

SILICON PHOTONICS ARE HERE AND GLOBALFOUNDRIES IS INNOVATING

A LEADER IN SILICON PHOTONICS

SUMMARY

One of the most impressive feats of the twenty-first century has been the innovation of processors with advancements in size, complexity, and capabilities. Since Gordon Moore first postulated that the number of transistors would double every generation, the semiconductor industry has invented ways to make transistors smaller. Moore's theory, commonly known as "Moore's Law", has driven the semiconductor market and propelled the complexity of processors to a point where transistor size cannot be measured accurately.

In recent years, the semiconductor market struggled to keep up with Moore's Law. As silicon electronic-based transistors become smaller and denser, they run into thermal issues, a higher risk of interference, and consume more power. Silicon photonic technology is advancing quickly to replace traditional silicon electronics, and GlobalFoundries (GF) is one of the companies leading the way.

GF is already a leader in silicon photonics with its connectivity and networking solutions for the data center market. This paper will explore how silicon photonics addresses today's semiconductor challenges, how it could disrupt data centers and the way we compute, and the breadth of GF within the silicon photonics market.

WHAT IS SILICON PHOTONICS?

Silicon photonics uses photons within a silicon component rather than an electron. If we think of electronics as manipulating electrons, photonics is similar but with photons. Rather than manipulating electricity through transistors and other electrical components, photonics would be a manipulation of light through optical components.

Optical components have properties that make silicon photonics a better technology for computing than its electrical counterpart. You can think of light as energy in its purest form. It requires less energy to move light through a medium than electricity, especially at long distances. Since photons travel at the literal speed of light (186,000 miles per

second), silicon photonics offers extremely low latency. Light also does not generate heat like its electrical counterpart, making it ideal for the data center.

As we look at the state of the data center today, arguably, silicon photonics could not have come at a better time. Over the past decade, the semiconductor industry has been unable to keep pace with Moore's Law, while the amount of data that needs processing has skyrocketed. The data center needs higher bandwidth inside and between data centers and lower latency systems to process the increasing amounts of data. The engineering of chips has also transitioned toward an aggregated system-on-chip (SoC) design that requires high-speed bandwidth between blocks and subsystems.

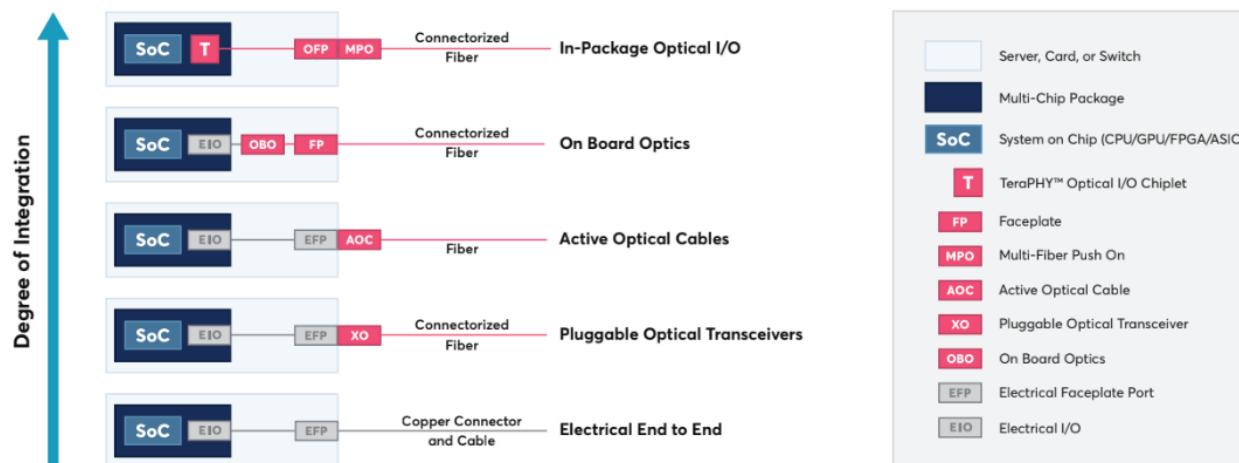
THE PRESENT AND FUTURE OF SILICON PHOTONICS IS IN THE DATA CENTER

Silicon photonics has been a familiar face within the data center for some time now. GF began developing its photonics foundry following its acquisition of IBM Microelectronics in 2015. The total addressable market (TAM) for Silicon Photonic transceivers in 2020 was about \$740 million, with expected growth to a TAM of \$4.1 billion by 2025. Optical transceivers for the intra-data center, which is connectivity from one data center to another, have become a mature market where optical transceivers are capable of .5TBps per pluggable transceiver at over 10 kilometers.

