New IBM Research Technology Could Enable Today's Massive Supercomputers to be Tomorrow's Tiny Computer Chips

Advancement in using light instead of wires for building supercomputers-on-a-chip

December 6, 2007 - Yorktown Heights, N.Y ... Supercomputers that today consist of thousands of individual processor "brains" connected by miles of copper wires could one day fit into a laptop PC, thanks in part to a breakthrough by IBM scientists announced today.

And while today's supercomputers can use the equivalent energy required to power hundreds of homes, these future tiny supercomputers-on-a-chip would expend the energy of a light bulb.

In a paper published in the journal Optics Express, the IBM researchers detailed a significant milestone in the quest to send information between multiple cores -- or "brains" -- on a chip using pulses of light through silicon instead of electrical signals on wires.

The breakthrough -- known in the industry as a silicon Mach-Zehnder electro-optic modulator -- performs the function of converting electrical signals into pulses of light. The IBM modulator is 100 to 1,000 times smaller in size compared to previously demonstrated modulators of its kind, paving the way for many such devices and eventually complete optical routing networks to be integrated onto a single chip. This could significantly reduce cost, energy and heat while increasing communications bandwidth between the cores more than a hundred times over wired chips.

"Work is underway within IBM and in the industry to pack many more computing cores on a single chip, but today's on-chip communications technology would overheat and be far too slow to handle that increase in workload," said Dr. T.C. Chen, vice president, Science and Technology, IBM Research. "What we have done is a significant step toward building a vastly smaller and more power-efficient way to connect those cores, in a way nobody has done before."

Today, one of the most advanced chips in the world -- IBM's Cell processor which powers the Sony Playstation 3 -- contains nine cores on a single chip. The new technology aims to enable a power-efficient method to connect hundreds or thousands of cores together on a tiny chip by eliminating the wires required to connect them. Using light instead of wires to send information between the cores can be as much as 100 times faster and use 10 times less power than wires.

"We believe this is a major advancement in the field of on-chip silicon nanophotonics," said Dr. Will Green, the lead IBM scientist on the project. "Just like fiber optic networks have enabled the rapid expansion of the Internet by enabling users to exchange huge amounts of data from anywhere in the world, IBM's technology is bringing similar capabilities to the computer chip."

The report on this work, entitled "Ultra-compact, low RF power, 10 Gb/s silicon Mach-Zehnder modulator" by William M. J. Green, Michael J. Rooks, Lidija Sekaric, and Yurii A. Vlasov of IBM's T.J.Watson Research Center in Yorktown Heights, N.Y. is published in Volume 15 of the journal Optics

Express. This work was partially supported by the Defense Advanced Research Projects Agency (DARPA) through the Defense Sciences Office program “Slowing, Storing and Processing Light”.

IBM’s Chip Innovation Leadership

Today's announcement by IBM bookends a decade of innovation from IBM Labs that have transformed the IT industry with new materials and design architectures to build smaller, more powerful and energy efficient chips.

IBM's pioneering work to move the industry from aluminum to copper wiring, unveiled in 1997, gave the industry an immediate 35 percent reduction in electron flow resistance and a 15 percent boost in chip performance.

Since then, IBM scientists have continued to drive performance improvements to continue the path of Moore’s Law. And in 2007 alone, IBM announced:

- High-k metal gates (January 2007): a solution to one of the industry's most vexing problems -- transistors that leak current. By using new materials IBM will create chips with "high-k metal gates" that will enable products with better performance that are both smaller and more power efficient.
- eDRAM (February 2007) - By replacing SRAM with an innovative new type of speedy DRAM on a microprocessor chip, IBM will be able to more than triple the amount of embedded memory and boost performance significantly.
- 3-D Chip Stacking (April 2007) - IBM announces the creation of three-dimensional chips using "through-silicon vias," allowing semiconductors to be stacked vertically instead of being placed near each other horizontally. This cuts the length of critical circuit pathways by up to 1,000 times.
- Airgap (May 2007) - Using a "self assembly" nanotechnology IBM has created a vacuum between the miles of wire inside a Power Architecture microprocessor reducing unwanted capacitance and improving both performance and power efficiency