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Self-Powered Silicon Laser Chips

A new method of turning waste heat into electrical power might speed up communications inside computers -- and mark another advance in the field of silicon photonics.

By Neil Savage

A computer scientist at UCLA has transformed one power-hungry component of a silicon laser into a generator of energy -- which could help engineers trying to incorporate faster optical elements into commercial processors.

"Not only are we not dumping energy in, we're actually recovering it," says [Bahram Jalali](#), a professor of electrical engineering at UCLA's Henry Samueli School of Engineering and Applied Science "It sounds too good to be true, but it is true."

As computer chip makers pack more and more transistors onto a silicon chip, they're running into a fundamental limit: how much data they can push out of the chip, or from one motherboard to another, over copper wires. As they increase the power and amount of data, electrical resistance builds up -- until the wires hit their speed limit.

Telecommunications companies overcame this problem years ago when they replaced copper wires with beams of light carried through glass fibers in long-distance communications. Now chip makers such as Intel are building tiny versions of these faster systems, by taking advantage, over much shorter distances, of the greater carrying capacity of light waves, which are unaffected by electrical resistance.

Two years ago, Jalali achieved a breakthrough when he made a laser out of silicon. Most lasers are made from other materials; because of its physics, silicon does not easily emit light. But generating optical signals would be cheaper and easier if lasers could be made from silicon, whose properties are already well understood by the semiconductor industry. Then, last year, Intel followed up on Jalali's work with a better version of a silicon laser, as well as a modulator to encode signals onto the light beam - - and the field of silicon photonics was born (see "[Intel's Breakthrough](#)," July 2005).

But there was a problem. To get the lasing effect, both Jalali and Intel used an external laser and fired it into the silicon, where the energy of the light beam interacted with the material to produce new light. Hitting the silicon with high-intensity laser light causes the silicon to generate unwanted electrons, though, which in turn can absorb the

photons being produced, undermining the laser effect. "The material becomes like a sponge, soaking up the light," says Jalali.

Intel addressed the problem by attaching an electrical diode and running a current across the chip to essentially "vacuum up" the electrons. But that required about one watt of electrical power -- enough to run a million transistors on the chip. The current running through the chip also produced waste heat that could cause the chip to stop functioning.

Jalali wondered what would happen if he reversed the voltage bias of the power from the diode, which would reverse the electrical field within the silicon. The result: the reversed bias still swept out the stray electrons, but it did so without consuming that watt of power.

In much the same way that a solar cell generates electricity when struck by photons in sunlight, the extra electrons in silicon lasers are released when two photons from the laser combine within the silicon. Jalali's device scoops up the free electrons and uses them to run transistors on the chip. Around two-thirds of the optical power that was lost to generating electrons can be recovered and put to use, Jalali says. Instead of using up one watt of power in the electron cleanup and generating extra heat, his method produces several milliwatts of power.

Jalali, whose work is funded under a Defense Advanced Research Projects Agency program to advance silicon photonics, announced his results at a conference in Canada last week. He says that to be practical the electron-harvesting equipment would have to be shrunk to one-tenth its current size, which he expects could take about three years.

Mario Paniccia, director of Intel's Photonics Technology Lab, says Jalali's work shows that silicon photonics is on its way to becoming practical. "It's in the right direction...How exactly you would use [the generating effect] and apply it still has to be optimized," he says. "It's not something you would think would happen, but once you see it, it makes sense."

Intel is working on a program to develop several key components of a silicon photonics system, including not only the light sources, but also modulators for adding a signal, optical amplifiers to boost it, photodetectors, and low-loss waveguides. Paniccia expects that the laboratory work could translate into real-world products by 2010, starting with communication between racks of computers, then along a computer's backplane (the circuit board that allows other boards, such as audio cards, to be plugged in) and finally from one chip to another.

Jalali's approach isn't a cure-all, though. At very high optical intensities, the number of

stray electrons becomes so high that the reverse bias isn't enough to remove them all without using more power. And for some applications, chip designers would prefer a laser sitting on the chip and running on electricity, instead of being pumped by light from another laser, as the current silicon laser chips require. But, in many cases, Jalali says, the external laser source is an advantage because it cuts down on power use on the chip.

Paniccia likens the development of silicon photonics to the creation of the transistor. Vacuum-tube-based computers used to fill entire rooms, until transistors shrank them, and the integrated circuit eventually led to hugely powerful computers that could be carried in shoulder bags. Likewise, he imagines silicon photonics one day shrinking the routers and other equipment that fill a switching room to chip size. Says Paniccia: "It will enable optics, and the benefits of optics, to go places they couldn't go before."

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