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A Technical Research Report: Silicon Photonics

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Abstract

Silicon photonics technology is the implementation of fiber optics inside computers and between digital devices. This technology is currently being developed by Intel, Corp., but preliminary lab tests demonstrate never before seen data transfer speeds from a computer bus. Silicon photonics uses a basic send-receive method to function. Bits of data are converted into a beam of light by the Transmitter Chip, which is sent across a fiber optic cable to the Receiver Chip. The Receiver Chip decodes the information from the light, recreating the bits of data that were originally sent. As computers and other electronic devices scale up their processing power, silicon photonics and other high-speed bus technologies become increasingly necessary to make sure data can be sent and received as fast as can be processed.

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Introduction

Light has been used to transmit information since the 1790's (Alwayn, 2004). One method of implementing this technology is called fiber optics, which is used today in the in telecommunications sector over 200 years later. Fiber optics made it possible to connect Internet nodes across long distances, including over oceans.

Fiber optics works by using extremely fast pulses of light to transmit digital information through hair-thin strands of glass fibers. As of today, fiber optics technology has only been employed to send and receive data over long distances. However, new lab research and experimentation has shown that fiber optics can be used over short distances as well, such as inside computers. This new technology, developed by Intel and UC Santa Barbara, is called Silicon Photonics (Foresman, 2010).

The purpose of this report is to give a brief history of silicon photonics, and explain how this technology works, showing how data is transmitted from point A to point B. In addition, this report will speculate about the future of silicon photonics.

The first section shows how silicon photonics evolved from fiber optics. The second section gives an overview of the silicon photonics process. The third section describes the main components involved in silicon photonics: the transmitter chip, the fiber optic cable, and the receiver chip. The fourth section describes the silicon photonics operating principle in depth, showing how these components function together to transmit information. The fifth section is a discussion section and the conclusion of the report, introducing silicon photonics as a possible key to overcoming future computing plateaus.

Evolution of Silicon Photonics

Fiber optics technology in its current form has been employed for a variety of uses since the late 1970s (Alwayn, 2004). This technology boasts extremely high data transmission speeds compared to traditional copper wiring, and low error rates. Today, fiber optics is used in telecommunications to deliver high-speed internet, television, and phone services to millions of Americans' homes.

Silicon photonics was developed as a result of heavy industry funding from large tech companies such as Apple, Inc. and Intel Corp. since 2007 (Foresman, 2009). The objective of the development of this technology was to create a data link that is faster than current computer data transmission standards such as the Universal Serial Bus (USB) and FireWire. The most important innovation that went into silicon phononics were the hybrid silicon lasers, which were developed by Intel in conjunction with UC Santa Barbara.

Description of Silicon Photonics Technology

Silicon photonics is a type of fiber optics technology that uses computer chips and fiber optic cables to send and receive data inside computers, through an optical data link. The two main parts involved in the optical data link are the Transmitter Chip and the Receiver Chip. The Transmitter Chip is made up of various subparts including hybrid silicon lasers and modulators, a multiplexer, and a silicon transmitter. The silicon transmitter is attached to the fiber optic cable linking the Transmitter Chip to the Receiver Chip. The Receiver Chip reverses the output of the Transmitter Chip, so its subparts are exact opposites of the Transmitter Chip subparts, in reverse order. The Receiver Chip is made up of a silicon receiver, a demultiplexer, and photodetectors. All of these parts work together seamlessly to push data as fast and error-free as possible.

Silicon photonics uses a basic send-receive method to function. Bits of data are converted into a beam of light by the Transmitter Chip, which is sent across a fiber optic cable to the Receiver Chip. The Receiver Chip decodes the information from the light, recreating the bits of data that were originally sent.

Two main parts are involved in the optical information transmission process: the Transmitter Chip and the Receiver Chip. The subparts of the Transmitter Chip are the hybrid silicon lasers and modulators, the multiplexer, and the silicon transmitter. A fiber optic cable attaches the Transmitter Chip to the Receiver Chip. The Receiver Chip is made up of a silicon receiver, a demultiplexer, and photodetectors.

Main Components Involved in Silicon Photonics

Transmitter Chip. The transmitter chip is a four-inch long by two-inch wide green printed circuit board that encodes binary data into a single beam of light. This chip is attached to the Receiver Chip by a Fiber Optic Cable. Subparts of this chip include hybrid silicon lasers and modulators, a multiplexer, and a silicon transmitter. See Figure 1.

