# Photonic integrated multiwavelength transmitters for Fiber-To-The-Home networks

## Multi-project wafer run and generic integration concept


K. Ławniczuk, M.K. Smit, X.J.M. Leijtens
COBRA Research Institute
Eindhoven University of Technology
Eindhoven, the Netherlands
e-mail: k.lawniczuk@tue.nl

M.J. Wale
Oclaro Technology Ltd.
Caswell, Towcester, Northamptonshire
NN12 8EQ, United Kingdom

R. Piramidowicz, P. Szczepański
Faculty of Electronics and Information Technology,
Warsaw University of Technology
Warsaw, Poland



*Abstract*— **In this paper we present measurement results of monolithically integrated photonic transmitters for application in the next generation Fiber-to-the-Home (FTTH) networks. 4- and 8-channel transmitters were integrated onto a single chip, using multiple lasers with distributed Bragg reflector (DBR) resonators and electro-optical modulators in Mach-Zehnder configuration. Optical signals are multiplexed into a single output port using an arrayed-waveguide grating (AWG).**



***Keywords-component; photonic integration, multiwavelength transmitters, InP, multi-project wafer run***


## I. Introduction

Nowadays photonic integration is the most promising technology for realization functionally advanced and compact optical circuits. Additionally, by offering high-speed elements that operate at a data rate of at least 10 Gbps, this technology may satisfy the requirements for photonic devices to be used in the next generation optical communication systems. In such networks, like future-proof FTTH systems, the key components (transceivers) are typically localized in the central office (CO) [1]. It means that in the CO the detection of upstream signals and the transmission of downstream signals take place. By combining passive and active optical components into a monolithically integrated photonic circuit, a multi-wavelength transmitter for the CO can be made. We have chosen indium phosphide (InP) and related ternary and quaternary compounds as an attractive material for the integration, mainly because of the direct-bandgap properties suitable for light generation and detection, light guiding, and fast phase modulation.

## II. Design and Fabrication

The photonic integrated transmitters presented in this paper were realized on an InP-based platform following the generic integration concept [2]. This approach enables design and fabrication of a wide variety of different photonic devices using the same technological processes and a limited set of basic building blocks [3]. Additionally, by participating in multi-project wafer (MPW) runs a significant reduction in fabrication and packaging costs of photonic chips should be possible in the near future. Within the EU programme EuroPIC [4] we explore such generic processes and develop photonic building blocks in cooperation with foundry fab partners: Oclaro in the United Kingdom and Fraunhofer Heinrich Hertz Institute in Germany. Our devices were realized in an industrial fab according to these generic concepts as one of the first multiwavelength transmitters of this kind.

One of the methods to realize photonic multiwavelength transmitters is through integration of an array of DBR-based lasers with an AWG. In our photonic circuit, the downstream modulated (DS) signals, as well as the upstream data (CW), are generated by a single device. To generate the DS data, modulation is required. This has been done by introducing electro-optical modulators in a Mach-Zehnder configuration, as schematically presented in Fig. 1 (*left*). The AWG acts here as multiplexer of all generated CW and modulated DS signals and directs the signals into a common output waveguide.

The photograph of the fabricated chip is shown in Fig. 1 (*right*). It contains a 4-channel and an 8-channel transmitter as well as a number of test structures of DBR laser. The transmitters integrate DBR-based lasers with 1-mm-long Mach-Zehnder modulators (MZMs). Each DBR laser consists of 4 sections: (1) a front grating (FDBR) providing partial reflection (50 µm long), (2) a rear grating (RDBR) giving near 100% reflection (500 µm long), (3) a phase control section (PH) to fine tune the phase of the generated signal (130 µm long), and (4) a semiconductor optical amplifier (SOA) that provides the gain within the structure (500 µm long). The wavelength selection is done by proper design of the grating period of the DBR sections and this can be additionally fine-tuned by current injection into each of the gratings and to the phase elements as well. The tuning range of the DBR-based lasers is sufficient to tune each of the sources to the peak of the

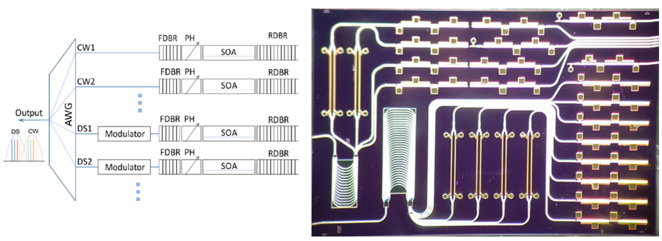


Figure 1. Schematic of the transmitter (*left*) and the photograph (*right*) of the fabricated devices. The size of the chip is only 4 mm x 6 mm.

proper AWG passband. The AWGs were designed for a central wavelength of 1550 nm, and a channel spacing of 100 GHz (8-channel device) and 200 GHz (4-channel device).

