Indium arsenide may provide clues to quantum information processing

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"We're not saying we've built a quantum computer," Andreas Fuhrer tells PhysOrg.com, "but this is an important first step towards spin manipulation via the spin-orbit interaction."

Fuhrer, a scientist with the Department of Solid State Physics/Nanometer Consortium at Lund University in Sweden, points out that one way quantum information processing might come about is through the manipulation of spin states.

Fuhrer and his colleagues have directly measured spin-orbit interaction strength in a two-electron molecule along a nanowire made of indium arsenide (InAs). With the first example of tunable few-electron quantum dots in a material with strong spin-orbit interaction, they believe that spin-orbit based spin manipulation is a step closer to becoming reality.

Fuhrer worked with Fasth and Samuelson, also associated with the Solid State Physics/Nanometer Consortium, and with Golovach and Loss from the University of Basel in Switzerland to understand the spin-orbit interaction of electrons in quantum dots along a nanowire. Their findings are published in a piece in *Physical Review Letters* titled, "Direct Measurement of the Spin-Orbit Interaction in a Two-Electron InAs Nanowire Quantum Dot."

"This is the first time tunable quantum dots with a single electron have been realized in indium arsenide nanowires," Fuhrer explains via email. "While other material systems often require complex gate arrangements to confine the electrons in artificial atoms, the nanowire basically has the confinement in two directions built in due to its nanoscale crosssection."

The scheme set up by Fuhrer and his colleagues works fairly simply. Indium arsenide nanowires self-assemble during crystal growth into rods. "It's not a bulk semiconductor like some other materials used for this purpose," Fuhrer points out over the phone. "It is a really thin wire that is an ideal starting point for making quantum dots. You can induce as many of these artificial atoms along the nanowire as you like and couple them to each other."

In addition, the spin-orbit interaction might allow the spin states of quantum dots to be manipulated merely by applying pulses to the gates that confine the electrons. "Usually six gates, or sometimes more, need to be used." In the paper, Fuhrer and his coauthors use four gates, but they have data to show that it would work with two gates per quantum dot.

Additionally, most efforts to manipulate spin make use of conventional electron spin resonance, a technique that can be difficult to bring close to each individual quantum dot. "We expect that with our scheme it will be enough to pulse the gate." Fuhrer then goes on to expound in greater detail through email: "When the gate is pulsed, you jerk the electron to one side along the nanowire, and by the movement of the orbital part of the electron wavefunction, also rotate the spin because of the spin-orbit coupling. This promises to be faster and easier than existing spin-manipulation techniques if we can demonstrate that spin states live long enough for computations to be feasible."

The main problem with this setup, Fuhrer admits, is that quantum information can be lost through decoherence. Typically, the idea is to decouple the spin from everything, including orbital motion, in order to avoid destroying the quantum calculations. "We're hoping, though, that by strongly confining the electrons and by keeping track of the orbital energy levels, we can get around this."

Fuhrer says that realizing few-electron quantum dots in InAs is an important first step. "The next step is to measure the spin lifetimes and manipulate the spins." He points out that within the next five to ten years efforts will be made to use such a setup for quantum information processing. "We still need to study this alternate option of spin state control. It could offer the possibility of manipulating qubits more easily."