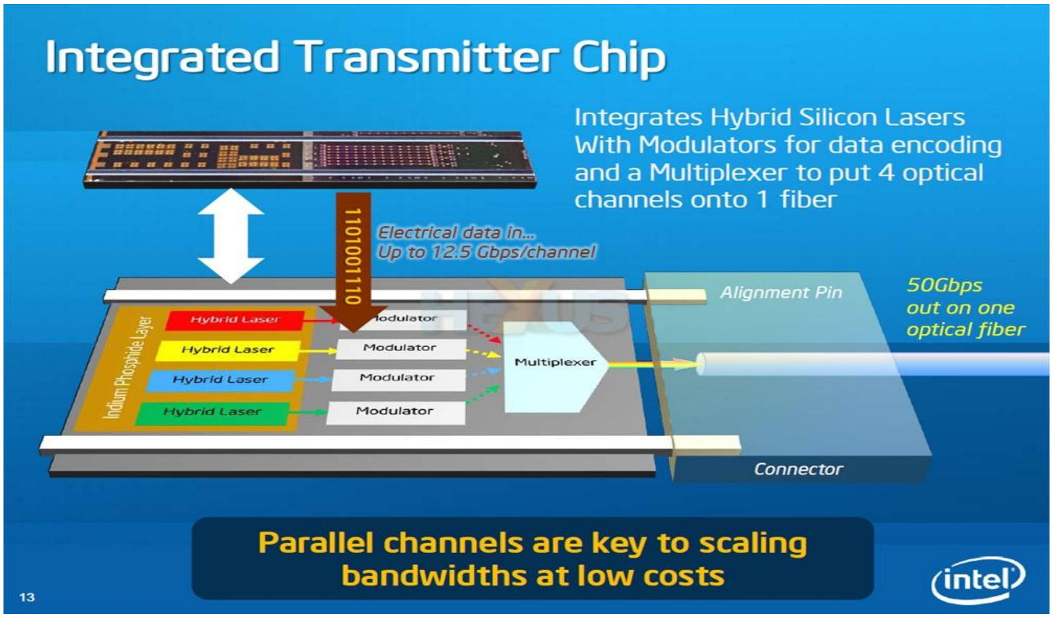

Figure 1. The Transmitter Chip and its subparts. *Source:* img.hexus.net/v2/news/intel/silicon-photonics/silicon-photonics-2010-02-big.jpg

Hybrid Silicon Lasers and Modulators. The hybrid silicon lasers and modulators take up almost the entire four-inch by two-inch surface area of the transmitter chip. These parts generate the laser light at the different frequencies required to represent binary data from computers. The modulators are connected to the multiplexer. See Figure 2.

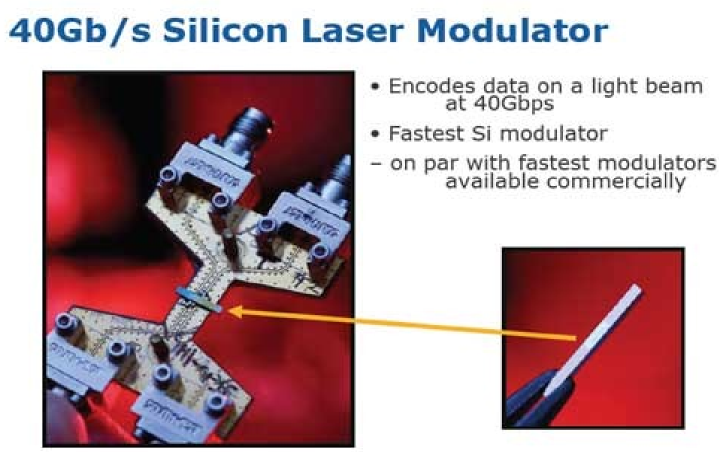

Figure 2. A silicon laser and modulator. *Source:* images.trustedreviews.com/images/article/inline/5532-Modulator.jpg

Multiplexer. The multiplexer is an extremely small logic gate that joins separate lasers into a single beam of light. The multiplexer is connected to the laser modulators on one end and the silicon transmitter on the other end.

Silicon Transmitter. The silicon transmitter is a plastic optical interface between the multiplexer and the fiber optic cable. The transmitter's approximate dimensions are one-inch long by one-quarter inch wide by a half-inch deep.

