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New Architecture for reconfigurable WDM-PON Networks based on SOA Gating Array

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Abstract

A new architecture of reconfigurable WDM-PON networks for the dynamic capacity allocation is proposed and experimentally demonstrated. The architecture based on an SOA gate allows 1μs switching time to the re-allocation of wavelength resources.

1 Introduction

Optical access networks have provided large bandwidths to home users, business users, and mobile backhaul. In those networks, the network traffic is fluctuating with time and place. For example, a home user demands bandwidth mainly in the evening for applications such as high-definition videos. During the day, the bandwidth can be diverted to business users who have high-demand for a virtual video conference and high-volume file transfers for short durations. Thus, it is necessary to allocate the network bandwidth to users according to the traffic variation. This dynamic capacity allocation of network resources also improves the system efficiency [1].

With enormous traffic increment, a static wavelength division multiplexed passive optical network (WDM-PON) has got a great interest in optical access networks due to their large capacities. However, a static WDM-PON has lack of the re-configurability required to adapt their capacity allocation to instantaneous traffic. In the other word, traffic statistical multiplexing in a static WDM-PON can only be performed in the time domain within a wavelength channel, not across all channels.

To solve the dynamic capacity allocation in WDM-PON networks, we propose a new architecture of WDM-PON networks with a remote node (RN) based on semiconductor optical amplifier (SOA) gates. A remote node, controlled by a central office (CO), manages the allocation of network resources in the middle of network, which also improves the network performance in terms of security and power consumption. For the proof of the concept, we successfully demonstrated the wavelength allocation with 1μs switching time of SOA gates under the WDM-PON scenario.

2 Proposed network architecture

Figure 1 shows the proposed network architecture, which consists of three parts: an optical line terminal

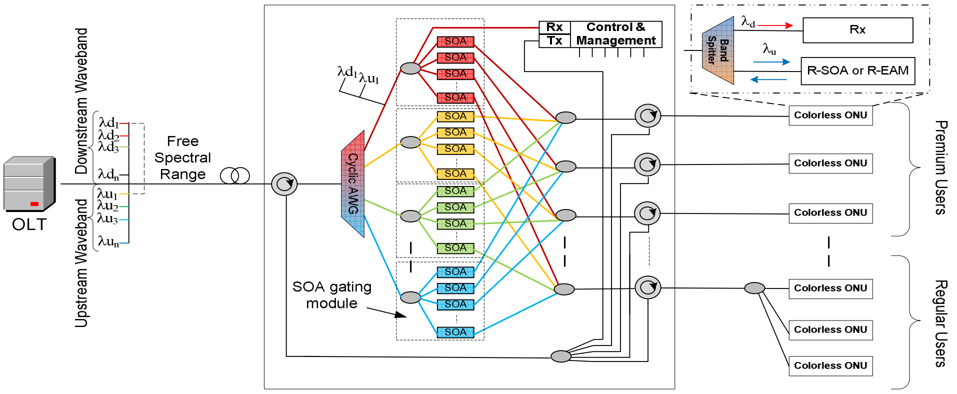

Fig. 1 Reconfigurable WDM-TDM PON architecture for dynamic capacity allocation

(OLT), a RN, and optical network units (ONUs). A remote node based on SOA gating modules, which is the main part of the system, is able to allocate desired optical channels to one or more output ports connected to ONUs.

The OLT transmits two wavelength bands for downstream and upstream link. After transmission of a certain distance, those optical signals are separated into pairs of up- and down-stream wavelengths by an arrayed waveguide grating (AWG) router in the RN, in which a pair of up- and down-stream wavelengths are a free spectral range (FSR) of the AWG apart from each other. Then, each pair of optical signals is routed to the corresponding SOA gating module, which consists of a 1xN passive coupler and an SOA gating array, and each output is connected to different ONUs as shown in Fig. 1.

Thus, by gating each SOA gate independently according to the control signal from the OLT, the pair of optical wavelengths can be dynamically allocated to ONUs. For example, usually an optical channel (λ_1) is shared by several ONUs. If a new demand of a certain ONU (*ONUx*) exceeds the available capacity of the channel, a static WDM-PON network cannot serve a new demand to the ONU. In the proposed architecture, however, by shutting the SOA gate, which is dedicated to the optical channel (λ_1), linked to ONUx, and opening another SOA gate linked to ONUx in the SOA gating module for λ_3, a new demand of ONUx can be served as depicted in Fig. 2.

