Nano Scale Disruptive Silicon-Plasmonic Platform for Chip-to-Chip Interconnection

Final planning of system demonstrator

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List of Partners concerned

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Executive Summary

This document shall incorporate (all) rules procedures concerning the technical and administrative management of the project and is therefore to be updated on a regular basis. Please look at www.navolchi.eu regularly for the latest version.

Change Records

Version	Date	Changes	Author
1 (submission)	2015-07-17		Claudia Hoessbacher
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Introduction

Following review no3, the commission recommended an additional milestone report on the final planning of the system demonstrator based on actual progress in devices. In this milestone, MS50, we summarize the progress in individual devices and report on the final planning of the system demonstrator. So far, activities towards NAVOLCHI's demonstrator were mainly related to the transmitter side which are described in detail. The plasmonic **4-channel MZM array** has been **successfully demonstrated at 36 Gbit/s**. The optical link using **multicore fibers** was proven to **work well** for the demonstrator, while the **electrical board** is still **under fabrication**. For the receiver, IMEC forwarded **Ge-PDs** to ETH which are **about to be characterized**.

Progress in devices

On the **transmitter** side, significant progress in the **metallo-dielectric nanolaser** was achieved during the last months. TU/e presented the first metal-cavity nanoLED based on III-V materials coupled to a silicon waveguide. While the results are promising and will be improved until the end of the project, the linewidth and the output power of the light source are not yet at a stage to be integrated in the system demonstrator, which has high quality requirements. Moreover, NAVOLCHI's plasmonic phase **modulator** (KIT) has been realized by with attractive characteristics. 40 Gbit/s on-off keying (OOK) modulation were demonstrated in a Mach-Zehnder configuration with a phase shifter length as small as 29 µm. The modulator therefore fulfills all requirements for the system demonstrator.

On the **receiver** side, concerning the development on the plasmonic **amplifiers**, the most promising development is related to HgTe QDs operating at 1550 nm wavelength. While sufficient gain could not be achieved with optically pumped polymer waveguides, a second design based on SiN waveguides and electrical pumping is on the way. Furthermore, PbS-QD Shottky **photodiodes** with a responsivity of 0.45 A/W at 1550 nm were demonstrated by UVEG. However, since response times were still around 100 µs, further improvements in speed are necessary, before the devices can be used for high-speed data transmission experiments.

Final planning of the system demonstrator - Overview

Though improvements in individual device performance were made, NAVOLCHI's system demonstration has particular high quality device requirements. These requirements will probably be met by individual devices in the future. However, since the project is about to be finished, NAVOLCHI demonstrator planning will focus on the contingency plan according to the "Description of Work" document (page 80). The planned chip-to-chip plasmonic interconnect is shown in Fig. 2. Light from an **external laser** is fed to an array of **four plasmonic modulators**. The light splitting in four channels can be done either off- or on-chip. All four modulators are driven with electrical signals coming from an FPGA after amplification on an **electrical board**. IMEC's conventional **Si-Ge photodiodes** are used to make the optical to electrical signal conversion. The electrical signals after the photodiodes are amplified with the trans-impedance amplifiers and fed into the second FPGA. The optical link between transmitter and receiver will be realized through **multicore fibers**. With this scheme, we target the specifications summarized in Table 1.

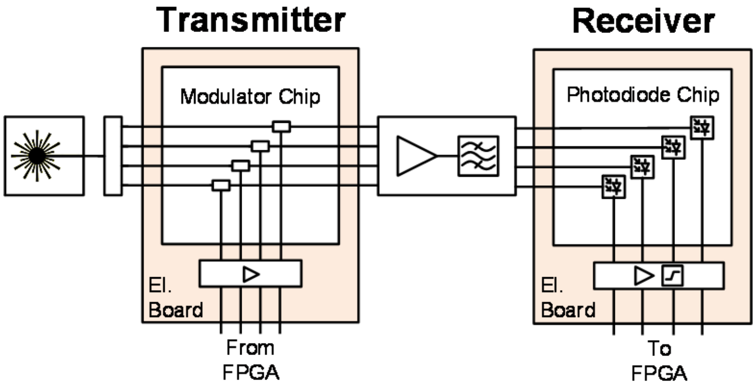

Fig. 1 Schematic of NAVOLCHI system demonstrator consisting of an external laser source, NAVOLCHI's plasmonic phase modulator and conventional Ge p-i-n photodiodes. A PCB board will provide necessary driving electronics. Between transmitter and receiver, a fiber coupling scheme (multicore fibers) will be used.