Fiber Optic Cable. A fiber optic cable is a cable that transmits information using light. It can be of any length and any width, depending on the type of plastic shielding that is used. The fiber optic cable used in silicon photonics contains two 62.5 micron wide clear fibers (Oschler, 2009). This cable connects the transmitter chip and the receiver chip. See Figure 3.

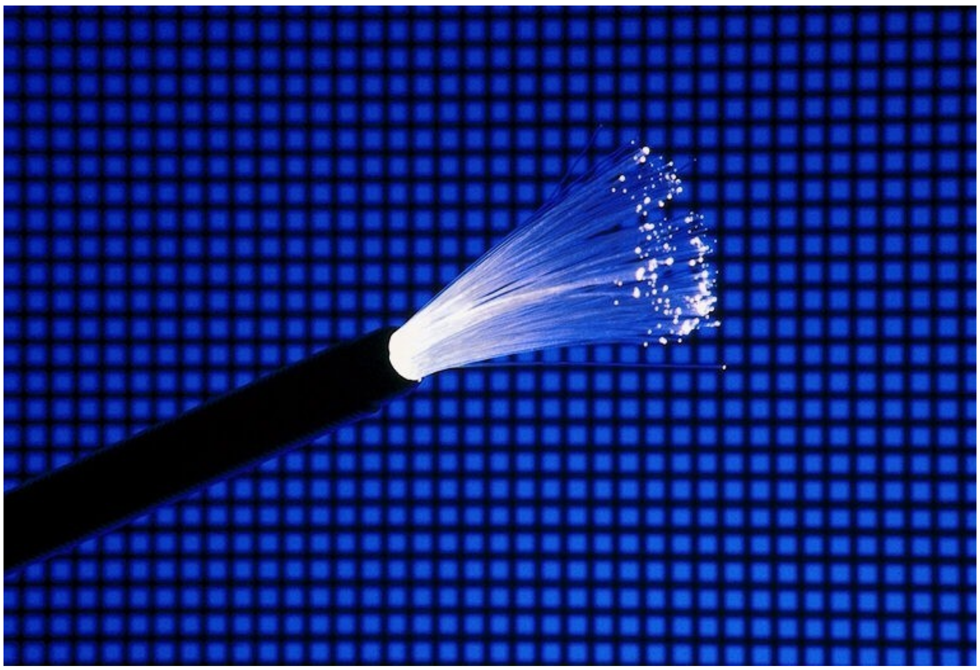

Figure 3. A fiber optic cable with fibers exposed on one end. *Source:* telecomnewspk.com/wp-content/uploads/2010/09/FiberOpticCable-300x200.jpg

Receiver Chip. The receiver chip is a four-inch long by two-inch wide green printed circuit board that decodes binary data from light. This chip is attached to the transmitter chip by a fiber optic cable. Subparts of this chip include a silicon receiver, a demultiplexer, and photodetectors. See Figure 4.

