12.5-GHz Spaced Downstream Transmitter for Long Reach DWDM-PON

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Abstract: A downstream transmitter based on comb source and injection-seeding scheme is proposed for long reach DWDM-PON with 12.5-GHz channel spacing. RSOAs are used in OLT and 1.25-Gbps data is directly modulated on each channel. The experimental results show that transmission over 150-km SMF is achieved.
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1. Introduction

The next generation access network desires large number of users, long distance transmission and high sustainable rate [1]. Dense wavelength division multiplexing passive optical network (DWDM-PON) is intensively considered as a promising solution to meet these demands [2], since it utilizes the limited bandwidth more effectively and increases number of users in C-band. To reduce the cost of colorless transmitters in DWDM-PON system, broadband injection schemes based on amplified spontaneous emission (ASE) are proposed, which use reflective semiconductor optical amplifiers (RSOAs) and Fabry-Perot laser diodes (FP-LDs) for light source injection locking and data modulation [3-5]. These schemes have been standardized for metro and access network applications [6]. A 1.25-Gbps upstream transmission system with 60-km fiber reach and 25-GHz channel spacing has been demonstrated [3], and the key factors for limiting long distance transmission are the intensity noise of the spectrum sliced ASE light and optical back reflection. Symmetric 1.25-Gbps WDM-PON system combining self-seeding and re-modulation techniques has been demonstrated, with the error free bidirectional transmission over 20-km fiber [4]. Among these proposed systems, RSOA is verified to be an attractive choice for the colorless transmitter, owing to its advantages of simultaneous modulation and amplification, as well as wide wavelength range.

In this paper, with the aims to achieve larger number of users, higher wavelength efficiency and longer transmission distance, we propose and experimentally demonstrate a 12.5-GHz spaced downstream transmitter for long reach DWDM-PON. The optical comb wavelengths with 12.5-GHz channel spacing are de-multiplexed by an arrayed waveguide grating (AWG) and injected to the RSOAs for 1.25-Gbps downstream modulation. We investigate the transmission performance of a 40-channel transmitter, while this scheme could support more than 300 channels in C-band theoretically. The experimental results show that with the forward error correction (FEC) limit of bit error rate (BER) @1e-3, 150-km single mode fiber (SMF) transmission can be supported. This architecture is suitable for the remote area where a large number of users don't need much bandwidth but locate far away from the central office, such as country area, Siberia and west area of China

2. Experimental Setup

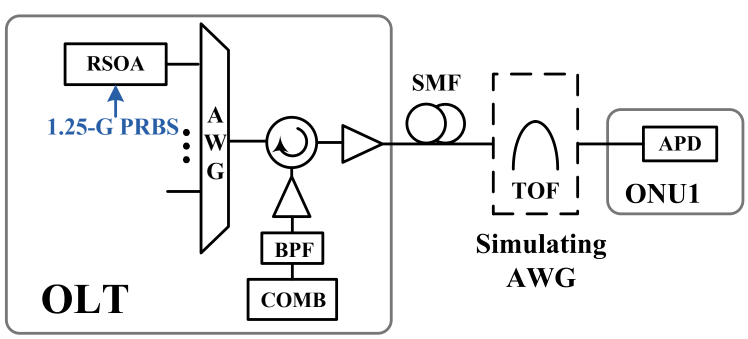

Fig. 1 Experimental architecture of the proposed downstream transmitter and transmission system.

Fig.1 depicts the experimental configuration of the proposed downstream transmitter and the transmission system. The downstream transmitter mainly consists of an optical comb source, a 12.5-GHz spaced AWG and N RSOAs (N corresponds to the number of output ports of AWG). The comb, also named Optical Frequency Comb Generator, generates light source with a comb-like light spectrum over the total C-band. It consists of a Fabry-Perot Electro-Optic (FP-EO) modulator and a temperature controller. The channel spacing of the output comb depends on the modulation radio frequency (RF). The central wavelength is 1549.6 nm, and the RF is set as 12.5 GHz, which means the channel spacing is 0.1 nm, therefore more than 300 channels could be supported in total C-band. Corresponding to the number of AWG's output ports, 40 channels are filtered out by a band passed filter (BPF) and amplified by the following Erbium Doped Fiber Amplifier (EDFA). After passing though the AWG, all the wavelengths are injected into the RSOAs for the wavelength locking and data modulation. In our experiment, the ROSA is modulated by 1.25-Gbps pseudo random binary sequence (PRBS) data with a word length of 2^{31}-1. The modulated signals are multiplexed by the AWG and then boosted by an EDFA before entering the SMF.

