

# InP-based integrated OLT and ONU with cyclic AWG for WDM-PON

*Student Paper*

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## ABSTRACT

In this work we demonstrate integrated multichannel transceivers dedicated to cost-optimized, fiber-optic communication systems. Two different transceivers are discussed - Optical Line Termination (OLT) and Optical Network Unit (ONU), designed for an application in the WDM-PON access system. The application of cyclic arrayed waveguide gratings (AWGs) is tested in order to achieve better performance of integrated transmitters. Open eye diagrams and an error-free operation at -17 dBm prove the applicability of developed circuits to access systems with wavelength multiplexing.

**Keywords:** photonic integrated circuit, InP, multichannel transmitter, arrayed waveguide grating, optical access network, cyclic AWG

## 1. INTRODUCTION

Modern transmission systems exploited today, all-optical and optically transparent at the level of core and metropolitan network, enable extremely high speeds of data transmission of the order of Tb/s. The main bottleneck limiting the bandwidth is still in the access networks, which are partially still based on copper lines, utilized previously for telephone networks, limiting the possibilities of fast data transmission [1]. Consequently, the development towards the optical access networks is a must. Nowadays passive optical networks (PON) are the most popular solution offering advantages of broad-band transmission, simplicity and low cost of equipment. In order to provide a high-speed, all-optical, symmetric transmission of digital signals, the passive optical networks with the wavelength division multiplexing technique (WDM-PON) [2] are considered as one of attractive approaches. WDM-PONs might offer higher bandwidth per optical network unit (ONU), lower splitting losses and higher link reach?? [3]. A typical WDM-PON uses a single Optical Line Termination (OLT) and several Optical Network Units (ONUs). Generally, OLT is located at a service provider's signal office and ONUs are located at end users' premises.

The InP-based PICs offer advantages of low cost, small size and limited power consumption and provide impressively high reliability. This has resulted in extensive research of PICs applications in the optical telecommunication, addressing topics such as access networks, metro and core networks as well as data communication [4]-5].

In this work, we present and discuss the design of a transmitter with a cyclic arrayed waveguide gratings (AWG) for application in access systems. Application of cyclic AWGs is a solution for compensating technological problems with appropriate matching the wavelengths of integrated lasers with the bandwidth transmission of AWG channels, reported in our previous works [6-7].

## 2. DESIGN

The schematic of the proposed WDM-PON system based on PICs is presented in Fig 1. The OLT Tx PIC was designed for operating as an OLT transmitter. It has six channels connected to an 8×8 AWG. Each of these channels contains a DBR laser and an electro-absorption modulator. Each laser comprises a 150 μm-long semiconductor amplifier (SOA), two Bragg gratings and two isolation sections. The emission wavelengths of the lasers are matched to the AWG passbands. Two channels are connected to the photodiodes, which allows testing the spectral characteristic of the AWG. The AWG has the following parameters: channel spacing  $\Delta\lambda = 0.8$  nm, FSR = 6.4 nm and central wavelength  $\lambda_C = 1572.8$  nm. The choice of the spectral parameters was dictated by the wavelength range of modulators (1570-1580 nm). All outputs of the AWG are connected to the outputs of the chip. The OLT Rx was designed as the receiving part of the OLT. It consists of an array of eight photodiodes connected to a cyclic AWG (with the same parameters as in the previous chip). The last of the designed chips was intended for operating as two ONU circuits. It contains two transmitters and two photodiodes. The OLT Rx and ONU TxRx have also test structures of lasers with modulators and photodiodes.

The downstream signal is generated by OLT Tx and with one of the outputs of AWG connected through a circulator to the fiber-optic link. This signal is received by one of the photodiodes in ONU. The upstream signal is generated in the ONU TxRx and with circulators and (de)multiplexer addressed to the OLT Rx.

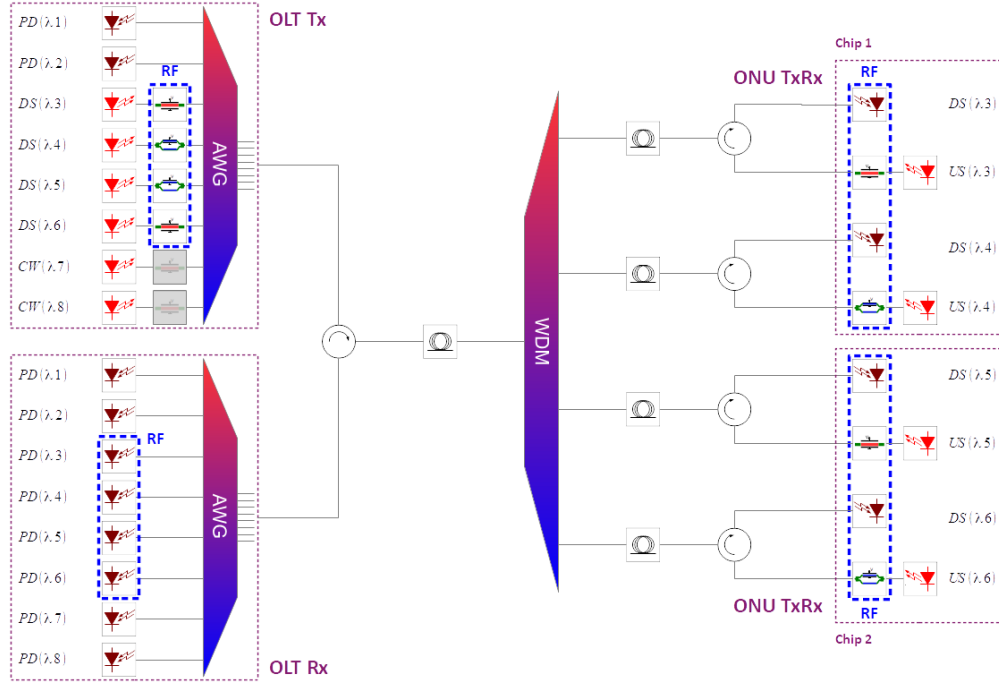


Figure 1. Schematic of proposed WDM-PON based on InP transmitters and receivers.

