The impending revolution of low-power quantum computers

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By 2017, quantum physics will help reduce the energy consumption of our computers and cellular phones by up to a factor of 100. For research and industry, the power consumption of transistors is a key issue. The next revolution will likely come from tunnel-FET, a technology that takes advantage of a phenomenon referred to as "quantum tunneling."

At the EPFL, but also in the laboratories of IBM Zurich and the CEA-Leti in France, research is well underway. As part of a special issue of *Nature* devoted to silicon, Adrian Ionescu, an EPFL researcher, has written an article on the topic.

Today's computers have no less than a billion transistors in the CPU alone. These small switches that turn on and off provide the famous binary instructions, the 0s and 1s that let us send emails, watch videos,

move the mouse pointer… and much more. The technology used in today's transistors is called "field effect;" whereby voltage induces an electron channel that activates the transistor. But field effect technology is approaching its limits, particularly in terms of power consumption.

Tunnel-FET technology is based on a fundamentally different principle. In the transistor, two chambers are separated by an energy barrier. In the first, a horde of electrons awaits while the transistor is deactivated. When voltage is applied, they cross the energy barrier and move into the second chamber, activating the transistor in so doing.

In the past, the tunnel effect was known to disrupt the operation of transistors. According to quantum theory, some electrons cross the barrier, even if they apparently don't have enough energy to do so. By reducing the width of this barrier, it becomes possible to amplify and take advantage of the quantum effect – the energy needed for the electrons to cross the barrier is drastically reduced, as is power consumption in standby mode.

"By replacing the principle of the conventional field effect transistor by the tunnel effect, one can reduce the voltage of transistors from 1 volt to 0.2 volts," explains Ionescu. In practical terms, this decrease in electrical tension will reduce power consumption by up to a factor of 100. The new generation microchips will combine conventional and tunnel-FET technology. "The current prototypes by IBM and the CEA-Leti have been developed in a pre-industrial setting. We can reasonably expect to see mass production by around 2017."

For Ionescu, who heads the Guardian Angels project (a project vetted for a billion Euro grant from the EU), tunnel-FET technology is without a doubt the next big technological leap in the field of microprocessors. "In the Guardian Angels project, one of our objectives is to find solutions to reduce the power consumption of processors. Tunnel-FET is

the next revolution that will help us achieve this goal." The aim: design ultra-miniaturized, zero-power electronic personal assistants. Tunnel-FET technology is one of the first major stages in the project's roadmap. IBM and the CEA-Leti are also partners in the project.

More information: Tunnel field-effect transistors as energy-efficient electronic switches, *Nature*, www.nature.com/nature/journal/ … ull/nature10679.html

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