In the remote node (RN), a tunable optical BPF (TOF) is used to imitate the AWG. The center wavelength of the TOF is set as 1549.5 nm and the 3-dB bandwidth is 10 GHz. In ONU, an Avalanche Photodiodes (APD) is used to detect the signal. The received electric signal is observed and analyzed by an oscilloscope.

3. Results and discussion

In order to investigate the proposed 40-channel transmitter's performance, firstly we study the optical spectrum feature of comb source which provides seeding light to RSOAs. The comb wavelengths after BPF are shown in Fig. 2, which is measured by an optical spectrum analyzer (OSA) with 0.15-nm resolution. The central wavelength of comb source is 1549.6 nm. Its optical power is about 2-dB less than adjacent peak. The central wavelength is carefully adjusted so that all channels correspond to the 12.5-GHz spaced 40-channel AWG used in our experiment.

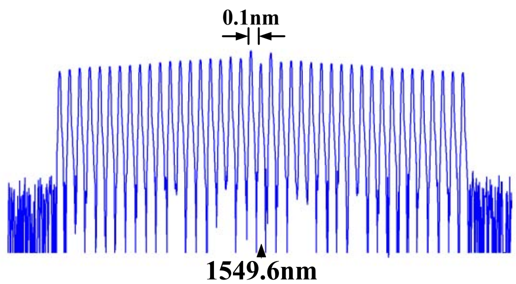

Fig. 2 Optical spectrum of comb source after BPF

All channels of optical source in Fig.2 are injected into the corresponding RSOAs through AWG. The injection locking property of RSOAs is shown in Fig.3. The output spectra of the tested RSOA with spontaneous emission and injection locking are shown in Fig. 3 (a) and (b), respectively. Fig.3 (b) is observed at the point of fiber input and the side mode is mainly caused by the light leak of circulator. The 19th channel of AWG (1549.5 nm) is locked and modulated by 1.25-Gbps data. 30-dB side-mode suppression ratio (SMSR) is achieved so that the inter-channel crosstalk is negligible.

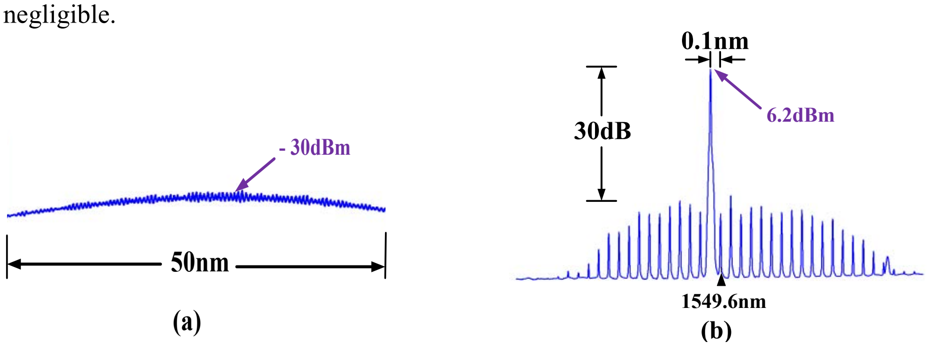

Fig. 3 Optical spectra of tested RSOA with (a) spontaneous emission and (b) injection locking.

Fig.4 depicts the eye diagrams for different distances and different BER. In Fig.4 (a), (b) and (c), it is obvious that under the BER@1e-4 condition, with the extension of transmission distance from Back-to-Back (B-t-B) to 150 km, eye diagram becomes more closed. This is mainly caused by optical power attenuation during the long reach fiber transmission. In Fig.4 (d) and (e), eye diagrams for BER@1e-10 with B-t-B and 25-km fiber transmission are achieved. Since the received optical power for 150-km fiber is low, the eye diagram for BER@1e-10 cannot be obtained.