Table 1 Targeted specifications of NAVOLCHI system demonstrator

Feature	Target
Number of channels	4
Distance between channels	50 µm
Data rate	4 x 40 Gbit/s
Modulator length	≤ 30 µm
Total insertion loss single modulator	≤ 40 dB
Optical bandwidth	100 nm
Energy consumption single modulator	≤ 300 fJ/bit

Optical link between transmitter and receiver

The optical link between transmitter and receiver shall provide minimum light loss and the possibility to place an additional optical amplifier between the two chips. This link is a particular challenge, due to the fact that the **distance between the optical channels is only 50 µm**. In deliverable 6.2, the consortium decided to use a **multicore fiber** (Chiral Photonics, PROFA) as shown in Fig. 2. The multicore fiber consists of 19 channels with a pitch of 50 µm where we use four for our system demonstrator. Transmission measurements showed a power penalty compared to standard single mode fibers of less than 1 dB. To investigate the optical crosstalk, we fed 4 different wavelengths through **4 different channels** of the MCF, while coupling to standard silicon waveguides. The optical output spectrum of each channel was recorded using an optical spectrum analyser. The **optical interchannel crosstalk** was found to be **better than -31 dB in all instances**, Fig. 2 (right).

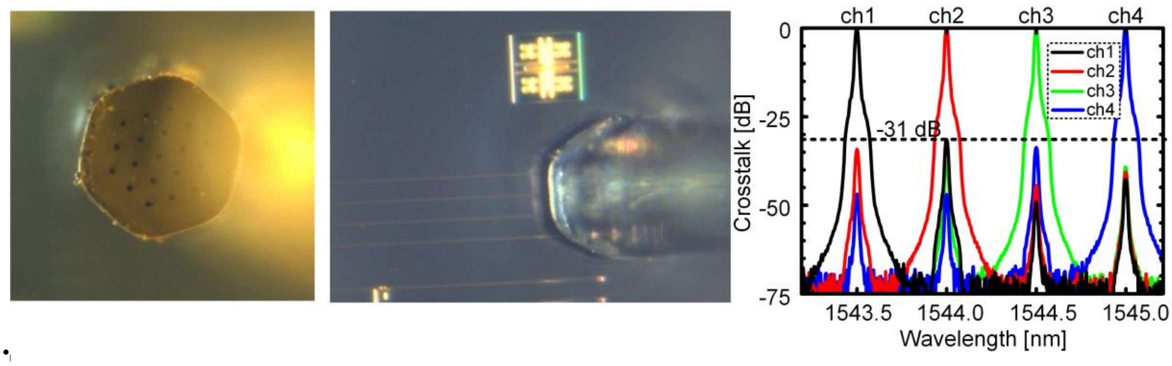

Fig. 2 Multicore fiber: (left) facet with 19 channels; (middle) top view when coupling to four channels on chip. (right) Optical interchannel crosstalk below -31 dB for four channels. The spectra were obtained by coupling four different wavelengths to the multicore fiber.

Transmitter electronics

Fig. 2 shows the electrical board and housing that are **currently in fabrication** by ETH. **Wire bonding** will be used to electrically interconnect the board with the photonic/plasmonic chip. Main **challenges** concerning the driving electronics are: Firstly, the **high frequencies** require high precision alignment and K-connectors in order to minimize electrical crosstalk and allow 40 GHz operation. Secondly, a **high thermal density** is expected due to the RF amplifiers that is addressed by a cooling unit below the transmitter. As shown on the right side of Fig. 2, a **first prototype** electrical board was fabricate where we used SMA-connectors (limited 10 GHz) to simplify fabrication. First tests on the electrical characteristics showed up to 24 dB gain at 1 GHz.

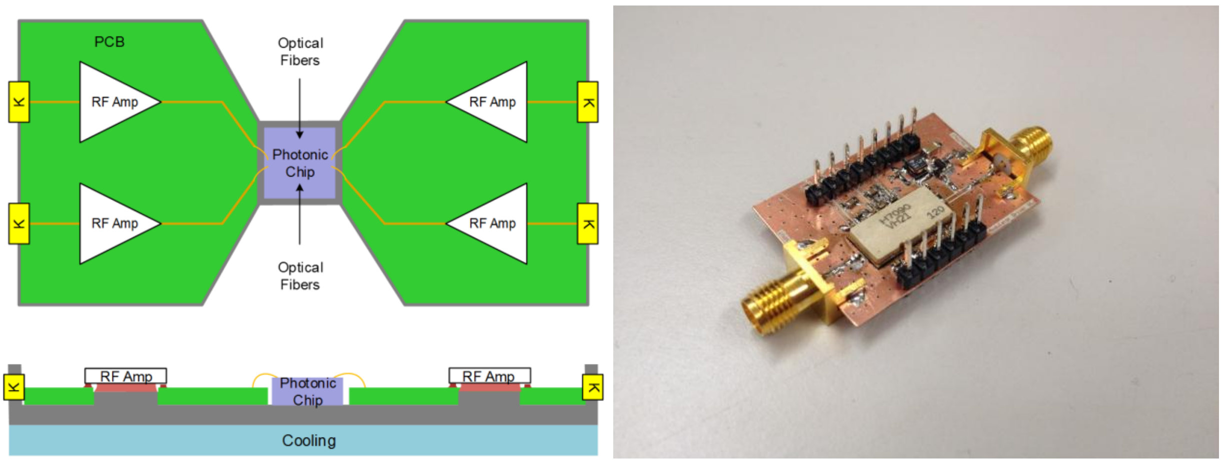

Fig. 3 Top view and cross section of planned transmitter electrical board (left) and its first prototype (right)