

# *Making the Transition to Photonic Clocking*

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In the microprocessor industry, it's no secret that copper interconnects are finding fundamental limitations as data transmission bandwidth and processor speed continue to rise. With higher data rates and clock speeds, and the current trend toward distributed multicore architectures, very high-speed interconnects within and between computing elements will be absolutely necessary. The recognized solution is to change from electronic to photonic interconnects for both data transport and clocking. Photonic clocking can not only solve the limitations of electronic clocking, it can also reduce jitter, skew, delay, crosstalk and power consumption while maintaining clock signal integrity for longer distances. Furthermore, it can be implemented for the next high-volume manufacturing cycle. Photonic clocking can meet the demands of both single-core processors at low gigahertz rates as well as multicore processors that run at 100 GHz and higher.

Though the transition to optical clocking is a "when, not if" situation, this price-sensitive market will demand a photonic solution that is also low in cost (i.e., compatible with the economics of microprocessor manufacturing). So the question is how to make this transition and to what architecture.

One-size photonic clocking will not fit all. Alternative systems must at least be compared for specs, efficiency (power/heat issues), scalability and, most importantly, cost. For a smooth transition:

## **Do**

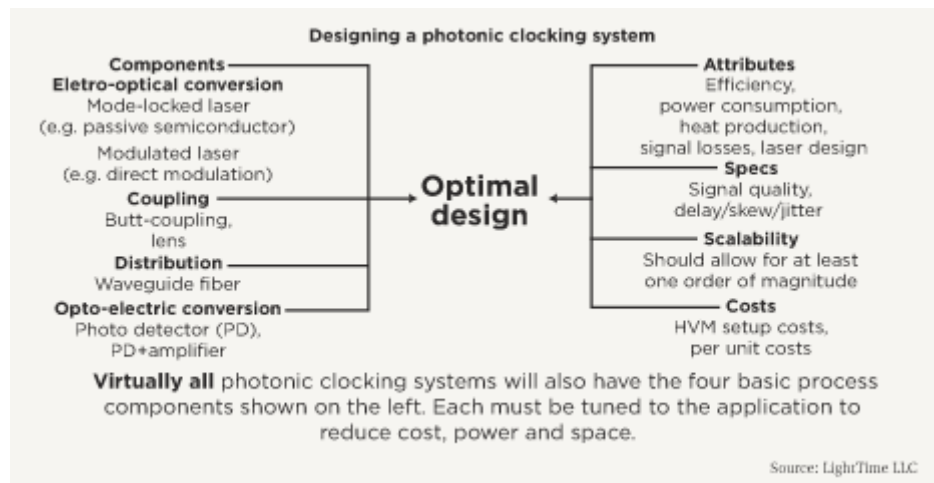
- **Work with what you have.** Most silicon-based microprocessor chip companies aren't going to change to GaAs so that you can build your laser on-chip. Therefore, you have to concentrate on efficient coupling to the chip or hybrid mounting onto it. If you are already working in GaAs or InP, then life just became a lot easier.

- **Minimize component counts.** Fewer components mean less to integrate and less to package. Smaller size usually means less chip real estate used, less power consumption, less heat production and, most important, lower cost.

- **Make it scalable.** Since microprocessor technology will continue to increase clocking rates, photonic clocking technology must scale with relative ease to at least one order of magnitude. Already, 2-GHz photonic clock systems have been demonstrated that can scale up to 20 GHz. Another laser design is scalable from 10 to more than 100 GHz. And with the increasing number of cores in microprocessors, the distribution system should be readily scalable, too.

- **Make it inexpensive.** To be implemented, any new technology needs to be cheaper or at least in cost parity with the incumbent technology. Microprocessors are a commodity and decisions will be based on the bottom line rather than what will make a product better.

- **Embrace compromise.** I would love to develop a photonic clocking system with a 100-GHz bandwidth, but it doesn't make sense financially. If there are unacceptable cost penalties in changing to a photonics solution, the microprocessor industry will push the current VCO/copper technology until those cost penalties go away. The good news is that acceptable photonic clocking solutions should be cost-viable in a 2008-2012 high-volume manufacturing cycle.



## Don't

- **Start at the beginning.** Or rather, begin at the end. Figure out the minimum and maximum electrical specs that an application needs. For instance, the electronics may need an optoelectronic signal conversion that generates 1 volt peak to peak with a rise time between 10 and 20 picoseconds at a frequency of 10 GHz. Spreadsheets are great for this and can be designed to do simple modeling.

- **Increase power consumption or heat generation.** To be accepted, a future photonic clocking solution must be no worse than today's VCO/copper counterparts, which have already nearly reached the limits of tolerable heat generation.

- **Use the highest-performance components available.** Your photonic signal is only as good as the weakest link in your design. For example, using a 2-watt laser when you only need 100 milliWatt to trigger your electronics doesn't make much sense technically or financially.

- **Use software.** At least, wait until near the end of the design process. No computer software can brainstorm, devise unique alternatives or determine what makes an optimal design from all perspectives. Use software to confirm and refine, not to create.

-**Give them revolution.** Strive for incremental technology changes wherever possible. Big changes usually imply unknown risks, require time-delaying testing and make adoption over incumbent methods a more difficult management decision. The transition from electrical to optical usage in microprocessors is already a revolutionary step in that industry. Also, incremental change is not only less risky but usually less costly.



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