We evaluate the transmission performance of 20-km, 50-km, 100-km and 150-km fiber respectively. The BER performance for downstream signals is shown in Fig.5. Error free transmission (BER@e-10 level) is achieved when the fiber length is less than 100 km. In 150-km case, we only achieve BER @1e-4 due to the low received optical power. About 1-dB power penalty after 100-km and 1.5-dB power penalty after 150-km SMF transmission at FEC threshold (1e-3) [7] are observed. These power penalties are mainly due to the slight fiber chromatic dispersion.

The power margin analysis of the downstream transmission is also carried out. In 100-km case, the optical launching power after the EDFA is 10 dBm, and the total loss is 27.8 dB including 100-km fiber (20.8 dB) and the TOF (7 dB). The received sensitivity in 100-km SMF transmission is 29.5 dBm @e-10, as shown in Fig.5. So the calculated power margin for 100-km transmission is 11.7 dB. The power margin shows the proposed system can support at least 100-km transmission with the BER@1e-10. For 150-km case, the power margin is 3.2 dB with the BER@1e-3.

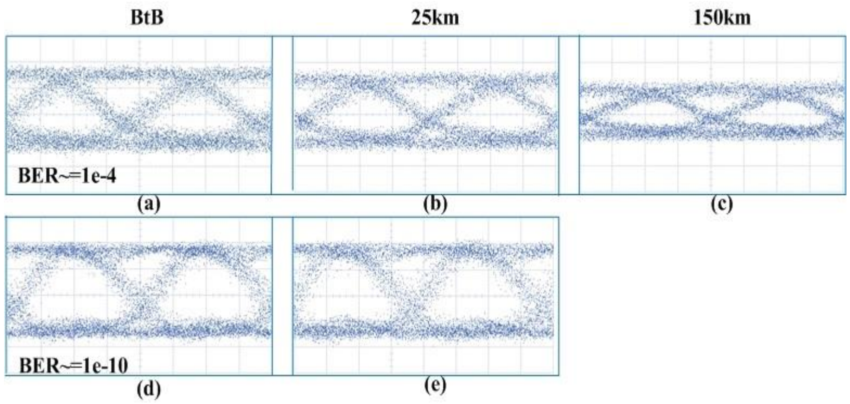

Fig. 4 Measured received eye diagrams for various transmission distances and BER

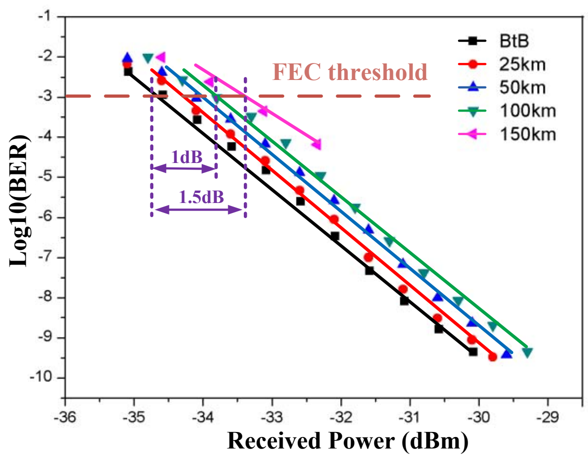

Fig. 5 Measured BERs with different fiber distances for this downstream scheme

4. Conclusion

In this paper we propose and experimentally demonstrate a novel configuration for the downstream transmitter in 12.5-GHz spaced DWDM-PON. The comb source and RSOAs are used to realize the injection seeding and directly modulation. Owing to the high spectral efficiency, more than 300 channels are possible to be supported within C-band. Due to large number of comb output channels, this scheme can be extended for both the upstream and downstream transmission, and it could be a cost-effective candidate for the practical applications of future long reach DWDM-PON.

5. Reference

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