All chips, realizing the above described functionalities were designed using generic approach and fabricated in a generic foundry process [8-9]. Fig 2. presents microscope photographs of designed and manufactured circuits.

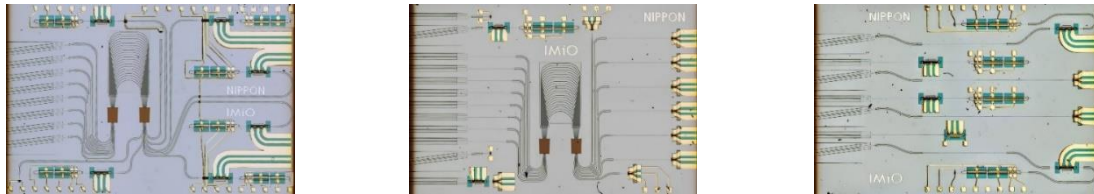


Figure 2. Microscope photographs of designed PICs from left: OLT Tx, OLT Rx, ONU TxRx

### 3. CHARACTERIZATION

For experimental evaluation all the chips were mounted on copper blocks and thermally stabilized at 20°C. The output signal was collected from SSCs with SMF fibres. Measured thresholds of all lasers were in the range from 30 mA to 40 mA. The output power of both transmitters reaches about 0.5 mW (-3 dBm). The single-mode operation was observed with side-mode suppression ratios above 30 dB. The static extinction ratio above 15 dB was recorded.

The dynamic measurements of both transmitters were also performed. The 10 Gb/s PRBS signal was applied to the modulators together with DC voltage. The signal from the PRBS was amplified by a broadband amplifier (SHF 100APP) to amplify the RF signal. A digital sampling oscilloscope was used to capture the eye diagrams, which were measured in a back-to-back configuration (B-t-B). The biasing parameters were adjusted to achieve the most open eye diagram. The SOA of a laser was biased 154 mA /180 mA, the DC modulator bias were 1.64 V/1.5 V and  $V_{pp}$  1 V/0.5 V for the OLT Tx/ONU Tx Rx. A sample measured eye diagram is presented in Fig. 3. The dynamic extinction ratios were 6.3 dB (OLT Tx) and 7.2 dB (ONU TxRx). The eye diagram is more open in ONU TxRx than in OLT Tx, due to the absence of AWG in the latter.

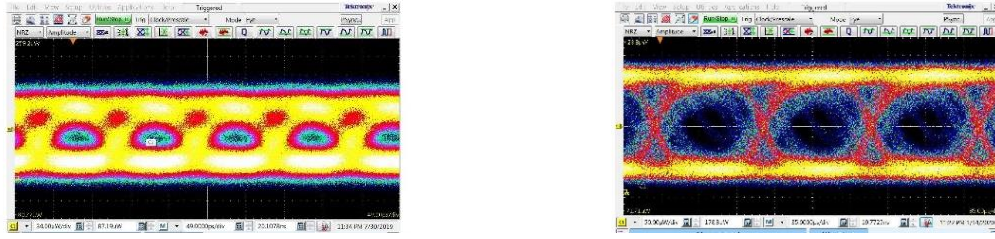


Figure 3. Recorded 10 Gb/s eye diagrams of OLT Tx (left) and ONU TxRx (right) transmitters.

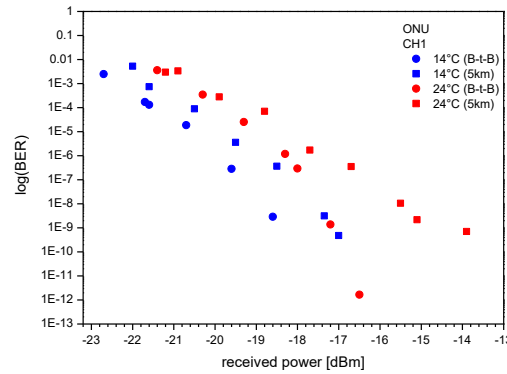


Figure 4. Bit error for ONU transmission in back-to-back configuration and 5 km in 14 °C and 24 °C.

The bit error ratio (BER) measurements were performed using a BER tester. Figure 4. shows measured BER curves of the channel CH1 of the ONU TxRx chip, recorded for two different temperatures (14°C and 24°C). The transmitter in the lower temperature shows better performance with an error-free operation of -17 dBm compared to -14 dBm for 24°C.

#### 4. CONCLUSIONS

In conclusion, we have demonstrated the WDM-PON link based on PICs equipped with a cyclic AWG. The output power of the transmitters was around 0.5 mW, extinction ratio was above 15 dB, side mode suppression ratio was above 30 dB. Open eye diagrams and error-free operation at -17 dBm prove that photonic integration technology can be efficiently applied to develop a new type of transmitters for access systems.

#### ACKNOWLEDGEMENTS

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