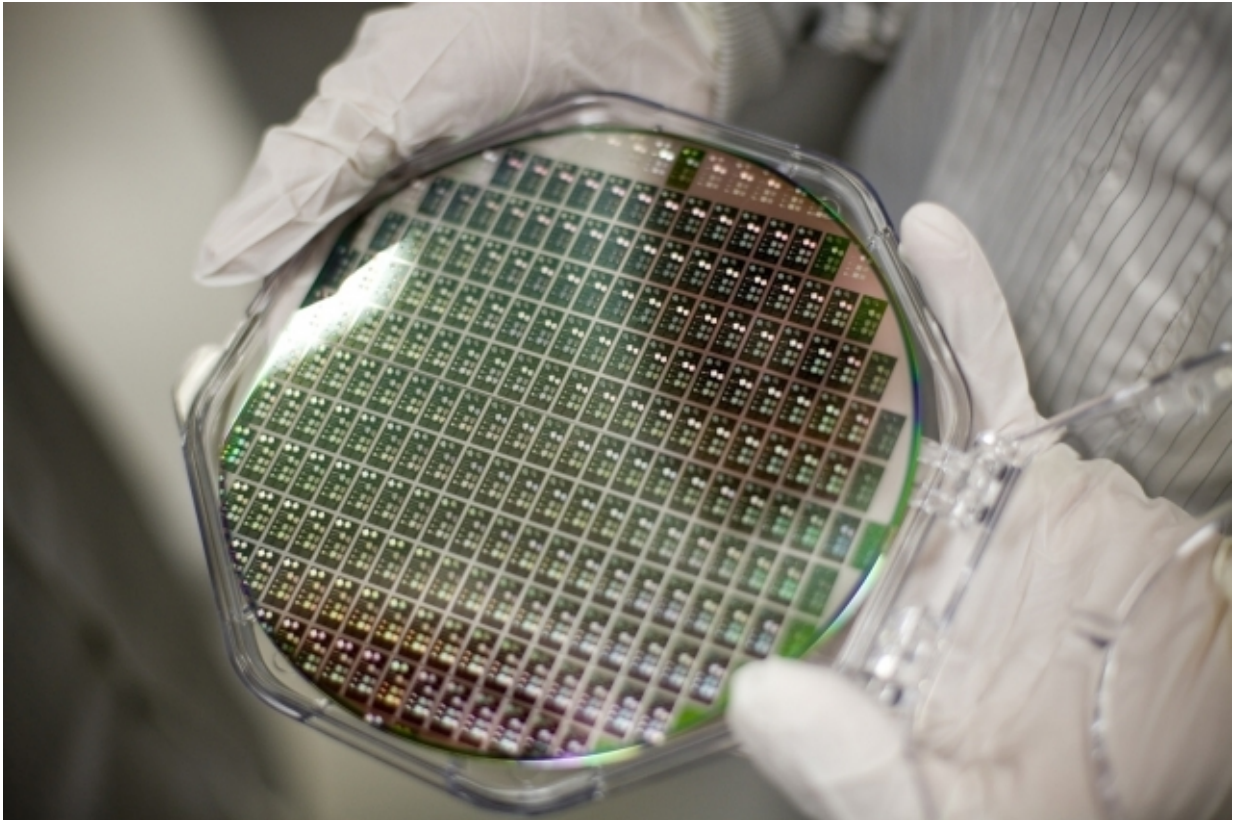


# Silicon photonics meets the foundry

September 9 2015, by Eric Bender

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A researcher displays chips that integrate germanium lasers. In 2010, Lionel Kimerling and his colleagues demonstrated the first such lasers that can produce wavelengths of light useful for optical communication and operate at room temperature. Credit: MIT Microphotonics Center

Advances in microprocessors have transferred the computation bottleneck away from CPUs to better communications between

components. That trend is driving the advance into optical interconnection of components, now moving from systems to boards to chip packages to chips themselves.

A related issue with input-output (I/O)-intensive applications such as server farms is the energy consumption required to transport bits of data around. Using [photonics](#) technology for I/O components can both improve performance and reduce energy consumption.

But to be commercially viable these photonic I/O devices must leverage the vast existing silicon infrastructure and integrate with silicon as much as possible. That means these components can't directly follow the spectacular successes of the optical fiber systems that run the Internet, cautions Lionel Kimerling, MIT professor of materials science and engineering and director of the MIT Microphotonics Center.

"We don't look at this the way we still look at fiber, which is to stuff as much bandwidth as we can onto the fiber and send it as far as we can," Kimerling says. Instead, developers working to integrate optics tightly with silicon electronics must address not only bandwidth but packaging and cost issues.

