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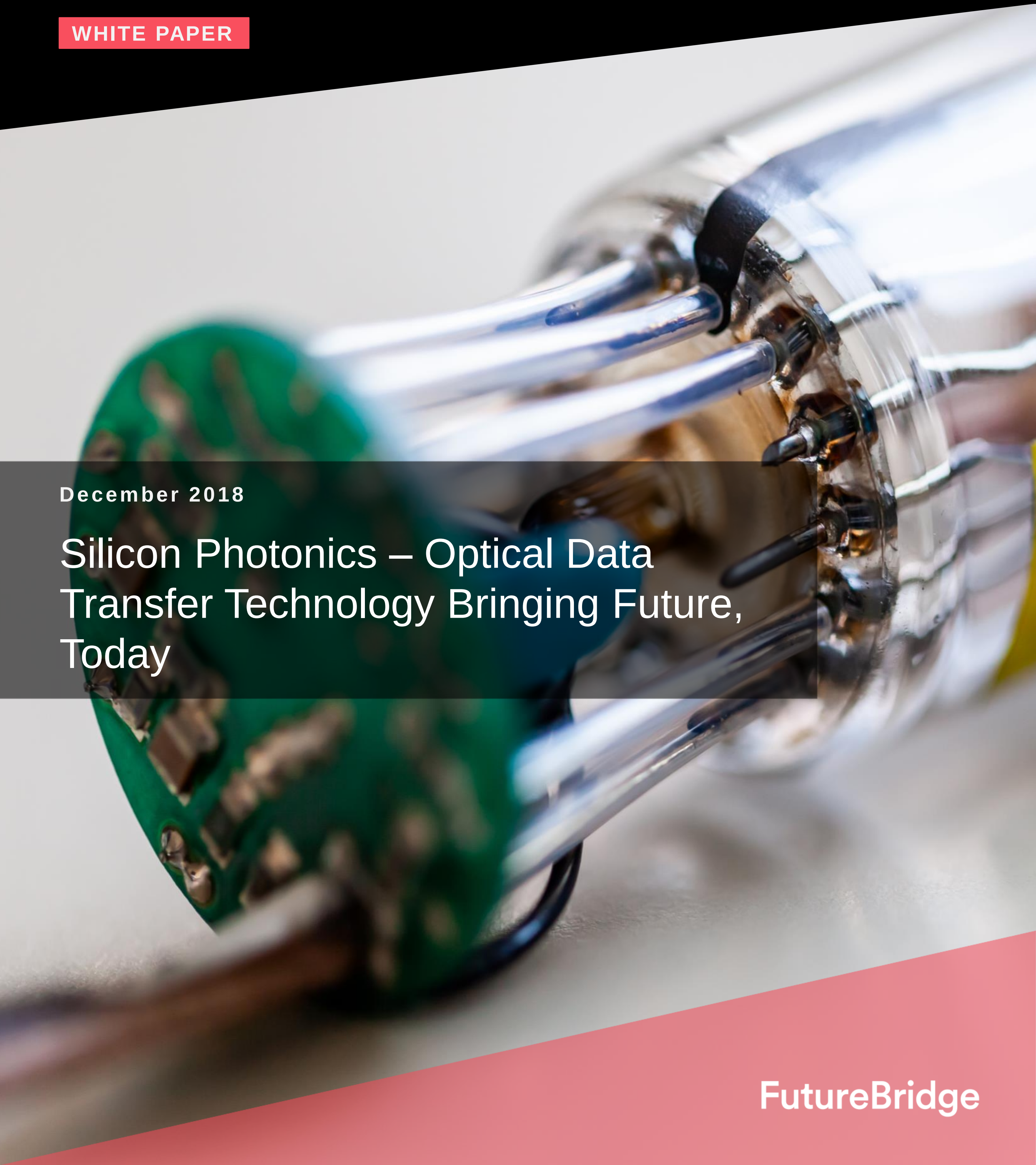

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Silicon Photonics – Optical Data Transfer Technology Bringing Future, Today

FutureBridge

Silicon Photonics is a data transfer technology that is expected to change the outlook of how much data could be transferred. Silicon Photonics has shifted the emphasis on device/structure optimization and performance to controlling photons instead of controlling electrons. Silicon Photonics technology has high usage in data transfer applications, and it is already being used in data-hungry data centers of large technology firms. With more research and development, it could open doors for a number of key applications, such as automotive, telecom, sensors, optical routers, and signal processors. Simply put, Silicon Photonics can revolutionize the technology industry if all the concerning limitations are eliminated.

