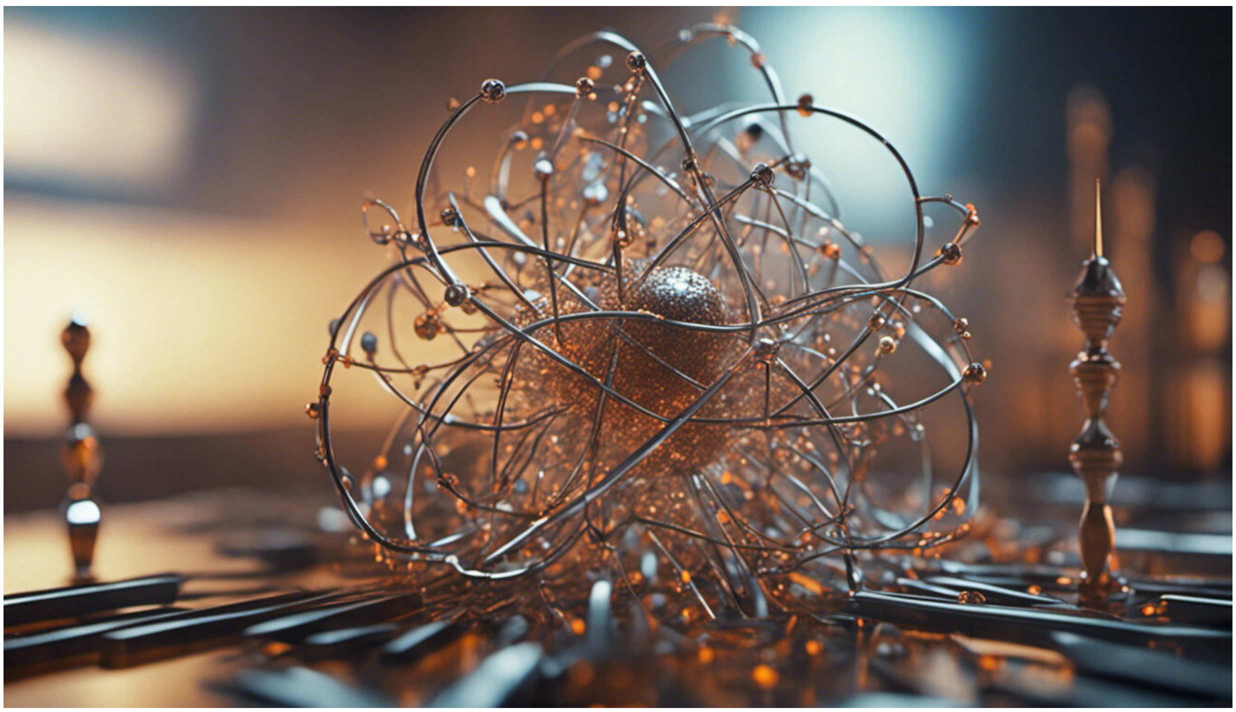

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For any computer, being able to manipulate information is essential, but for quantum computing, singling out one data location without influencing any of the surrounding locations is difficult. Now, a team of Penn State physicists has a method for addressing individual neutral atoms without changing surrounding atoms.

"There are a set of things that we have to have to do quantum computing," said David S. Weiss, professor of physics. "We are trying to step down that list and meet the various criteria. Addressability is one step."

Quantum computers are constructed and operate in completely different ways from the conventional digital computers used today. While conventional computers store information in bits, 1's and 0's, quantum computers store information in qubits. Because of a strange aspect of quantum mechanics called superposition, a qubit can be in both its 0 and 1 state at the same time. The methods of encoding information onto neutral atoms, ions or Josephson junctions—electronic devices used in precise measurement, to create quantum computers—are currently the subject of much research. Along with superposition, quantum computers will also take advantage of the quantum mechanical phenomena of entanglement, which can create a mutually dependent group of qubits that must be considered as a whole rather than individually.

"Quantum computers can solve some problems that classical computers can't," said Weiss. "But they are unlikely to replace your laptop."

According to the researchers, one area where quantum computers will be valuable is in factoring very large numbers created by multiplying prime numbers, an approach used in creating difficult-to-break security codes.

Weiss and his graduate students Yang Wang and Aishwarya Kumar, looked at using neutral atoms for quantum computing and investigated ways to individually locate and address an atom to store and retrieve information. They reported their results in a recent issue of *Physical Review Letters*.

The researchers first needed to use laser light to create a 3-dimensional lattice of traps for neutral cesium atoms with no more than one atom at each lattice site. Other researchers are investigating ions and superconducting Josephson junctions, but Weiss's team chose neutral atoms. Research groups at the University of Wisconsin, in France and elsewhere are also investigating neutral atoms for this purpose.

"We are studying neutral atom qubits because it is clear that you can have thousands in an apparatus," said Weiss. "They don't take up much space and they don't interact with each other unless we want them to."

However, Weiss notes that neutral atoms cannot be held in place as well as ions, because background atoms in the near vacuum occasionally knock them out of their traps.

Once the cesium atoms are in place, the researchers set them to their lowest quantum state by cooling them. They then shift the internal quantum states of the atoms using two perpendicular, circularly polarized addressing beams. Many atoms are shifted, but the targeted atom, which is where the beams cross, is shifted by about twice as much as any other atom. This allows them to then uss microwaves to change the qubit state of the target atom without affecting the states of any other atoms.

"One atom gate takes about half a millisecond," said Weiss. "It takes about 5 microseconds to retarget to another atom."

Currently, the researchers can only fill about 50 percent of the laser atom traps with atoms, but they can perform quantum gates on those atoms with 93 percent fidelity and cross talk that is too small to measure. The goal is 99.99 percent fidelity. With continued improvements the researchers think that this goal is in reach.

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