Working out a timescale for quantum operations

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One of the issues affecting quantum systems is coherence. Understanding coherence and how it breaks down (decoherence) is one of the keys to putting together a powerful quantum computer. And, because wires made from metal are likely to be involved, it is not surprising that some scientists are interested in finding out how decoherence comes about in metallic quantum systems. A recent experiment done with mesoscopic wires may shed light on the question of quantum coherence in metallic systems.

A team led by Chris Bäuerle and Laurent Saminadayar, scientists associated with the Institut Neél and Université Joseph Fourier in France, worked in collaboration with scientists from the Laboratoire de Photonique et Nanostructures in France, as well as the Ruhr-Universität Bochum in Germany to measure electronic phase coherence time in wires produced from a metallic two-dimensional electron gas. The results are presented in *Physical Review Letters*: “Effect of Disorder on the Quantum Coherence in Mesoscopic Wires.”

For the most part, theories of electron coherence in metals revolve around temperature dependence. However, investigating only the effects of temperature dependence has proved insufficient. Bäuerle and his colleagues decided to look for another parameter to test. “Instead of looking at temperature dependence,” he tells PhysOrg.com, “we decided to look at the effect disorder has on the coherence of the system. We modify the diffusion coefficient.”

Bäuerle and his peers created wires with a diameter of approximately 1/25 of a hair and added ions to them, creating obstacles. “Without obstacles, electrons could go through without any change in trajectory and remain coherent. If you add obstacles, however, the electrons will diffuse through the system with a certain degree of randomness.”

As one might expect, though, the number of obstacles placed in the system contributes to how quickly the information moving through the system decoheres. “The more obstacles we add, the faster the decoherence,” Bäuerle explains. “The way electrons diffuse through the system agreed with theory when many obstacles were present.”

When the number of obstacles is decreased, the measurements Bäuerle and his colleagues took from the experiment revealed some surprises. The team was trying to establish a timescale for quantum operations by modifying the intrinsic disorder until the timescale brakes down to something basically useless. “There is a fundamental limit that we don’t understand,” Bäuerle says. “There was a stronger decrease than we expected when only very few obstacles are present.” He believes that understanding the workings of quantum coherence are important if a workable quantum information processor is to be achieved.

The next step in trying to understand quantum coherence is to add magnetic obstacles to the system. “Right now,” Bäuerle explains, “we are just using normal ions. In future we would like to make a little quantum dot and insert a little magnet inside and see what happens. However, this is technically very difficult. I think it’s possible, though, but it will take a bit of time to realize.”

Until then, Bäuerle and his peers will have to content themselves with working to understand the implications of their current experiment. When added to work with temperature dependence, the parameter of disorder may help answer a few more questions.

More information: Y. Niimi, et. al. “Effect of Disorder on the Quantum Coherence in Mesoscopic Wires.” *Physical Review Letters* (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.226801 .

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