Kimerling and other MIT researchers have developed a wealth of optical interconnect technologies. They've also been working closely with industry since the 1990s, "finding where the pinch points are and what needs to be done to solve them," he says. And with funding from the National Institute for Standards and Technology, the Microphotonics Center joined with the International Electronics Manufacturing Initiative to create the Photonics System Manufacturing Consortium, which aims to develop a viable roadmap for manufacturing integrated photonics on silicon.

## **Cutting costs to shed light**

Right now the optical transceiver is moving onto the circuit board; next it will move inside the chip package, and then it will be inside the chip itself," says Kimerling. "There are significant challenges for each one of those steps. Cost, bandwidth density, and power efficiency are the big three, and cost is the one that's really controlling the entry of photonics into the system."

"The more photonics components go into a system, the cheaper they have to be in order for the system to be affordable," he notes. "Up until now, the optical products have been premium-priced, with high margins and not a lot of emphasis on cost-cutting. But once you get into high component numbers in a system, you've got to reduce the cost enough to beat down manufacturing, which will in turn drive simplification of design."

Optical interconnects confront two classical issues in how engineers adopt new technologies. First, semiconductor systems engineers who design for electrical interconnection typically lack the skill set to add optical components. Second, on the photonics side, is the difference in design paradigms between computing and optics.

In computers, Kimerling explains, engineers design a Complementary Metal Oxide Semiconductor (CMOS) circuit and can expect it to work. But in optical devices, "when I start to make something I have to figure out what kind of materials do I want, how do I put it together, what temperatures do I need and is this compatible with other devices?" he says. "It's doing everything from scratch."

"In the long run, everything should be monolithic," he adds. "You shouldn't be gluing anything down or soldering anything together. But that doesn't mean that the world will wait until you can do it monolithically. We definitely will go through a hybrid phase, where solder-bumping the photonic subsystem onto the electronic control chip

will be the early packaging solution. It solves the problem of trying to integrate two disparate processes with nanometer transistors and micron optics."

"The hope with [silicon photonics](#) is that we can take the best from silicon integrated circuits including that design discipline to establish a process design kit that includes all the rules as to how to build a component," Kimerling says. "Once we get that together, we'll be able to make these integrated devices and make them in volume." He notes that IBM is creating such a kit for its semiconductor foundry in Burlington, Vermont.

## **Into the microprocessor foundry**

Advances in microprocessor performance increasingly are limited by the ability to feed data into the microprocessor and the energy cost of getting the data, says Rajeev Ram, professor of electrical engineering at MIT. His group develops energy-efficient photonics, "and the way we do that is to miniaturize the devices," he says. "By the time we've embedded them into these circuits, the photonics occupy a negligible footprint on the chip."

He and his colleagues are now working to demonstrate full-scale multi-core computing with an entire computer that uses only photons to communicate with memory, and to show that such a computer should be much more energy-efficient and offer potentially higher performance.

In order to achieve this goal, Ram's lab aims to overcome major hurdles in integrating optical interconnection for microprocessors within existing manufacturing systems.

"A typical microprocessor fab costs between 1 and 3 billion dollars," he points out. "It's unlikely that if we want to demonstrate a new

architecture that we'll be allowed to manipulate the factory in any way. So we gave ourselves the challenge of taking a state-of-the-art [microprocessor](#) manufacturing process, and using the same layers and materials for the photonics."

One offshoot of this is intellectual property that will make it possible for any company with a great application for photonics and accompanying high-performance circuit design to walk into a foundry and get an optical design to work in that foundry, he says. "Early on, we developed an approach if we have no freedom to modify the fab at all."

One such process is patented and another patent application is pending. "Between the two, you should be able to do photonic functionality on any fab," Ram says.

## **Making material progress**

Over time, new materials and devices will provide far more powerful integration of photonics on silicon. Germanium lasers, demonstrated by Kimerling's group in 2010, offer a prime example.

"One of the big issues today is the [light source](#)," Kimerling explains. "In commercial applications today the light source is bump-bonded, independently of the optical circuit, but it would be great to get a monolithic light source. Our germanium laser would be a way to do that. It's at the research rather than the commercial stage at this point, but it's on a good path."

MIT has been granted patents both on the laser and on a method to integrate similar devices into an optical circuit, growing germanium crystals on amorphous substances at temperatures low enough for fabricating electronics as well. Such approaches, focused on the long term, will achieve monolithic integration for chips with an electronic

front end with optics embedded in the back end, he says.

Overall, the MIT patent portfolio in silicon photonics has grown to more than 60 patents that cover functions such as on-chip lasers, modulators and demodulators, and sensors. Applications range from data processing and communications to sensors on a chip.

**More information:** Businesses interested in learning more about MIT optical interconnect technologies should contact the Technology Licensing Office at [tlo@mit.edu](mailto:tlo@mit.edu) or 617-253-6966.

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