An Integrated Radio-over-fiber and Passive-optical-network for Bidirectional Photonic Accesses

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***Abstract*—A bidirectional transmission system based on Radio-over-fiber (ROF) and Passive Optical Network (PON) technology is proposed and demonstrated. In this paper, a local oscillator with 15GHz via first Mach-Zehnder modulator (MZM1) and 1.25-Gb/s data via second Mach-Zehnder modulator (MZM2) generate double sideband (DSB) signal. The DSB signal is separated by fiber bragg grating (FBG) into two optical downstream signals. One is the central carrier; the other is the subcarrier, which transports from optical line terminal (OLT) to base station (BS) by 25km single-mode fiber (SMF) transmission. The power penalty of the system is < 0.1 dB(central carrier for downlink and uplink), downlink and uplink transmission of BER values are lower than 10^{-9}.**

Keywords- Double Sideband; Fiber Bragg Grating; Mach-Zehnder modulator; Passive Optical Network; Radio-over Fiber.

I. INTRODUCTION

Radio-over-fiber (ROF) system and Passive-optical-network (PON) have developed rapidly during the past decade. They can be applied to microwave communication systems, such as wavelength division multiplexing (WDM), optical add-drop multiplexing (OADM) and orthogonal frequency-division multiplexing (OFDM) [1]-[3]. The ROF system provides broad bandwidth for users to solve transmission congestion. Optical fiber has lots of advantages in long distance transmission, including high bandwidth, low power loss, and immunity to electromagnetic interference [4]. Rayleigh backscattering (RB) results in power fading, deteriorating system performance and increasing bit error rate because the fiber crystal structure is not uniform in the manufacturing process, shifting the refraction.

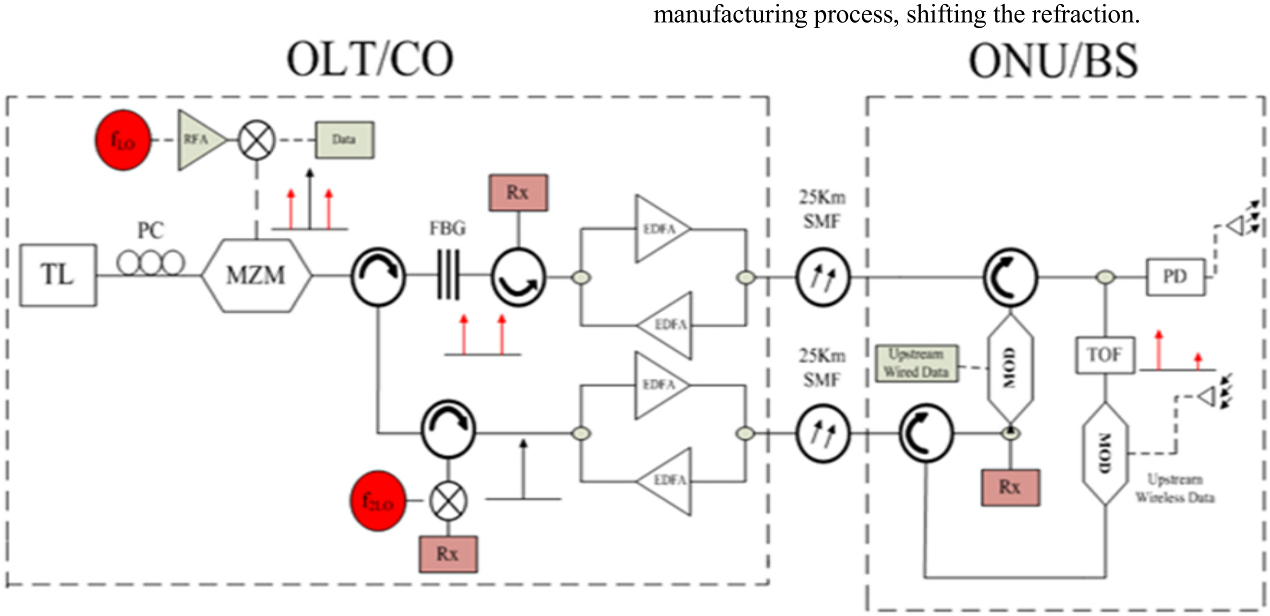

Fig. 1. ROF-PON schematic diagram.