## III. Measurements Results

The measurements were done at room temperature using a lensed fiber-tip to couple the light out from the chip. A high resolution (0.16 pm) Optical Spectrum Analyzer, APEX P2041A, was used to record the spectral characteristics of the transmitters. To obtain static characteristics, we used needle probes to bias the SOAs, DBRs, PHs and modulators. To measure the dynamic RF response of the MZMs, a submount and wire bonding to DC and RF pads was required.

The measured emission spectra of the 4-channel transmitter, with a channel spacing of 200 GHz, are presented in Fig. 2. The conditions set to the DBR laser were chosen to optimize the device for the generated wavelength and the output power. The SOAs were biased around 100 mA and the DBRs between 0.6 mA and 12.5 mA. The obtained threshold currents of the DBR lasers are less than 18 mA. The measured out-coupled output power is above 1 mW. The fine tuning of the lasers (of 1.5 nm within the AWG passband) can be done by applying the current to the phase section and this experiment is shown in Fig. 3 for one of the DBR lasers from the 4-channel transmitter. The measured tuning range of a single DBR is 9 nm.

The static extinction ratios of one of the modulators integrated into 8-channel transmitter and wire-bonded device is presented in Fig. 4. The obtained $V_{\pi}$ is 4.6 V (reverse biased) with the static extinction ratio up to 25 dB. The signal directed to the modulator originated in the DBR laser integrated within the circuit. We performed the measurements for different

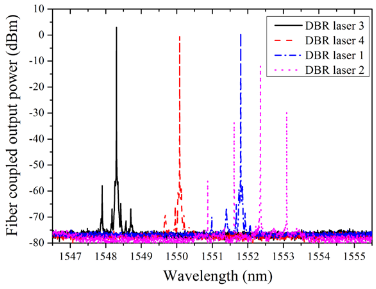


Fig. 2. Emission spectra measured for the 4-channel transmitter. The wavelength generated by the DBR laser no 2 was not properly tuned to the center of the AWG passband, which can be noticed on the spectrum.

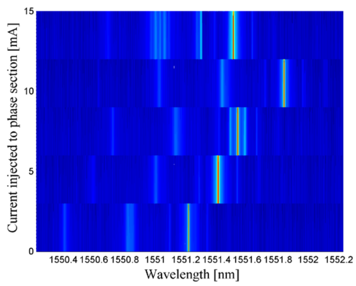


Fig. 3. The fine tuning of the DBR laser no 1 while biasing the SOA with 60 mA and changing the current injected to the PH. The source can be adjusted to the required wavelength, within the AWG passband by proper bias of the PH element. DBR mirrors remain unbiased for the experiment.

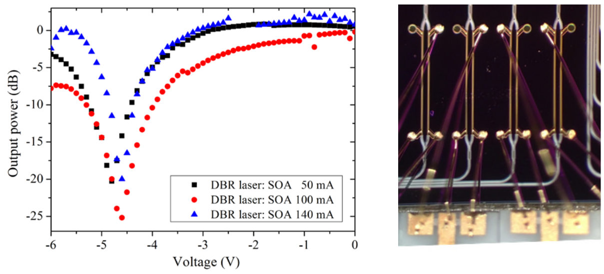


Fig. 4. Measured extinction ratio of 1 mm long MZM while changing the current injected to the SOA of the DBR laser (*left*). The photograph of wire-bonded modulators (*right*).

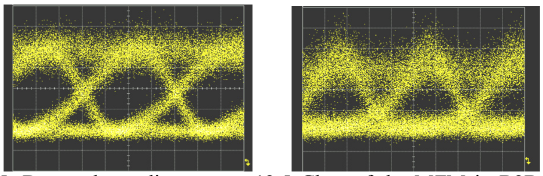

Fig. 5. Detected eye-diagrams at 12.5 Gbps of the MZM in B2B (*left*) and after transmission through 20 km long SMF (*right*).

currents injected to the SOA to evaluate that the $V_{\pi}$ is not significantly dependant on the injected optical power. The dynamic RF experiments showed that this kind of MZM can operate with the data rates up to 12.5 Gbps, which is shown in Fig. 5. For the RF dynamics we performed measurements in back-to-back (B2B) configuration (without a fiber) and after introducing 20 km long single-mode fiber (SMF) into transmission setup.

## IV. Summary

We demonstrated the operation of monolithically integrated photonic transmitters based on DBR lasers and Mach-Zehnder modulators. The results show that complex photonic integrated circuits can be effectively realized using a generic approach and fabricated through participating in the standardized MPW runs offered by the foundry's platform. First characterization results of the devices show very promising performance of this type of photonic circuit to be used in next generation optical networks.

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