All-optical cross-connect switch for Data Center Network application

Kristif Prifti[1], Rui Santos[2], Janguk Shin[3], Hongju Kim[4], Netsanet Tessema[1], Patty Stabile[1], Steven Kleijn[2], Luc Augustin[2], HyunDo Jung[3], Sangho Park[3], Yongsoon Baek[3], Sungkyu Hyun[4], Nicola Calabretta[1]

1: IPI research institute, TU/e Eindhoven University of Technology, Eindhoven, The Netherlands
2: SMART photonics B.V., Eindhoven, The Netherlands
3: Department of Photonic-Wireless Convergence Component Research, ETRI, Daejeon, Republic of Korea
4: R&D Center, Coweaver Co., Seoul, Republic of Korea
k.prifti@tue.nl

Abstract: We demonstrate a C-band optical cross-connect switch based on InP integrated photonics, butt-coupled to a silica PLC for facile optical alignment. The switch allows the development of low power, low latency and low-cost WDM-switches. © 2020 The Author(s)

1. Overview

Intra-data center traffic has been increasing rapidly due to cloud computing, multiple IoT applications and Big Data. To address the traffic issue properly, data center networks strongly demand a switch with high capacity, low latency and low power consumption.

We have fabricated and packaged our optical WDM cross-connect switch based on InP integrated photonics, featuring low-latency, low-power consumption and data format agnostic, enabling a novel optical data center network (DCN) architecture removing legacy electrical Ethernet switches with high-power consumption at the inter-TORs network. This optical switch has been developed as part of the Eurostar OLYMPICS project, by a consortium of SMART Photonics, Technical University Eindhoven, ETRI and Coweaver.

The InP integrated photonics chip was designed as a 1x8 wavelength-selective switch, using the generic integration platform offered by SMART Photonics. Light is coupled into the chip via a spot-size converter then amplified by an integrated SOA and broadband divided over 8 switch modules. The switch module consists of two AWGs (arrayed waveguide gratings) with a channel spacing of 400 GHz. The first AWG demultiplexes the incoming light into 8 channels, each fitted with an SOA that acts as a gate. Light passes through when the SOA is pumped above its transparency current and is then multiplexed via the second AWG to an output spot-size converter (Figure 1, inset). The electrical interfaces were designed to allow both wire bonding and flip-chip bonding.

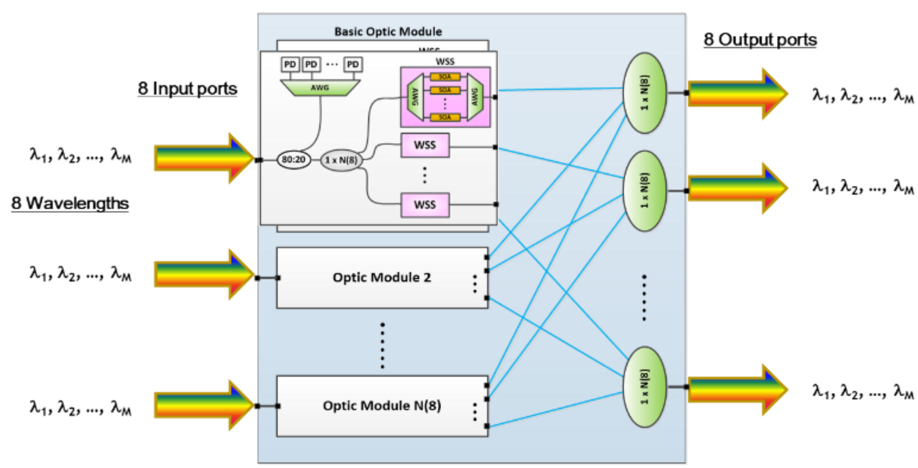

Figure 1. Schematic of the InP photonic integrated circuit 1x8 switch inside a Nx8 switch.

To avoid the costly alignment of many individual optical fibers to the InP chip, a PLC silica chip is butt-jointed to the InP chip described above, with minimal coupling loss ensured by the spot-size converters on the PLC (Figure 2). The pitch converter based on silica PLC adapts the pitch of InP chip outputs (1000, 750μm) to that of fiber array block(250μm). At the output, optical fibers are pigtailed to the PLC allowing facile connection to the network using a shuffle network to interconnect the outputs of the 8 1x8 modules to the 8 WDM output ports. The packaged optical switch is controlled by the specially designed SOA driving board supporting sub-nano second switching operation. Lastly, all the packaged active and passive optical components are installed on the line card shown in figure 2 which provides the physical and electrical communication interfaces with optical signals and upper layer control signals, respectively.