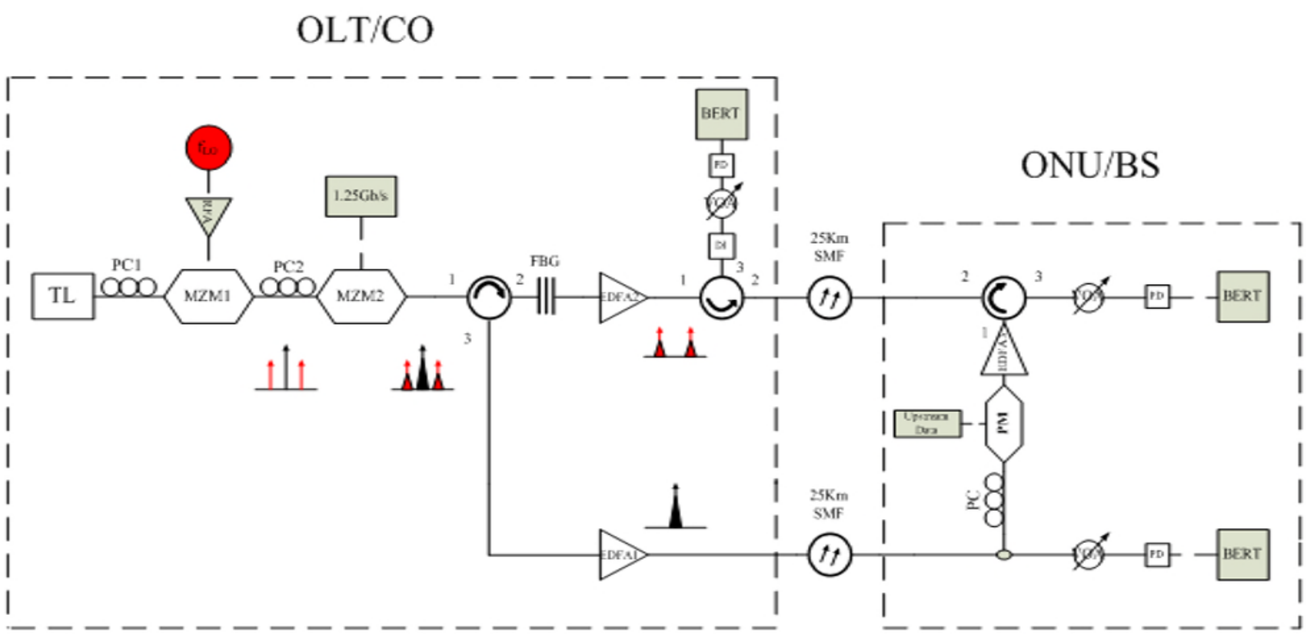

Fig. 2. Experimental setup of bidirectional ROF-PON system.

To solve the RB of power fading, many schemes and demonstrations have been proposed, such as using different path or wavelength between uplink and downlink transmission [5][6]. In this paper, we propose a bidirectional ROF-PON system. The ROF-PON schematic system is shown in Fig. 1, which has only one tunable laser used as an optical source. Part of central carrier is remodulated for upstream transmission, making the structure simple, low cost, and highly flexibility to create different transport structure.

II. EXPERIMENT SETUP

Fig. 2 is the bidirectional ROF-PON system configuration. OLT consists of tunable laser (TL), LO, MZM, polarization controller (PC), FBG, optical circulator (OC), erbium doped fiber amplifier (EDFA), and microwave signal generator. TL is used as an optical source with central wavelength of 1530nm. LO is generated at 15GHz by a microwave signal generator. The MZM1 is driven by an optical source and LO to generate DSB signal. 1.25-Gb/s data and DSB signal are modulated by MZM2 to generate the microwave signal with data.

We use different transmission paths in this system because of the RB. DSB signal is separated by FBG to central carrier and subcarrier as two downstream signals. Each downstream signal is amplified by EDFA via a 25km SMF transmission to base station (BS). BS includes PC, phase modulator, EDFA, OC, variable optical attenuator (VOA), photo-detector (PD), and bit error rate tester (BERT). We use a 10:90 optical coupler to separate the central carrier into two signals. One is used for measuring the BER, the other is reused as upstream light carrier. All of the optical signals are measured by an optical spectrum analyzer (OSA). VOA adjusts the optical signal power. PD transforms the optical signal to an electrical one and measures the BER value. The upstream light carrier uses phase modulator to generate upstream data signal via a 25km SMF transmission. The upstream light signal passes OC and DI to transfer the phase modulated signal into the intensity modulated one. The optical signal goes into receiver to perform O/E convert for BER test.