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Introduction

Silicon Photonics is one of the key technologies in the Photonics domain that uses “Silicon” as the optical medium to transfer data from one place to another by means of optical rays, which are capable of transferring more amount of information in lesser time. Earlier, copper was the predominant medium of data transfer in networking and storage area networks (SANs); however, owing to high losses from copper usage, now optical fibers are preferred. Silicon Photonics includes a combination of laser and silicon technology, both integrated on the same chip. This results in high performance, thanks to the availability of high bandwidth and better propagation speed of infrared (IR) beams compared to electric current. Moreover, technology has the potential to enhance the reliability of electronic ICs by reducing power consumption, weight, and size.

Applications of Technology

Even though Silicon Photonics is an old technology, its usage is observed now only. It has already started getting acceptance from data centers. The technology can also be used for telecom, metro, and long haul applications.

More and more research is going on about the adoption of Silicon Photonics technology in the automotive industry. For now, more focus is on pinpointing sub-components like modulators, optical splitters that could be manufactured with the help of the technology. In the future, more and more components are expected to integrate the technology for wider adoption. For example, Silicon Photonics will be incorporated into sensor applications, medical applications, emerging applications like a three-dimensional integrated circuit (3DICs), digital signage, digital cinemas, and video recording applications.

Applications in Data Centers

It has been nearly four decades now that the tech world has spent millions and millions of dollars to develop the IT infrastructure. In order to mitigate this continuing ‘years of spending’ process, the industry came up with the concept of cloud computing with massive-sized data centers. Since then, the demand for cloud computing has always been on the rise. Moreover, to address this ever-increasing demand for high-performance computing -- considering the technology’s advantages of improving data transfer speeds and increase in bandwidth -- adoption of Silicon Photonics in data centers has increased since 2016. Facebook and Microsoft are two such examples of large cloud service providers that have started using 100G Ethernet with single mode-based optics infrastructure in their cloud centers to deal with the rising demand for high-speed data transmission. Many transceiver modules used in these optic infrastructures are made with the help of Silicon Photonics technology.

New Silicon Photonics chips could also be made with the help of production infrastructure that is used for CMOS fabrication. This provides low-cost, small–sized, and high-yield devices that could be used in a range of applications, which are as given below:

- 100G (or beyond) long-reach inter-data-center networks or data center interconnect (DCI), which connects data center clusters together using coherent optics (e.g., CFP2-ACO, CFP8-ACO) or direct modulation (<100 km)
- 100G/200G/400G mid-reach single mode transceivers (500 m to 2 km) for intra-data-center interconnects, with modules such as PSM4/DR4 (parallel single-mode fibers)
- CWDM4/CLR4/FR4 (wavelength multiplexing over duplex fiber pair)
- Data centers that are situated at metro areas
- Mobile front-haul networks and optical transport networks

Applications in Automotive

The automotive industry will be one of the key applications for Silicon Photonics technology in the near future. For instance, high amount of Silicon Photonics adoption could be observed in advanced driver-assistance systems and autonomous driving applications. It could be used in LiDAR for optical communication between vehicles, for rain and luminosity detection, adaptive front lighting applications, LED indoor lighting, and in 3D Scanning for automotive manufacturing applications.

Other applications in the auto industry that could see the introduction of Silicon Photonics are external and internal environment detection, driver drowsiness detection, and night vision

Applications in Sensors

Accurate measurement of the concentration of antibodies is required for efficient disease diagnosis. For this, biosensors are used. According to IUPAC1 definition, “A biosensor is a self-contained integrated device which is capable of providing selective quantitative analytical information using a biological recognition element which is in direct spatial contact with a transducer element.”

Silicon waveguides could be used for biosensing purpose owing to its high refractive index. Such high refractive index provides high sensitivity for surface sensing, and smaller rings of ring resonator could be used without reducing the quality factor by bending loss.

