Silicon Photonics for Data Centers and Other Applications 2016

Chanel runway in fashion at Paris’ Grand Palais – October 2016
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ABOUT THE AUTHORS

Dr Eric Mounier, Photonics, MEMS & Sensors Senior Analyst

With almost 20 years of experience in MEMS & Sensors applications, markets and technologies analysis, Dr Eric Mounier provides a very deep insight to the industry about the current and future trends for MEMS.

At Yole Développement, Dr. Eric Mounier is in charge of MEMS & Sensors, but also covers printed electronics and future disruptive technologies such as photonics.

He has contributed to more than 250 marketing & technological analysis and 80 reports in these topics, contributing the MEMS industry moving forward.

Jean-Louis Malinge

Jean-Louis is an accomplished Business Management executive with extensive experience as a General Manager and CEO in France and the United States. He also serves in numerous Boards of Directors. He is adept in formulating strategies to position or reposition numerous businesses, has led numerous acquisition projects and managed the creation of a successful Joint-Venture in Asia.

Jean-Louis is currently a Venture Partner with Arch Venture Partners. He is also Managing Director of YADAIS a consulting firm in Telecommunications and Photonics.

Jean-Louis was Kotura President & CEO from 2004 to 2013 when Kotura was acquired by Mellanox. Kotura, Inc., a worldwide leader in silicon photonics, designs, manufactures and markets CMOS optical components which are deployed throughout the communications network.

Formerly, Jean-Louis served as Vice President – Optical Networking Products for Corning, Inc. Jean-Louis’ prior experience include Technology Director with Amphenol and Thompson CSF in France.

Jean-Louis’ credentials include an Executive M.B.A. from MIT Sloan School in Boston, Massachusetts. He also holds an engineering degree from the Institut National des Sciences Appliquées in Rennes, France.
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COMPANIES CITED IN THIS REPORT

WHY THIS REPORT?

• Big data is getting bigger by the second. Transporting this level of data around with existing technologies will reach its limit in power consumption, density, weight. **Photons** will continue to replace electrons throughout the networks, including in the DC, in the rack and very soon on the board.

• **Silicon photonics** is an exciting field mixing optics, CMOS, MEMS, Advanced Packaging technologies. All these technologies converge in Si photonics, taking benefit from semiconductor wafer manufacturing scalability to reduce costs.

• Across the world, large R&D acquisitions & large R&D programs are being performed, creating **IP position** for the current players.

• Signs of **growing investments** from the VCs are appearing with recent creation of a few startups.

• Although Silicon photonics is creating a lot of buzz, the market is still modest with estimated sales **below $40M** today (2015) with very few companies actually shipping products to the open market. However, we estimate the packaged transceivers market with SiPh to be **$6B** in 10 years.

• But it is **big promises**, especially in data centers & HPC that are the big markets that will dwarf all other silicon photonics applications in the near future. But Si Photonics can also be seen as an “enabling technology” for other applications such as sensors, life science, quantum computing, telecom, consumer.

• In order to give clues to this technology and applications, Yole Développement releases this **third edition** of its “Silicon Photonics Market & Technologies” report.
SILICON PHOTONICS

Today’s status & roadmap

• Back in 2000, Bookham launched first SiPh products. Then in 2006, VOA was the 2nd Si photonics products on the market.

• Today still few Si photonics products are on the market.

• In the near term (~2020+), Si photonics chips will be deployed in high-speed signal transmission systems, which far exceed the capabilities of copper cabling: HPCs, Data Centres, Medical applications.

• As Si photonics evolves and chips become more sophisticated, we expect to see the technology used more in processing tasks such as interconnecting multiple cores within processor chips to boost access to shared cache and busses.

Roadmap
Silicon Photonics on data centers

Si photonics used for core interconnections within processors
Silicon Photonics will start being used in rack in data centers
Photons will get closer to the chips!

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SILICON PHOTONICS APPLICATIONS

- DATA CENTRES
- HIGH PERFORMANCE COMPUTING
- QUANTUM COMPUTING
- AEROSPACE & HIGH END
- TELECOM
- SENSORS & BIOSENSORS
- CONSUMER
THE SI PHOTONICS BUILDING BLOCKS

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>TYPE</th>
<th>MAIN CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Source</td>
<td>Laser</td>
<td>Single mode fiber, coherent light, intensity modulated</td>
</tr>
<tr>
<td>Modulator</td>
<td>Mach-Zehnder</td>
<td>Interferometric, wavelength modulated</td>
</tr>
<tr>
<td>Detector</td>
<td>APD</td>
<td>High sensitivity, low noise</td>
</tr>
<tr>
<td>Multiplexer - Tmix &amp; DEMUX</td>
<td>WDM</td>
<td>Wavelength division multiplexing, demultiplexing</td>
</tr>
<tr>
<td>Couplers</td>
<td></td>
<td>Light coupling, wavelength division multiplexing</td>
</tr>
</tbody>
</table>

SI PHOTONICS WDM DEVELOPMENTS

- In 2016, there is NO SiPh WDM products yet; current suppliers use parallel fibers: Luxtera, Kotura, – Cisco uses WDM for TOSA.
- This is however in developments at most players for SiPh WDM: Mellanox (Industry Consortium), IBM, Siearrays, Aurora …

MOSTLY DEVELOPMENTS

SILICON PHOTONICS TOTAL MARKET VALUE – ALL APPLICATIONS

- SiPh total market value forecast

DIFFERENT APPROACHES

- Players have different approaches depending on their “historical” backgrounds.

- Electronics system-level / assembly approaches.

- Optical system-level / assembly approaches → they are very close to market needs.

- "Pure" IC players: looks for small CDs.

- "Pure" optical players: looks for best optical design.
## OTHER APPLICATIONS: HIGH END & QUANTUM COMPUTING

- Quantum computer using an all-optical architecture where qubits are replaced by photons is a promising approach.
- Big challenge is the integration of photonic components usually incompatible with other on a single substrate. Recent advancements in Si photonics is a new approach.
- Physical Sciences Inc. (PSI) of Andrews Air Force Base and the Air Force Office of Scientific Research have formed a team to develop a Compact CMOS-Compatible Photonic Chip for Quantum Computing.

## OTHER APPLICATIONS: BIOSENSORS FOR MEDICAL

- In medical, optical biosensors have the advantages of very high sensitivity, direct, real-time & label-free (no need for a binding agent) operation with multiplexed capabilities.
- Using integrated optics on Si would lower production cost because of CMOS scalability, while adding mechanical stability and higher interaction.
- Optics can be used as a transducer to detect and measure physical changes in biological components.

## OTHER APPLICATIONS: LIDAR SENSORS

**LIDAR need lower cost for autonomous cars**

- To be autonomous, a car needs the following sensors:
  - Radar sensors (short & long-range)
  - Ultrasonic sensors
  - Cameras (visible, NIR, LWIR)
  - LIDAR
  - Dead reckoning sensors

- The “autonomy pack” for a car should be $10-$15k for at least the next 10 years.
  - Self parking = $2,000
  - Urban & autoguide = $5,000

- Improvements must be made to reduce cost, especially for LIDAR (Light Detection and Ranging).
  - The LIDAR on Google’s self-driving car uses 64 lasers to map the physical world, collecting more than a million data points on its surroundings every second.
  - This costs about $50,000. The next-gen Google car will have an $8,000 version, which is still too expensive for consumer adoption.
  - Sub-$100 LIDAR is a single-beam unit made for much simpler applications.
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