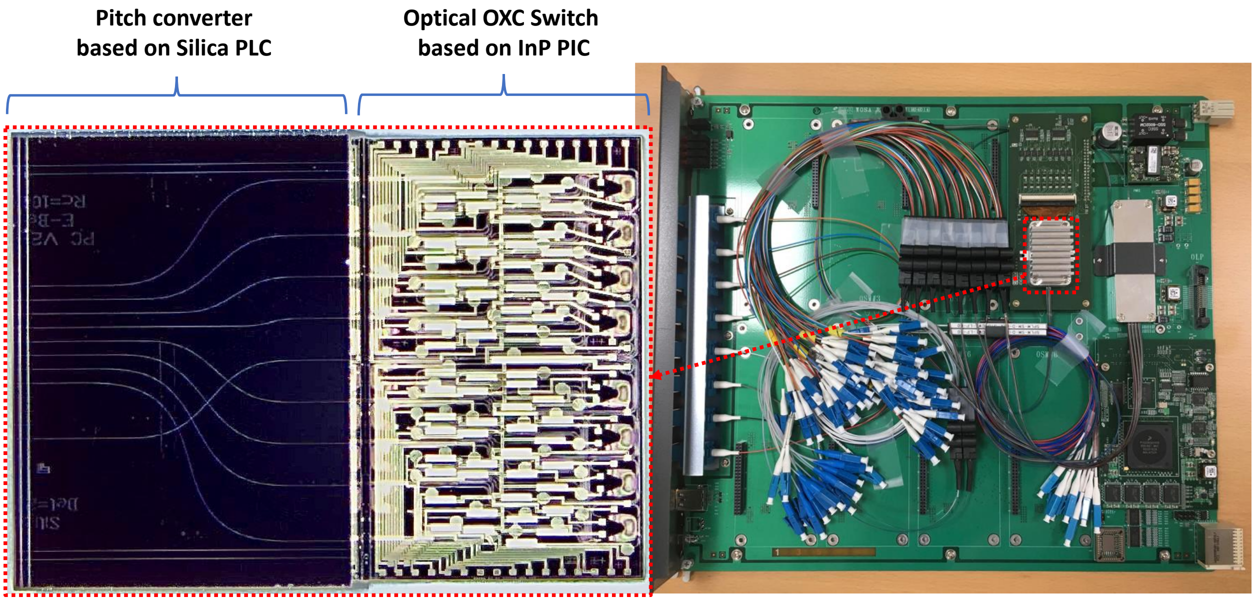

Figure 2. Left: Photograph of the PLC butt-coupled to the InP integrated circuit. Right: the line-card with its optical core highlighted.

The InP WSS chip performance was measured on a test bench, schematized in figure 3A. A preliminary measurement, sweeping a tunable laser through one WSS to test the on/off output power ratio and channel spacing of the AWGs, is shown in figure 3B. Signal transmission through the WSS was measured using a BERT at the WSS output with 6 dBm of 10Gb/s NRZ-OOK signal at the input. Preliminary BER curves are shown in figure 3C, including the back to back curve as reference. From the BER curves is seen that for the four channels with the highest output power (in Figure 3B) the power penalty is < 2 dB.