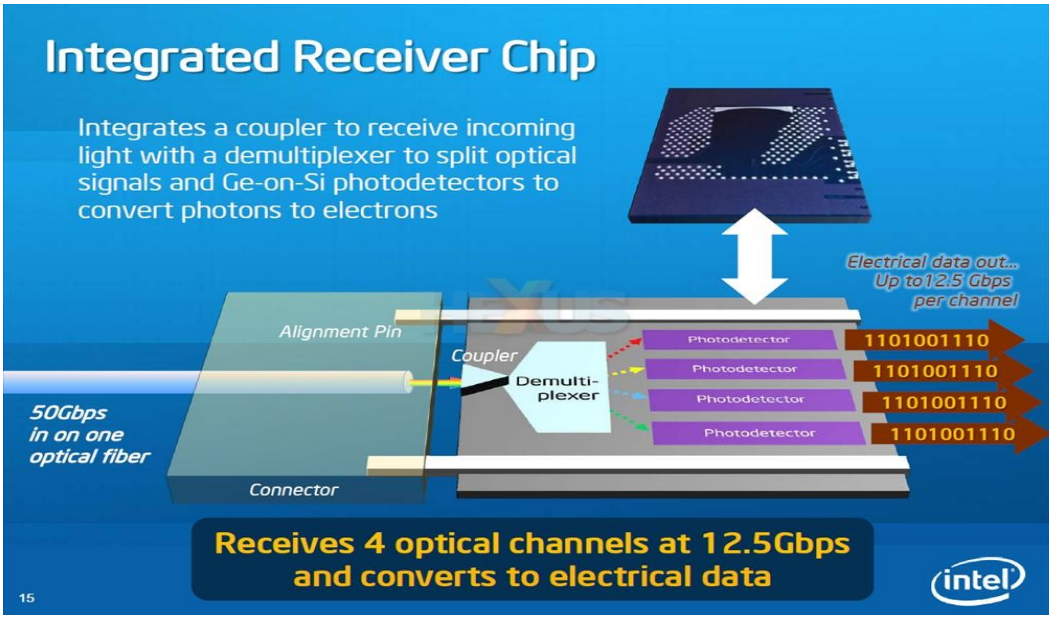

Figure 4. The Receiver Chip and its subparts. *Source:* img.hexus.net/v2/news/intel/silicon-photonics/silicon-photonics-2010-03.jpg

Silicon Receiver. The silicon receiver is identical to the silicon transmitter on the transmitter chip. See Figure 5.

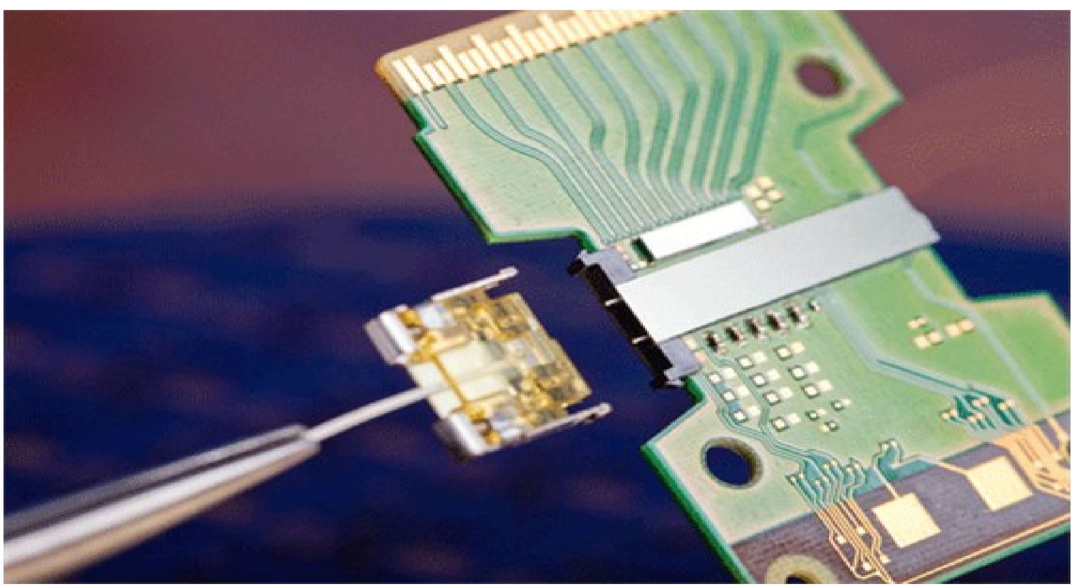

Figure 5. A silicon receiver located on the receiver chip. *Source:* www.computerweekly.com/PhotoGalleries/242184/2452_20_A-50Gbps-Silicon-Photonics-transmit-module.gif

Demultiplexer. The demultiplexer is an extremely small logic gate that separates lasers from a beam of light. It is the exact opposite of a multiplexer, and functions to reverse its output. The demultiplexer is connected to the silicon receiver on one end and the photodetectors on the other end. See Figure 6.

