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Quantum dot transistor simulates functions of neurons

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A transistor that simulates some of the functions of neurons has been invented based on experiments and models developed by researchers at the Federal University of São Carlos (UFSCar) in São Paulo State, Brazil, Würzburg University in Germany, and the University of South Carolina in the United States.

The device, which has micrometric as well as nanometric parts, can see light, count, and store information in its own structure, dispensing with the need for a complementary memory unit.

It is described in the article "Nanoscale tipping bucket effect in a quantum dot transistor-based counter", published in the journal *Nano Letters*.

"In this article, we show that transistors based on quantum dots can perform complex operations directly in memory. This can lead to the development of new kinds of device and computer circuit in which memory units are combined with logical processing units, economizing space, time, and power consumption," said Victor Lopez Richard, a professor in UFSCar's Physics Department and one of the coordinators of the study.

The transistor was produced by a technique called epitaxial growth, which consists of coating a crystal substrate with thin film. On this microscopic substrate, nanoscopic droplets of indium arsenide act as quantum dots, confining electrons in quantized states. Memory functionality is derived from the dynamics of electrical charging and discharging of the quantum dots, creating current patterns with periodicities that are modulated by the voltage applied to the transistor's gates or the light absorbed by the quantum dots.

"The key feature of our device is its intrinsic memory stored as an electric charge inside the quantum dots," Richard said. "The challenge is to control the dynamics of these charges so that the transistor can manifest different states. Its functionality consists of the ability to count, memorize, and perform the simple arithmetic operations normally done by calculators, but using incomparably less space, time, and power."

According to Richard, the transistor is not likely to be used in quantum computing because this requires other quantum effects. However, it could lead to the development of a platform for use in equipment such as counters or calculators, with memory intrinsically linked to the transistor itself and all functions available in the same system at the nanometric scale, with no need for a separate space for storage.

"Moreover, you could say the transistor can see light because quantum dots are sensitive to photons," Richard said, "and just like electric voltage, the dynamics of the charging and discharging of quantum dots can be controlled via the absorption of photons, simulating synaptic responses and some functions of neurons."

Further research will be necessary before the transistor can be used as a technological resource. For now, it works only at extremely low temperatures - approximately 4 Kelvin, the temperature of liquid helium.

"Our goal is to make it functional at higher temperatures and even at room temperature. To do that, we'll have to find a way to separate the electronic spaces of the system sufficiently to prevent them from being affected by temperature. We need more refined control of synthesis and material growth techniques in order to fine-tune the charging and discharging channels. And the states stored in the quantum dots have to be quantized," Richard said.

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