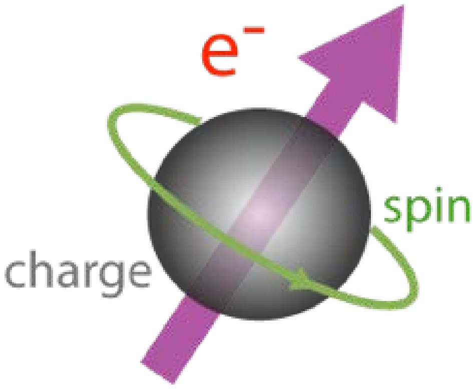
PRESS RELEASE – 19 DECEMBER 2013

Researchers in the Condensed Matter Physics Laboratory (École polytechnique / CNRS) have revealed a new spin filter effect in semiconductors

Today's microelectronic devices exploit the possibility to manipulate electrons with electric fields because they are charged particles. In semiconductors like Silicon it is possible using this method to reversibly transform the material from a good electrical conductor to an insulator. This type of charge switch, known as a transistor, is the basis for binary logic operations on data which is usually stored in the form of magnetic bits – called spins – on a hard drive. Electrons in semiconductors however, also have a spin which takes one of two values, "up" or "down", but this intrinsic property is not currently used for logic operations. Devices that exploit the electron's spin have been proposed in order to unify the manipulation and storage of data in one compact, integrated device that in principle has speed and efficiency advantages. For the moment though, efforts in "semiconductor spintronics" are mainly focused on understanding the ways in which the electron's spin can be manipulated and transported in semiconductors.

It is in this context that Fabian Cadiz, Alistair Rowe and Daniel Paget of the condensed matter physics laboratory (École polytechnique/CNRS) have shown in an article published in the 13th December issue of *Physical Review Letters*[1] **that a fundamental law of quantum mechanics – the Pauli Principle – results in a novel effect during the transport of spin polarized electrons in semiconductors in which the spin polarization of electrons increases over time and during transport.** This result is counter-intuitive in semiconductors which are nonmagnetic since the spin polarization usually decreases over time. In its presence, spin information can be transported over longer distances than would otherwise be the case and it will need to be accounted for in the design of a large number of proposed semiconductor spintronic devices.

[1] F. Cadiz, D. Paget & A.C.H. Rowe, Physical Review Letters vol. 111, 246601 (2013)



Electrons have both a charge and a spin. Today, only the charge is exploited in microelectronic devices. Plans to utilize the spin require a fundamental knowledge of the spin dynamics in semiconductors.

In their experiment, Cadiz, Paget and Rowe inject spin polarized electrons optically into a thin film of p-type GaAs using an optical microscope. In this process, known as optical pumping, the excitation laser is circularly polarized so that the rotational motion of the photons is transferred to the electrons' spin. The spin polarization is nonzero because, for example, there are more spin "up" electrons than spin "down" electrons. Since the laser is very tightly focused, the result is a spin polarized population of electrons in the laser spot, which subsequently diffuse outwards. During this outwards diffusion in the "normal" case, the electrons progressively lose their spin polarization so that at very large distances from the laser spot it is zero. The research team observed this behavior when the excitation laser power is small, that is to say, when the density of spin "up" and spin "down" electrons are small compared to a critical density known as the effective density of states.

By increasing the laser power, the spin densities can be increased so that they become comparable to the critical value. Near and above the critical density**, the quantum mechanical properties of the electrons are no longer negligible and they can no longer be treated as classical "billiard balls".** A fundamental consequence of the quantum nature of electrons is **that two such electrons of the same spin cannot be in the same quantum state at the same time – this is the Pauli principle.** At these densities therefore, scattering is reduced (and diffusion enhanced) because the probability of final state occupation is high. The key point is that **diffusion is enhanced to a greater extent for the majority spin "up" electrons than for the minority spin "down" electrons because there are more of them**. Spin "up" electrons therefore diffuse further than spin "down" electrons and the **spin polarization can actually *increase* during transport**. The researchers describe this spin filter effect very well with no adjustable parameters using coupled charge and spin diffusion equations. **These equations predict a number of other novel behaviors** which the researchers are now exploring in electrically contacted devices that resemble more closely a number of proposed spintronic devices.

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