Trapped ions and quantum computing

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"Quantum computing looks very promising," says Christopher Monroe, a professor at the University of Michigan. "But there are some big problems. One of those is that you have all this potential memory, but you can't look at it. It's tricky to get it out. You have to do things in a clever way and make sure that the information is not lost." Monroe and a team of students at the University of Michigan led by Louis Deslauriers just might have found one way to better isolate quantum information in a quantum. It involves cold electrodes and almost completely stationary atoms.

"Ion traps are widely regarded as the leading candidate for quantum computing," Monroe tells *PhysOrg.com*. "But we are at a bit of crossroads right now. Nearly all of the simple things have been done. We're poised to make the next step from three or four bits to a few hundred bits." And to do that, Monroe explains, it is important to understand how to suppress some of the background noise that comes with keeping ions in a trap. And one of these possible solutions is explained in "Scaling and Suppression of Anomalous Heating in Ion Traps," published September 8th on *Physical Review Letters*.

Monroe says that electrodes are needed for the ion traps. But these electrodes make electrical noise that causes problems with getting the desired information from quantum processing. "Our paper," he explains, "offers a sophisticated way to detect the noise. And we are able to move the electrodes around, and make them bigger and smaller, to get into the character of the noise." Monroe admits that he doesn't understand what, exactly, the noise is, or where it comes from. But his team now has a clue. At the suggestion of Deslauriers, the team has managed to discover, experimentally, that the noise reduces dramatically when the temperature of the electrodes is reduced. The Letter describes what happens when the electrode temperature is lowered from 300 K to 150 K. “The noise reduction is very significant,” says Monroe. “If we could get it to 4 K…” He trails off.

While quantum computing is only useful for a few known algorithms at this point, Monroe thinks that science can move beyond that. “Our understanding of the behavior of quantum systems as they get larger is murky, at best. Quantum information science is not just about computing, but also about understanding some very weird laws of nature. At the same time, people are excited about quantum information processing because it’s a radically different model of computing,” he says. “We’re finding that younger researchers and students are especially attracted to this field, coming from many disciplines in science and engineering.”

Monroe’s team isolates the individual trapped atoms in a vacuum chamber, and levitates them with electric fields produced from electrodes within 1/10 of a millimeter of the atoms. Sophisticated lasers are used to manipulate and probe the atoms. “Mostly, we use lasers to push the atoms around, and keep them cold and controlled. But it is clear that in order to add lots more atoms, we will also have to make the electrodes even smaller and more complex. And our paper shows that if we can cool them, the noise level goes down.” Monroe pauses before continuing. “This implies that even though the electrodes are miles away – atomically speaking – there is still a thermal connection to the atoms.”

But right now there are problems with continuing the thermal work. “To get it down as far as we’d like, we’d need liquid helium to cool the electrodes. And a lot more time. And money.” Plus, using helium and working with such low temperatures adds new challenges. “We may not be able to do it now," says Monroe, "but we expect to do it in the future." Monroe tells *PhysOrg.com* that several groups are taking notice of this work. "We hope to be able to help characterize systems and guide the development of quantum information processors," he says. "Our work points to a way out, really, and it is just a matter of time and money."

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