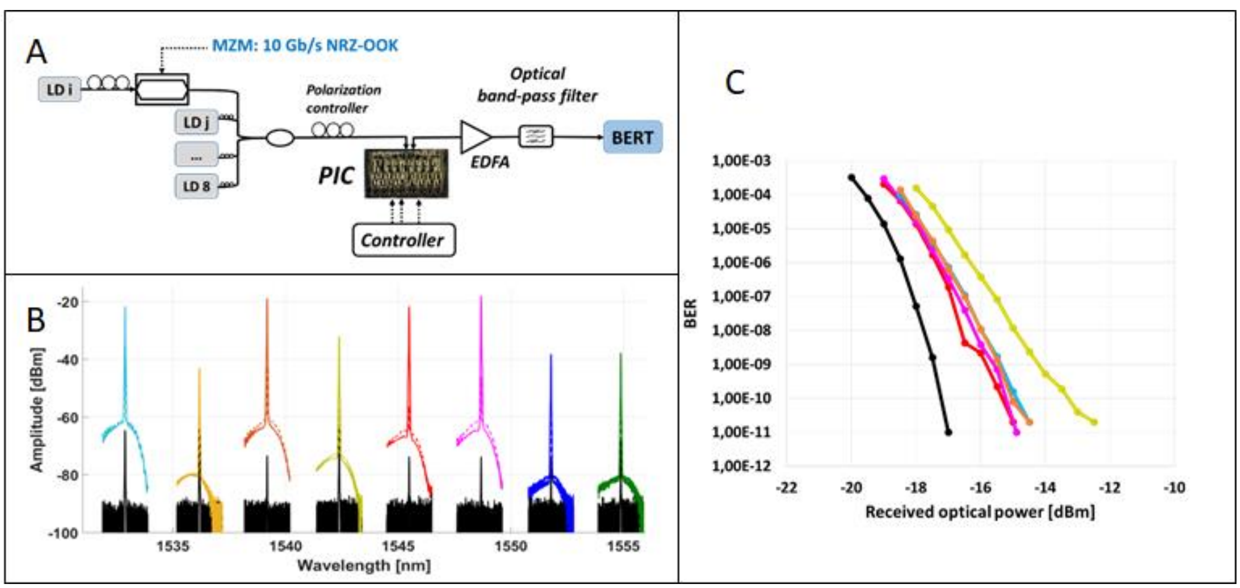

Figure 3 A. Schematic description of the experimental setup used to measure the WSS performance. B. Measured spectra of the eight WSS channels showing 400 GHz channel spacing. C. Recorded Bit Error Rate curves for five out of eight channels.

2. Innovation

Currently, most data centers are using legacy electrical packet switches based on Ethernet protocol for ToR-to-ToR interconnection, where optical packet signals carrying data and addresses are converted to electrical signals for the switching (O-E-O conversion). Legacy electrical switches consume a lot of power and expensive transceivers for the O-E-O conversion. Moreover, as the connectivity and data rate scales, the electrical switch fabric requires long process time, which results in latency. The fast (nanoseconds) and packaged optical switch we demonstrated is an innovative step to introduce high performance switching in data center networks while removing expensive and power consuming O-E-O conversion, resulting in considerable reduction in both energy consumption, latency and device cost.
Our application focuses on the intra-data center networks WDM optical matrix switches with low cost, low power consumption, and low latency. Using the SMART Photonics InP foundry C-band generic integration platform we have developed an InP-based WDM photonic cross-connect switch at 1550 nm. The InP chip is placed in a package module with an electrical PCB and housing to avoid interference between bonding wires of the 65 SOAs. Furthermore, the InP chip is butt-joint aligned to a silica PLC shuffle network with pig-tailed fiber output. The packaged WDM optical matrix switch subsystem uses the same platform as COW's commercial ROADM system and is embedded in a system line card accommodating the InP WDM photonic cross-connect switches with full SDN compatible control unit.

3. OFC Relevance

Developments in the field of fast (nanoseconds) and fully pigtailed WDM cross-connect switching are very relevant to the optical communication community gathered at OFC, as shown by the amount of sessions around this subject. The use of fully pigtailed WDM cross-connect switches is expected to increase further due to their increased adoption not only in data center interconnected networks but also in metro networks for 5G wireless access. We will demonstrate novel fully pigtailed prototype optical switch subsystem based on InP integrated photonics as a core component for a WDM cross-connect switch with reduced latency, power consumption and cost.

During the demo the pigtailed prototype optical cross connect switch will be transported to OFC and operated with an SDN controller to show the operation and reconfiguration of the multiple output ports. A remote connectivity with the TU/Eindhoven data center laboratory will show a real time operation of the prototype switch interconnecting 4 TORs (each of them connecting 4 servers), providing reconfiguration to a small scale data center.

Acknowledgement

In this research, the Korean team was financially supported by the Ministry of Trade, Industry and Energy (MOTIE) and Korea Institute for Advancement of Technology (KIAT) through the International Cooperative R&D program (Project N0002613). The work of all project partners was financed partially by the European Union Eurostars project: "Olympics" (Project ID 11471).