*** 北米連携センター情報***

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<u>●NIST、量子もつれ状態作るモジュールを開発</u>

【NIST, 2014/08/06】
米国標準技術局（NIST）の研究チームは、電気的相互作用の操作により電場トラップの別々のエリアにある 2 つのベリリウム・イオンをもつれ状態に置くことに初めて成功した。

「Nature」誌 8 月 7 日号掲載の論文で発表されたこのモジュールは柔軟な調整が可能な量子シミュレーターの一部として開発されたもの。電場トラップ技術を用いた高度な量子操作が強力な量子情報プロセッサに拡大できる可能性を秘めていることを実証している。

研究チームは、電場に個別のトラップゾーンを設けることで、イオン間の相互作用を微弱なものから強化しているが、これは複雑な量子マテリアルの動きをシミュレートする際に有効になると見られている。

研究チームはこのモジュールを数 10 個のイオンから構成される 2 次元ネットワークに拡大することで、従来のコンピュータでは極めて困難な現象のシミュレーションを行えるようになるとしており、また量子コンピュータへの応用も可能と考えられている。

（参考）本件報道資料
NIST Ion Duet Offers Tunable Module for Quantum Simulator
From NIST Tech Beat: August 6, 2014
Contact: Laura Ost
303-497-4880

Physicists at the National Institute of Standards and Technology (NIST) have demonstrated a pas de deux of atomic ions that combines the fine choreography of dance with precise individual control.
Andrew Wilson
Physicist Andrew Wilson in a NIST quantum information laboratory. NIST researchers have demonstrated fine control of two ions confined in separate zones of an electric-field trap, which is chilled to low temperatures in the silver chamber behind Wilson. The techniques will be useful in simulating complex quantum systems such as high-temperature superconductors.

Credit: Burrus/NIST
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NIST's ion duet, described in the August 7 issue of Nature,* is a component for a flexible quantum simulator that could be scaled up in size and configured to model quantum systems of a complexity that overwhelms traditional computer simulations. Beyond simulation, the duet might also be used to perform logic operations in future quantum computers, or as a quantum-enhanced precision measurement tool.

In the experiments, researchers coaxed two beryllium ions located in separate zones of an electric-field trap (a storage device) into an "entangled" state. An important resource for quantum technologies, entanglement involves an intimate connection between the particles such that a measurement of one ordains the state of the other. This is the first time ions in separate zones have been entangled by manipulating their electric interactions, an important feature that could be used in quantum simulation and computing.

The work demonstrates a high level of quantum control with microfabricated trap technology well suited to the scaling-up needed to make powerful quantum information processors. Having separate trapping zones enabled the research team to tune the ions' interactions from weak to strong—a feature expected to be useful for simulating the behavior of complex quantum materials.

"Even though the ions are confined apart from one another, we can now entangle them," NIST physicist Andrew Wilson says. "We plan to use this for quantum simulation and computing, but when I explain to my family what we're doing, the remote entanglement sounds kind of romantic."

"We focus on the idea that everything needs to be scalable," Wilson notes. "To do useful simulations we'll need versatile traps with more than two ions, and making traps using the same technology used to make computer chips gives us this capability. NIST pioneered this approach and we're fortunate to have great facilities for doing this sort of work."

Inducing the ions to perform a number of intricate quantum dances, the researchers first coaxed the ions to exchange a single quantum of vibrational energy (the smallest amount that nature allows). They then used lasers and microwaves to entangle the ions' "spins." Analogous to tiny bar magnets, the spins of the entangled ions pointed in the same direction, but were also in a "superposition" of pointing in the opposite direction at the same time. Superposition is another strange but useful feature of the quantum world.

The researchers say that extending the new module to make a two-dimensional network of a few tens of ions would be enough to perform useful simulations of phenomena that are extremely difficult to model even on the most powerful traditional computers. An example is the high-temperature superconductitivity—electron flow without resistance—observed in certain ceramics. Despite more than 20 years of study, the underlying mechanism remains a mystery. A quantum simulator might provide deeper insights.

The ion duet also could be used to perform logic operations in quantum computers, which would have a wider range of applications than quantum simulators. And NIST researchers also envision the ion duet as a sensor, in which one well-controlled ion is used to investigate a second ion with interesting features. For instance, a beryllium ion might be used to probe a charged anti-matter particle in another trap zone, Wilson says.

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*A.C. Wilson, Y. Colombe, K.R. Brown, E. Knill, D. Leibfried and D.J. Wineland. Entangling spin-spin interactions of ions in individually controlled potential wells. Nature. August 7. DOI 10.1038/nature13565.

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