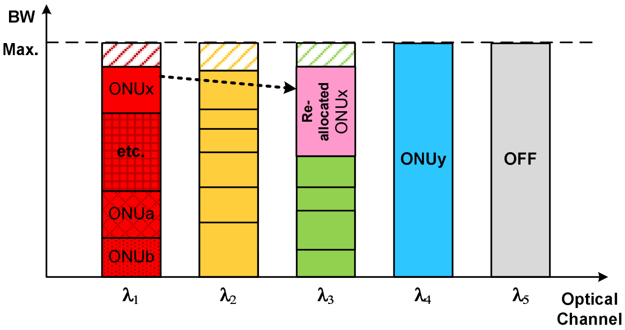

Fig. 2 Bandwidth allocations between optical channels

3 Experiments

Figure 4 shows the experimental setup of the proposed architecture. Two pairs of up- and downstream wavelengths are used: channel 1 (λ_{d1}=1560.92nm (down), λ_{u1}=1555.75nm (up)) and channel 2 (λ_{d2}=1549.32nm (down), λ_{u2}=1541.35nm (up)). The downstream optical signals are carrying the downstream data (*2.5Gb/s, PRBS* 2^{23}*-1*), but the upstream optical signals are of unmodulated continuous wave (CW) where they are used as a seeding optical signal for a reflective SOA (R-SOA) modulator in the ONU. In the RN, the outputs of the same optical channel are combined together to emulate the cyclic property of an AWG as depicted in Fig. 4. Then, each optical channel is injected to SOA gates, respectively. For an SOA gate, a standard SOA (CIP, SOA-S-OEC-1550) is used, which has a small signal gain of 22dB @100mA, a saturated output power of 8dBm @100mA. The ONU is served with different optical channel by gating the SOAs complementarily for each time slot of *50µs* as shown in Fig.3.

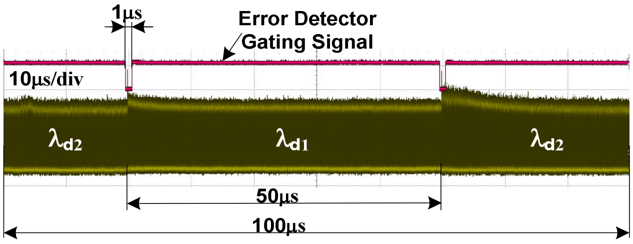

Fig. 3 Allocation of optical channels by gating SOAs (time trace)

For the upstream modulation, the CW optical signal (λ_d) is modulated through the R-SOA with 1.25Gb/s (PRBS 2^{23}-1). In the upstream link, the modulated upstream signal is transmitted directly to the OLT, not passing by SOA gates.

To evaluate the system performance, we did a bit-error rate (BER) test for up- and down-stream link. As shown in Fig. 5, three cases are considered: the entire system, SOA back-to-back (B2B) where 20km and 5km fiber links before and after the RN are removed, and optical B2B. In downstream link shown in Fig. 5(a), the cases of the entire system and SOA B2B show almost the same performance though there is 2 dB power penalty, compared to the optical B2B. Those mean that the SOA is the dominant source of impairment in transmission; the amplified spontaneous noise (ASE) noise and nonlinearity of an SOA degrades the signal-to-noise ratio of optical signals.

