# Researchers develop optical technique for controlling electron spins in quantum dot ensembles

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Scientists are closer to developing novel devices for optics-based quantum computing and quantum information processing, as a result of a breakthrough in understanding how to make all the spins in an ensemble of quantum dots identical.

This understanding, based upon a new optical technique and announced recently by researchers at the Naval Research Laboratory (NRL), the University of Dortmund, and the University of Bochum, is an important step toward realization of such quantum devices based on solid-state technology. The complete findings of the study are published in the September 28, 2007, issue of the journal *Science*.

An electron spin localized in a quantum dot is the quantum bit, which is the basic unit for solid-state based quantum computing and quantum information processing. The spin replaces a classical digital bit, which can take on two values, usually labeled 0 and 1. The electron spin can also take on two values.

However, since it is a quantum object, it can also take all values in between. Obviously, such a quantum unit can hold much more information than a classical one and, even more importantly the use of such quantum bits makes certain computer calculations exponentially more efficient than those using a standard computer. That is why, scientists around the world are trying to find an efficient way to control and manipulate the electron spin in a quantum dot in order to enable new quantum devises using magnetic and electric fields.

Until now, the major problem with using charged quantum dots in such devices is that the electron spins in different quantum dots are never identical. The electron spin precession frequencies in an external magnetic field are different from each other due to small variations of the quantum dot shape and size. In addition, the electron spin precession frequency has a contribution of a random hyperfine field of the nuclear spins in the quantum dot volume. This makes a coherent control and manipulation of electron spins in an ensemble of quantum dots impossible and pushes researchers to work with individual spins and to develop single spin manipulation techniques, which are much more complicated than an ensemble manipulation technique.

The team of researchers at the University of Dortmund, NRL and the University of Bochum has taken a significant step toward solving this problem by suggesting a new technique that would allow coherent manipulations of an ensemble of electron spins. Last year in a Science publication (Science, vol. 313, 341 (2006)), the same research team demonstrated a method, whereby a tailored periodic illumination with a pulsed laser can drive a large fraction of electron spins (up to 30%) in an ensemble of quantum dots into a synchronized motion.

In the new *Science* publication, the team shows that almost the whole ensemble of electron spins (90%) precesses coherently under periodic resonant excitation. It turns out that the nuclear contribution to the electron spin precession acts constructively by focusing the electron spin precession in different quantum dots to a few precession modes controlled by the laser excitation protocol, instead of acting as a random perturbation of electron spins, as it was thought previously. The modification of the laser protocol should allow scientists to reach a situation in which all electron spins have the same precession frequency, in other words to make all spins identical.

Future efforts involving the use of these identical electron spins will focus on demonstrating all coherent single q-bit operations using an ensemble of charged quantum dots. Another important use of such ensembles for quantum computing will be the demonstration of a quantum-dot gate operation. The macroscopic coherent precession of the electron spin ensemble will allow scientists to study several optical coherent phenomena, such as electromagnetically induced transparency and slow light, for example.

Source: Naval Research Laboratory

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