The computer industry is nearing a crisis: microchips get smaller and faster but they struggle to transfer data at sufficient speeds. Electrons flowing through standard chip connections are just too slow. Now EU-funded researchers have shown how chips with built-in lasers which use multiple wavelengths of light could in the future transmit data at terabit speeds.

Lasers are great for transmitting information. Every time you use the Internet or make a telephone call data, in the form of light pulses or photons, travels hundreds of kilometres through the optical fibre networks that crisscross the continent.

But the insides of computers still stick to old fashioned electronics. Microprocessors do their calculations with electrons, and they transfer data within and between chips using electrons too.

"Electronics is fast approaching a crunch point," explains Dries Van Thourhout from the Department on Information Technology at Ghent University, an associated lab of imec, in Belgium. "Up to now we have been trying to increase the speed of transistors, but that performance has stopped increasing now, it is just a question of packing more into a smaller space. But the biggest hindrance to performance is the speed of the connections between chips and devices. We call it the "interconnectivity bottleneck"."

Imagine a sweet factory which makes thousands of sweets per second, but the plant can only bag the sweets and dispatch them to the shops at a rate of a few hundred per second. Unless you slow down production you will end up with sweets piling up, rolling over the floor and clogging the system.

The powerful microprocessors in computers today use vast quantities of data and perform millions of calculations per second. You need to transfer this data around your computer (or your mobile phone for that matter). But the connections can’t keep up, they simply can not shift electrons fast enough. The only way to cope is to slow down data production.
This is where light comes in: you can use lasers to send photons down silicon ‘wires’ (light at infrared wavelengths travels remarkably well through silicon, says Mr Van Thourhout) instead of electrons. But the speed of light is not why optical interconnects are better. The real trick is that light can be ‘multiplexed’; basically you can send photons of different wavelengths through your interconnect at the same time. Use three wavelengths and you effectively triple the speed of data transmission.

Divide and conquer

With this in mind the 'Wavelength division multiplexed photonic layer on CMOS' (Wadimos [2]) project set out to develop a demonstration chip with multiplexing optical interconnects. The chip was based on technology developed in a predecessor project (PICMOS) which created the first ever microchip with integrated microlaser light sources, thanks to a unique bonding 'glue' developed by the PICMOS partners.

'The PICMOS project was a great success. We showed that optical interconnects could be manufactured and that they would work,' says Mr Van Thourhout. 'But it is one thing to make and demonstrate something in the lab. You won’t get chips like these into the mainstream or solve that interconnectivity bottleneck unless you can manufacture them at the industrial scale, making millions of them. PICMOS demonstrated the principle of optical interconnects. Wadimos is proving that multiplexing is possible and that the chips can be made in a standard CMOS fabrication plant.'

Europe’s largest chip manufacturer STMicroelectronics has worked in collaboration with universities and research institutions from France and Italy and a Dutch SME which specialises in lithography (etching) for electronic components. Together these partners have extended the results of PICMOS and adapted them to more commercial manufacturing processes.

One of the biggest challenges was to replace the gold connections on the microlasers in the PICMOS prototype. ‘You can’t have gold in a chip fabrication plant,’ explains Mr Van Thourhout. ‘Gold is a contaminant, so partner CEA-LETI developed a process that would mean the integrated lasers mounted on the chips could be connected using metals commonly used in chip manufacturing such as aluminium, titanium and titanium nitride.’

Belgian project partner imec has also worked to optimise the passive router structures in silicon and investigated the feasibility for their industrial production. Other project partners have contributed their expertise: the Lyon Institute of Nanotechnology (INL) in France demonstrated a new type of ‘microsource’ for which you can control the output wavelength. INL also worked with STMicroelectronics to develop a way to simulate the optical network on a chip. Finally the University of Trento, Italy, designed and demonstrated a new type of silicon router which could be used to ‘switch’ photons down particular optical pathways.

Bringing these developments together, the Wadimos team has produced a network of eight fully interconnected silicon blocks. The researchers have demonstrated successful multiplexing across these connections and the feasibility of optical filtering to direct and control the passage of photons through the silicon interconnects and their subsequent detection.

There is still plenty of research to do, however, especially to keep the lasers working in the high temperature environment of a chip's surface. Mr Van Thourhout says that they will need to find new materials that can cope with the heat.

'Nevertheless, we are very hopeful that this approach will prove very successful in the long term,' he asserts. 'We are taking an exploratory approach.' He explains that other research groups, especially those in the US, have developed optical interconnects that use an ‘off chip’ laser source; the laser
beam is split and redirected for each interconnect.

'These chips are more advanced and will soon be used in supercomputers,' says Mr Van Thourhout, 'and may eventually trickle down to mainstream computing, but in the long run it will be more efficient to have chips with integrated laser sources.

'We expect the Wadimos interconnects to allow computer processing power to continue to increase and overcome the data transmission bottleneck. Our goal is to make optical interconnects a standard technology that will support the development of yet more powerful, smaller microprocessors capable of transferring data at rates of 100 terabits per second.'

The Wadimos project received EUR 2.3 million (of a total EUR 3.2 million project budget) in research funding under the EU's Seventh Framework Programme (FP7), ICT (Next-Generation Nanoelectronics Components and Electronics Integration) programme.

Useful Links
- [Wavelength Division Multiplexed Photonic Layer on CMOS' website](http://www.wadimos.eu/) [2]
- [WADIMOS factsheet on CORDIS](http://cordis.europa.eu/projects/rcn/85248_en.html) [3]
- ['Photonic Interconnect Layer on CMOS by Waferscale Integration' website](http://picmos.intec.ugent.be/) [4]
- [PICMOS factsheet on CORDIS](http://cordis.europa.eu/projects/rcn/71218_en.html) [5]

Related Articles
- [Copper's not coping: new chips call on light speed](http://cordis.europa.eu/ictresults/index.cfm?section=news&amp;tpl=article&amp;ID=89457) [6]

Additional Information
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