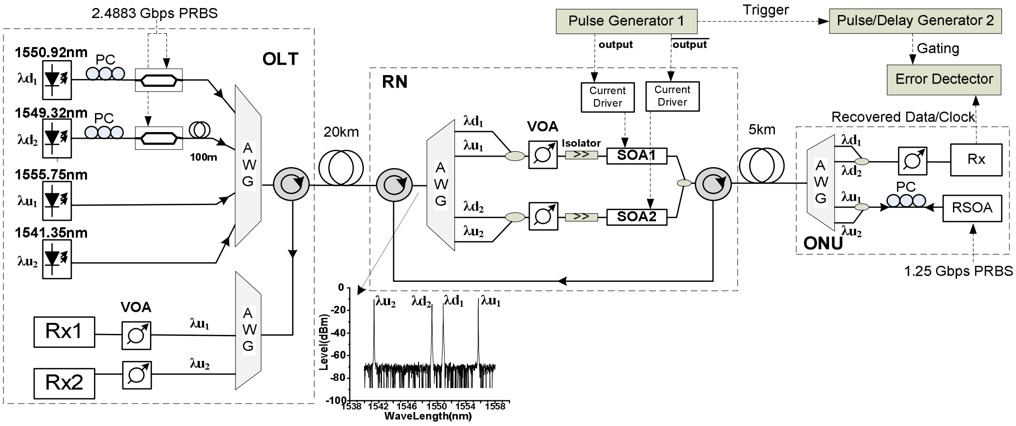

Fig. 4 Experimental Setup

In the upstream link, an R-SOA is used for the upstream modulation as mentioned before. Due to the chirping of an R-SOA and fiber dispersion, the quality of the modulated upstream signal gets worse with transmission. We think those effects and the Rayleigh backscattering contribute to the impairment, 6dB power penalty after transmission. Even though the CW optical signal for the upstream is exposed to the ASE noise of the SOA gate during the downstream transmission, the effect of the ASE noise to the upstream link is negligible as shown in Fig. 5(b).

4 Conclusions

In this paper, we proposed and experimentally demonstrated a new WDM-PON architecture for the dynamic capacity allocation. By dynamically allocating wavelengths with fast SOA gating in the RN, full flexible reconfigurability can be achieved. In the demonstration, SOA-gates in the RN gave 1µs fast switching time to reconfigure the optical connections to ONUs. When multiple applications are served to ONUs, the reconfiguration time of optical channels with different wavelength should be short enough to keep the seamless connections. According to the ITU-T recommendation G.114 [2] and Y.1541 [3] for the telephony that is the most delay-sensitive application, 1µs switching time can guarantee seamless performance of on-going services.

Acknowledgements

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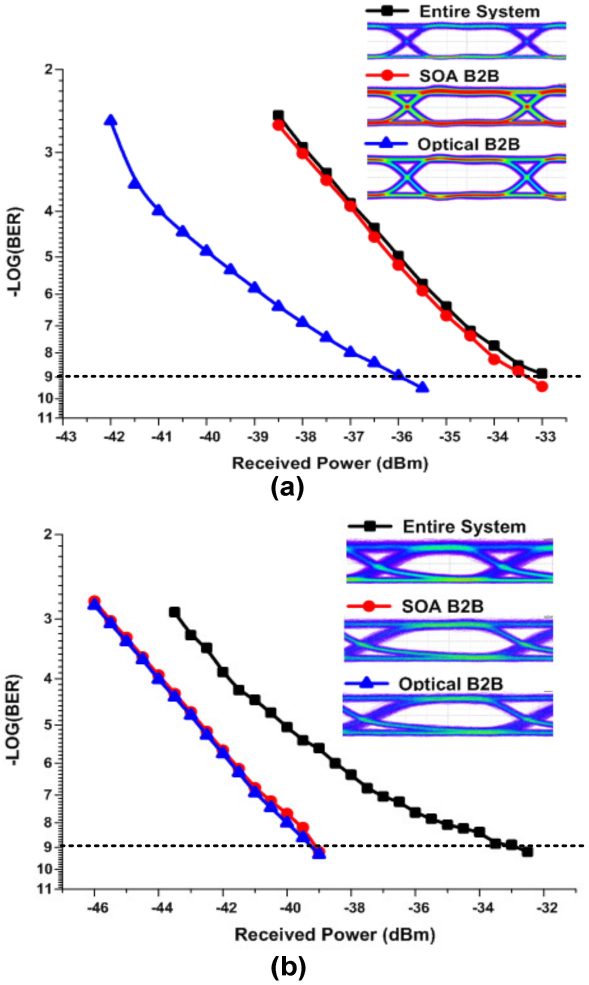

Fig. 5 BER Performance for (a) downstream link, (b) upstream link (25km bi-directional link)

5 References

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