Ion trap quantum computing

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(PhysOrg.com) -- “Right now, classical computers are faster than quantum computers,” René Stock tells *PhysOrg.com*. “The goal of quantum computing is to eventually speed up the time scale of solving certain important problems, such as factoring and data search, so that quantum computing can not only compete with, but far outperform, classical computing on large scale problems. One of the most promising ways to possibly do this is with ion traps.”

Stock, a post-doc at the University of Toronto, points out that ion trap quantum computing has made a lot of progress in the last 10 years. “Ions in traps have been one of most successful physical implementation of quantum computing in physical systems.” Stock believes that it is possible to use ion-trap quantum computing to create measurement-based quantum computers that could compete with classical computers for very large and complex problems - and even on smaller scale problems. His work on the subject, done with Daniel James, appears in *Physical Review Letters*: “Scalable, High-Speed Measurement-Based Quantum Computer Using Trapped Ions.”

“One of the most important considerations in quantum computing is the fact that quantum computing scales polynomially, rather than exponentially, as classical computing does.” This polynomial scaling is what makes quantum computing so useful for breaking data encryption. In order to make data encryption more secure, one usually increases the number of bits used. “Because of the exponential scaling, breaking data encryptions quickly becomes impossible using standard classical computers or even networks of computers,” Stock explains. “The improved scaling with quantum computers could be one a biggest threads to data encryption and security."

While this sounds promising, Stock points this out that there are still problems with quantum information processing: "While scaling would be better with quantum computing, current operation of quantum information processing is too slow to even compete with classical computers on large factoring problems that take 5 months to solve."

The way ion-trap quantum computing works now - or at least is envisioned to work - requires that ions be shuttled back and forth around the trap architecture. Stock explains that this takes time. "As the complexity of problems and the size of the quantum computing to be implemented increases, the time issue becomes even more important. We wanted to figure out how we could change the time scale," Stock explains. "We found that we could speed up the processing by using an array of trapped ions and by parallelizing entangling operations."

"Instead of moving ions around," Stock continues, "you apply a two-ion operation between all neighboring ions at the same time. The created multipartite 'entangled' array of ions is a resource for quantum computing." Actual computing is then based on measurement of ions in the array in a prescribed order and using a slightly different measurement basis for each ion. "In this scheme, it is the time required to read out information from the ions that critically determines the operational time scale of the quantum computer," Stock says.

Stock describes the measurement component as vital to this model of quantum computing. Instead of exciting the ions and getting them to emit a photon and measuring the photon, Stock and his colleague instead devised a different way in which they were able to measure the quantum bit encoded in a calcium ion. "You can use an ionization process to speed up measurement, since the electron can be extracted faster from the atom than you can get a photon out of an atom. The extracted electron is then guided onto a detector by the ion trap itself." All of this takes place on a nanosecond time scale. "By speeding up the measurement," Stock insists, "we can speed up the operation capability of the quantum computer."

Stock points out that this quantum computing scheme would be impractical as far as taking over common use from classical computers. "The lattice would have thousands of ions, which would need to be controlled, and carefully stored and protected. It means that the computer would be relatively large and impractical."

Uses for such a quantum computer are not limited to breaking data encryption. "This process would allow us to take problems of great complexity and still solve them on a humanly possible timescale. This could provide the key to modeling complex systems - especially perhaps in biology - that we can't solve now. This would be a tremendous advantage over classical computing."

More information: Stock, René and James, Daniel. "Scalable, High-Speed Measurement-Based Quantum Computer Using Trapped Ions." *Physical Review Letters* (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.170501 .