Other sensor applications where Silicon Photonics could be used are fiber optic strain gauges, Fabry-Perot optical sensors, fresnel lens sensors. Sensors in medical and oil & gas industries that are used for environmental monitoring could also be manufactured with Silicon Photonics technology

Advantages

Owing to the usage of Silicon with Photonics technology, the following are the advantages that could be observed

- Silicon-based chips with optical fibers that are used to build Wave Division Multiplexing (WDM) devices have the capability to operate up to 40 channels independently, with each channel having a different wavelength. This could enable data transfer at the rate of 1.6 Tbits/s, which will be highly preferred by high-speed data centers
- Silicon-based dispersion compensator could remove the limitation of chromatic dispersion, offering high tenability with low power consumption and can be integrated with on-chip photonics devices
- Silicon Photonics provides advantages of Silicon Photonics, which are as given below:
  - Low cost
  - Better integration
  - More functionalities embedded
  - High interconnect density
  - Better reliability as compared to legacy optics

Challenges and Limitations

As mentioned above, Silicon Photonics definitely has various advantages that could increase its demand in the near future. However, it will be imprudent to ignore its limitations/challenges that have restricted its widespread usage at present. Given below are some of the limitations of Silicon Photonics technology:

- As a waveguide, high material attenuations are observed in silicon as compared to group III-V materials and silica. Owing to high material attenuations, it becomes difficult to build complex structures, limiting design capabilities. Also, as compared group III-IV materials, such as Indium Phosphide, the performance of Silicon Photonics is subpar.

- Silicon waveguide requires additional structures (such as grating couplers or inverted taper) with extra coupling losses for coupling on/off silicon waveguide to fiber as the typical silicon waveguide is less than 1 micrometer in diameter.
- Silicon is not considered as a good light source as Silicon does not have lase effect due to indirect band gap; therefore, laser cannot be built monolithically on silicon die. Hence, additional materials need to be bonded on the silicon substrate. Typically, germanium is added for light detection, while group III-V compounds (e.g., indium phosphide or gallium arsenide) could be monolithically developed or bonded on top of the silicon waveguide for light generation.
- High packaging is one of the main disadvantages of optics as it accounts for a large share (nearly 80%) of the total component cost owing to the need to integrate different chips in the same package and because of alignment issues.
- Standardization is also one of the limitations as standards of Silicon Photonics ICs are yet to be decided. This could affect independent OEMs, as there is a lack of surety whether their product will work when supplied to customers or not as they could incur huge losses if the non-functioning products are mass-produced.
- The cost of Silicon Photonics needs to decrease significantly for more adaption in tier 2/tier 3 and enterprise data centers.
- For longer reach applications, InP-based optics will be the dominant segment owing to superior performance. Higher optics integration will be required to achieve better performance for Silicon Photonics as compared to InP-based optics.

Opportunities

Apart from the advantages and limitations that are mentioned above, there are some opportunities, which Silicon Photonics industry could target. Given below are the opportunities:

- Silicon Photonics transceivers could observe high adoption from hyperscale data centers in middle reach applications (0.5-2km), owing to low-cost offerings. However, common design tools/platforms and CMOS process need to be standardized first
- Silicon Photonics will be high in demand due to its usage in onboard optics for supercomputers or high-performance computers. This technology will enable high-speed and ultra-high density I/O through the integration of photonics and electronics on a single platform
- In the next five years, Silicon Photonics technology could be considered as a preferred technology, which can enable large scale system-on-chip

Way Forward / Conclusions

Although Silicon Photonics has several advantages, the technology is still considered to be in its infancy, and its market penetration is expected to be slow for the next five years. However, the outlook after five years is very bright, with demand is expected to rise showing a double-digit growth. Demand for Silicon Photonics products is already on the rise in data center market and for high-performance computing.

With the rise in data rates, integration of networking silicon with optics; through FPGAs with optical I/O, high-density switches or network interface controller; will be observed. Silicon Photonics industry is expected to strive for smaller and smaller form factors with high bandwidth densities, low cost per bit, and lower power per bit.

If the limitations and challenges are eliminated, then Silicon Photonics will be the future.

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