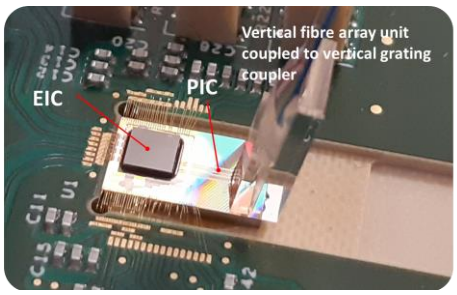
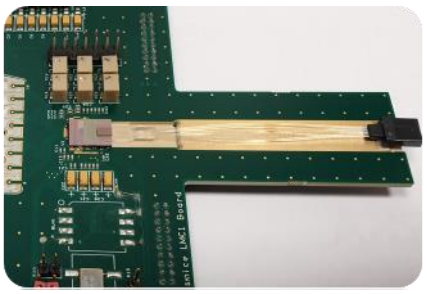
H2020 COSMICC (2015-2019) demonstrates a 100 Gb/s low-power consumption CWDM silicon photonics on-board optical transceiver module and a full library of new broad-band and athermal components on a SiN-enhanced silicon photonics platform including III-V/Si lasers for datacenter interconnects.



100 Gb/s per fiber 2-channel CWDM transceiver



24-channel polymer packaging substrate coupled to a Si photonic chip

To support the exponential growth of data traffic in datacenters, high-speed, power-efficient and low-cost transmission solutions are required

Since a few years, information and communication technologies have entered the Zettabyte era (1 ZB $=10^{21}$ bytes = 1 billion terabytes). In 2019, more than 10 ZB of information were created in a year and this number is doubling every 2 years. Datacenters are the main locations of data transmission and storage. The great challenge faced by our society is how to enable and support the exponential growth in digital information while reducing the power we consume. Compared to electrical cables, optical fiber interconnects are fast, have very low loss and do not heat-up the channel. Low-cost (<1€/Gbit/s), high speed (> 100 Gb/s per fiber) and energy efficient (< 10 pJ/bit) optical transceivers up to 2 km reach will be therefore be the key

The current optical transceiver solutions for intra-datacenter applications suffer from several limitations. VCSELs-based transceivers are low-cost but their speed and reach are limited while traditional telecom InP-based WDM transceivers can provide high rate and high reach but are too expensive. Optical integration on Silicon using CMOS compatible process, with mass-production capabilities has the promise to significantly reduce cost while meeting the needed performances.

The COSMICC consortium

The COSMICC consortium was formed to develop the technology over the whole value chain to build silicon photonics high data rate transceivers for datacenters, multiplexing several wavelength channels according to the CWDM (Coarse Wavelength Division Multiplexing) standard, with no thermal control in order to minimize the power consumption.

The consortium was led by CEA-Leti and gathered key industrial and research partners with world-leading positions in the fields of optical components (University of Soutampton, University of Paris-Sud, Cork Institute of Technology and University of Saint-Andrews), Silicon photonics

(STmicroelectronics France, CEA-Leti), CMOS electronics (STmicroelectronics Italy, University of Pavia), Printed Circuit Board-Packaging (Finisar, CEA-Leti) and PCB-embedded packaging (Vario-Optics), Optical transceivers (Finisar) and Datacenters (Seagate).

Key achievements

A major achievement was the development of a **2-channel CWDM silicon photonics transceiver packaged module at 100 Gb/s per fiber, consisting of a 3D assembly of a silicon photonic chip and its control electronic chip**. The silicon photonic chip integrated high-performance 50 Gb/s NRZ optical modulators and photodetectors, a 2-channel CWDM multiplexer and demultiplexer and vertical grating couplers for in-and out-coupling to the fiber. The control electronics was optimized to minimize energy consumption down to 5.7 pJ/bit at 50 Gb/s data rate. This transceiver is salable to 400 Gb/s with 4 fibers in parallel.

In parallel, the consortium has developed an **enhanced hybrid Si/SiN photonics technology platform**. Thanks to the introduction of a second guiding layer made of silicon nitride (a material that is 10 times less sensitive to temperature than silicon), **a full library of CWDM components was built**, including 4- and 8-channel athermal and apolar multiplexers/demultiplexers to increase the data rate to 200-400 Gb/s while removing the need for thermal control, polarization management components for the receiver part and broad-band edge and grating fiber couplers to cover the whole CWDM range.

SiN material was also used to develop athermal lasers. In a first step, **a hybrid III-V/SiN athermal laser formed by butt-coupling of a SiN and a III-V chip was demonstrated**. In a second step, technological developments were conducted to build **the first hybrid III-V/Si DFB laser integrated on the Si/SiN platform for future fully integrated transceivers with much reduced packaging compexity**. Ultra-compact and low-power Ge modulators were also integrated on the Si/SiN platform.

In addition, **a new low-cost, high-count (up tp 24) optical packaging scheme based on single mode Si/SiN/polymer waveguide coupling was developed** in order to allow for increased aggregated data rate above Tb/s by using 24 fibers**.** The implemented adiabatic coupling scheme will enable a reduction of the energy per bit of 40% at 50 Gbit/s compared to the grating coupler scheme**. A pilot line for single mode polymer packaging substrates** was developed for this purpose**.**

Impact and exploitation perspectives

Combining CMOS electronics and Si-photonics with innovative-high-throughput fiber-attachment techniques, the solutions developed in COSMICC are able to meet the future data transmission requirements in datacenters and high-performance computing systems.

SCINTIL Photonics, a spin-off of CEA-Leti, has been created to develop fully integrated photonic circuits.

Thanks to the new hybrid Si/SiN technology and the polymer packaging pilot line, new promising application markets can be addressed by the partners in the field of sensing, such as LIDARs for auntonomous cars and other environement sensors.

For more information, please see H2020 COSMICC Website : http://www.h2020-cosmicc.com/