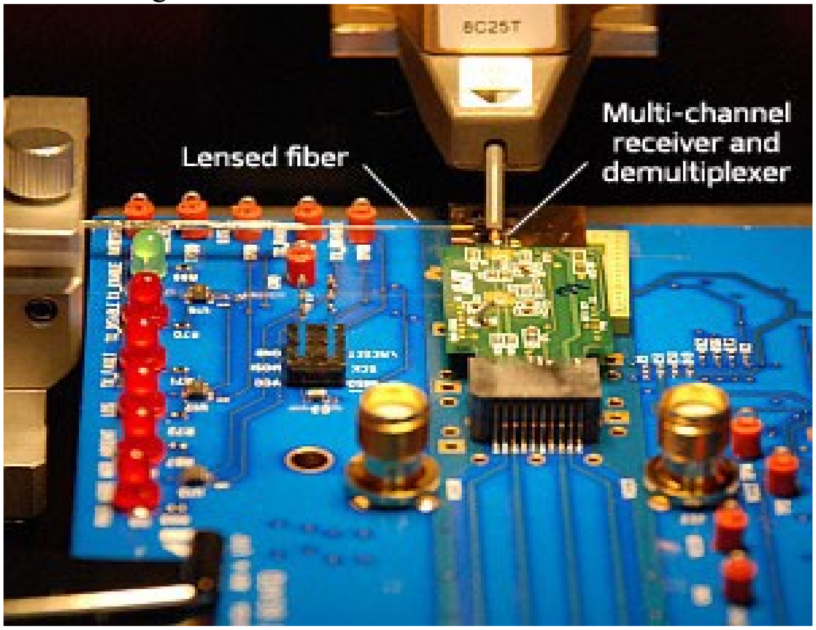

Figure 6. A demultiplexer on a printed circuit board. *Source:* www.nanowerk.com/news/id17855.jpg

Photodetectors. Photodetectors are small circular semiconductor diodes that convert light energy into electrical energy. The photodetectors on the receiver chip are connected to the demultiplexer, sending digital information out as the last step in the silicon photonics process. See Figure 7.

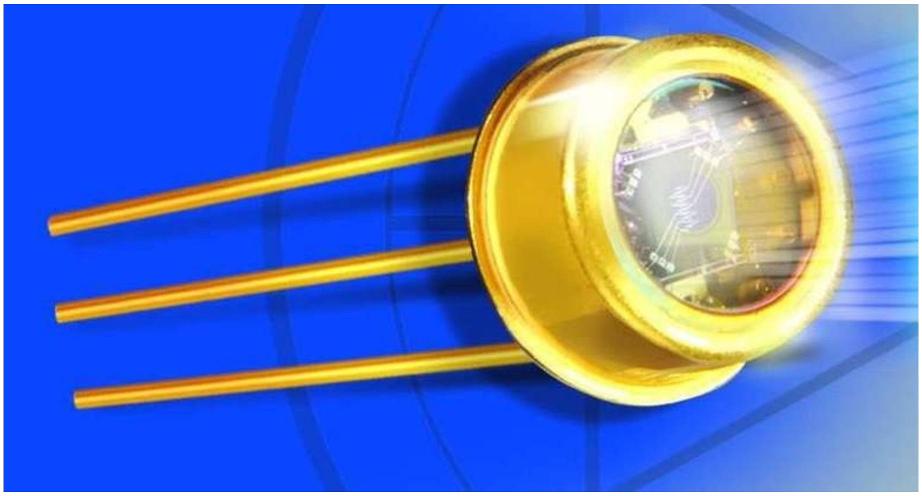

Figure 7. An illustration of a photodetector. *Source:* cfnewsads.thomasnet.com/images/large/452/452448.jpg

Theory of Operation

The silicon photonics process starts with the hybrid silicon lasers and modulators. These parts change binary "ones and zeros" into different frequencies of light. The different beams of laser light are then fed into the multiplexer which combines them into a single beam. The data at this point is fully encoded, and is physically transmitted by a silicon transmitter, via a standard fiber optic cable. At the other end of the cable, the silicon receiver on the Receiver Chip guides the light beam into the demultiplexer, which splits the beam back into the different frequencies of laser light. Photodetectors, which are the last parts involved in the process, reconvert the separate beams back into data forms computers can interpret, recreating the original transmission.

Discussion & Conclusion

Silicon photonics technology is still in its infancy. As of July 2010, testing in Intel laboratories is ongoing, with preliminary test results showing great promise. According to tech news publication Arstechnica, "the [silicon photonics] link was tested continuously for 27 hours, transferring over a petabyte of data with nary an error. Intel says this translates into a bit-error-rate less than $3e{-}15$" (Foresman, 2010). These results show that silicon photonics can indeed push large amounts of data with very low error rates.

To put these numbers into real-world context, the transfer rate demonstrated in the lab results show that an entire high-definition movie could be transferred in approximately one second (Foresman, 2010). This transfer rate is about 107 times faster than the current industry standard USB 2.0 specification, which incidentally was also developed by Intel.

Current data buses present substantially restrictive bottlenecks as computers and other electronic devices become more powerful. The development of silicon photonics technology today serves as a safety net, ready to step in if and when such bottlenecks become problematic in the evolution of computing technology.

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