The next milestone for silicon photonics technology targets inter-data center I/O, which is connectivity within a data center, from chip to chip and subsystem to subsystem (i.e., GPU, CPU). The data center is becoming more disaggregated, demanding more bandwidth and lower latency. Optical I/O (OIO) has the ultra-low latency and bandwidth to keep up with the demand for more data, and the aggregation of chips, without the concern of power consumption. Security is even an added benefit as optical connectivity in and of itself is not affected by electromagnetic interference due to its non-metallic property.

The challenge with OIO interconnects from chip to chip is that to see real cost benefits, the interconnect between the electrical chipllets must be integrated within the chipllet. The same principle applies to transportation. It makes more sense to fly from Austin, Texas, to Barcelona, Spain, than to drive from Austin to Houston, Texas, and then fly to Barcelona, Spain, and vice versa. The difference is that one medium brings me straight to the source, and the other brings me to a transition point. Co-packaged Optics replaces traditional electrical I/O (EIO) and brings silicon photonics straight to the source for all the benefits of OIO interconnects, low latency, and high bandwidth.

FIGURE 1: OPTICAL INTEGRATION WITHIN A CHIPLET



(Source: Ayar Labs)

GF and its notable partners including Broadcom, Cisco Systems, Marvell, NVIDIA, Ayar Labs, Lightmatter, PsiQuantum, Ranovus, and Xanadu are collaborating and successfully bringing co-packaged Optics (CPO) to market. A part of GF's announcement at [OFC](#) was GF Fotonix, its next-generation silicon photonics platform.

THE BREADTH OF GF SILICON PHOTONICS PORTFOLIO

Based on our research, GF has the only photonics foundry with a 300mm monolithic silicon photonics solution, [GF Fotonix](#). GF Fotonix combines GF's photonic system, radio frequency (RF) components, and complementary metal-oxide semiconductor (CMOS) circuitry onto the same wafer. This solution positions GF as a high-volume producer of transceiver parts with a higher return on investment (ROI). GF is the first to combine its 300mm photonics features and 300GHz-class RF-CMOS onto a silicon wafer. This combination brings high data rate optical chiplets at scale and reveals how silicon photonics is presently in the data center, not only in the future.

In talking with GF about its silicon photonics offerings, its base process design kit (PDK) has the versatility to cover different markets, including photonic-based computing. The challenges within the data center have accelerated the growth of photonic-based computing. As GF gets closer to the computing system, its feature set becomes broader for solutions like optical interconnects and, eventually photonic computing and even quantum photonic computing.

We believe GF differentiates itself with its monolithic photonic chip platform. Instead of having three separate chips— a photonics chip, an analog amplifier chip, and a laser driver chip—GF has created one photonic SoC. This monolithic platform is advantageous in that it not only reduces the number of chips but has the potential for better signal fidelity and lower bit error rate, leading to reduced latency. GF also shows that innovation happens on all geometries, not just the smaller 10nm, 7nm, or 5nm geometries, but also at 45nm.

All competition is good, and with Intel's acquisition of Tower Semiconductor, Intel should be GF's closest competitor. Although Intel's primary concern is the smallest of geometries with its IDM2.0, it has also demonstrated Co-packaged Optics with its photonics process.

Another way GF differentiates itself from the competition is with its EDA partnerships. Picking a diverse set of partners allows GF to address many applicable silicon photonics markets. GF has had EDA partnerships with big-name players within the silicon space for many years, like Cadence, Ansys, Siemens, and Synopsys.

WRAPPING UP

If there ever was a time to get excited about silicon photonics, the time is now. The data center is going through many significant changes that align perfectly with what silicon photonics can offer. Data centers need to accommodate for disaggregation, the high bandwidth and low latency required to keep up with HPC, the inability to keep pace with Moore's Law and its proportionate performance jumps, and the need for less power-hungry systems.

The technology is here, and GF and its EDA partners are making a huge splash within the data center with silicon photonics. GF has a comprehensive feature set within its silicon photonics solutions enabled on multiple geometries. The future of computing is silicon photonics, and we believe GF is leading the way.

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