It's all in the spin: Quantum physics cools down computers

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The future of Moore's famous law—that the number of transistors squeezed onto a computer chip can be doubled about every two years—is widely seen as threatened by the damaging heat generated by the chips themselves as their transistors become more densely packed.

But a new theory of circuit design from Stanford researchers, recently confirmed by experiments in Germany, exploits the celebrated quirkiness of quantum physics to drastically reduce the heat produced by electricity coursing through the tiny veins of semiconductors.

Stanford physics Professor Shoucheng Zhang says a new generation of semiconductors, designed around the phenomenon known as the Quantum Spin Hall Effect, could keep Moore's law in force for decades to come.

Beyond semiconductors, the theoretical aspect of the effect is intriguing on its own, Zhang said. He and a team at the University of Würzburg published their results Friday, Sept. 21, in *Science Express*, an online version of *Science* magazine.

Using special semiconductor material made from layers of mercury telluride and cadmium telluride, the experimenters employed quantum tricks to align the spin of electrons like a parade of tops spinning together. Under these extraordinary conditions, the current flows only along the edges of the sheet of semiconductor.

Interestingly, electrons with identical spins travel in the same direction together, while electrons with the opposite spin move in the opposite direction. Unlike existing semiconductors, this unusual electric current does not generate destructive heat through dissipation of power or the collision of electrons with impurities in the semiconducting material.

The electrons' strange behavior constitutes a new state of matter, Zhang said, joining the three states familiar to high school science students—solids, liquids, gases—as well as more unworldly states such as superconductors, where electrons flow with no resistance. He describes the quest for new states of matter as the holy grail of condensed matter physics.

Similar effects have been demonstrated before, but only at extremely cold temperatures and under the effects of powerful magnetic fields—conditions that cannot exist inside the common computer. "What we managed to do is basically get rid of the magnetic field," Zhang said.

There are other candidates for the next generation of computer chips, including nanotube technology. But Zhang believes that Quantum Spin Hall Effect chips might have the advantage because they can be made from materials already familiar to chip makers. In the long run, so-called "spintronics" could see the spin of electrons becoming more important than their electrical charge: Semiconductors would operate on the basis of spin alone, without electrons moving in their usual form of electrical current.

Zhang's theoretical work was aided by graduate student Taylor Hughes and former graduate student Andrei Bernevig. The U.S. Department of Energy and National Science Foundation funded their work.

Source: Stanford University