Silicon photonics – optics to the chip at last?

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Optics dominates long distance communications, but will it ever be useful on silicon chips or their successors? Early interest in optics for logic faded as integrated circuits advanced, but optics for communication and interconnect has become increasingly interesting. There, optics is competing against copper, not silicon. Basic issues of physics favor optics for communication anywhere a high density of information has to be communicated over any substantial distance.[1,2]

Despite physical advantages, and despite growing problems with interconnection at all levels, optics has never made any impact at the level of integrated circuits. Why? The physical arguments for using optics off chip are particularly strong, with possible substantial reductions in power and increases in communication density, but the cost targets are daunting for introducing a new technology such as optics. Prior technologies have never been integrated well with silicon. Silicon itself is a frustrating optoelectronic material, because of its indirect gap. III-V materials, which give good optoelectronic devices, are not easy to integrate with silicon processes.

The idea of on-chip optics on silicon is gaining momentum in research. Significant advances have been made in the past year or so in silicon optical systems (waveguides, couplers), and in active optoelectronic devices (modulators). Low-cost optical connections off of silicon are becoming more realistic. Serious attempts are being made at commercializing optoelectronic chips made entirely in a CMOS platform. A possible path for the introduction of optics to silicon is the progressive evolution of integrated optoelectronics on silicon for transceivers, leading to technology we may be able to use for other applications, such as possibly optical interconnects on chip.

At the same time, radical ideas are emerging from nanophotonics, in dielectrics, semiconductors, and now also nanometallics, all in principle compatible with CMOS. With such nanotechnologies, it is possible to make optical devices much more compact than before, and to contemplate completely new kinds of structures, such as miniaturized metallic optical antennas and 50 nm sized waveguides that could concentrate and guide light into high-speed, low-capacitance photodetectors the same size as current transistors. We can only speculate on what the impact of such ideas would have, but they all make optical interconnects even more interesting, and, who knows, maybe some of us will even start thinking about optical logic again?

1. D. A. B. Miller, "Physical reasons for optical interconnection", *Intern. J. Optoelectronics* **11** 155 (1997).
2. D. A. B. Miller, "Rationale and challenges for optical interconnects to electronic chips", *Proc. IEEE* **88**, 728 (2000).