III. EXPERIMENT RESULT

The wavelength of TL is approximately 1530nm and the optical spectrum is shown in Fig 3. Due to the sensitivity of the MZM affected by polarization, we set a PC before MZM to improve the stability of the MZM. The DSB signal is generated first by MZM, which is presented in Fig. 4. DSB signal with 1.25Gb/s data is generated by the second MZM and the optical spectrum is shown in Fig. 5.

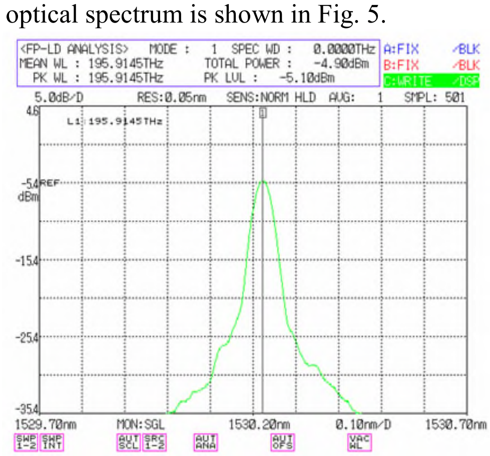

Fig. 3. Optical spectrum of TL in 1530nm.

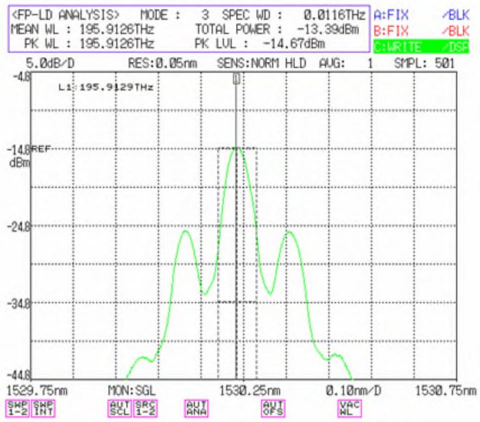

Fig. 4. DSB signal output from the first MZM.

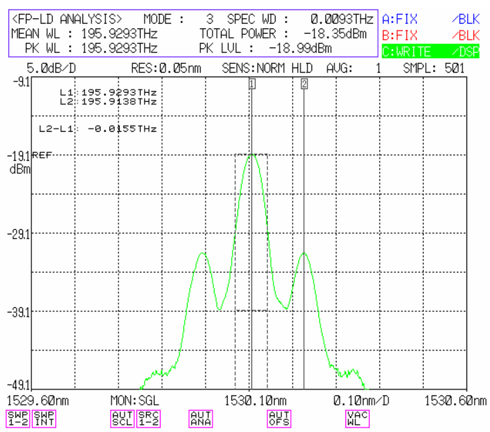

Fig. 5. DSB signal with 1.25Gb/s data output from the second MZM.

After the DSB signal is separated by FBG, the central carrier and subcarrier are used as downstream signals for different paths transmission. The central carrier wavelength is reflected by FBG and the subcarrier passes through FBG. The optical spectrum of central carrier and subcarrier is shown in Fig. 6 and Fig. 7. The downstream signal is amplified by EDFA for avoiding transmission power loss for 25km SMF transport.

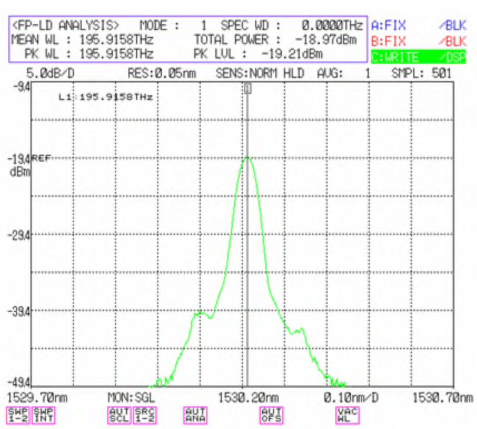

Fig. 6. The optical spectrum of central carrier which is reflected by FBG.

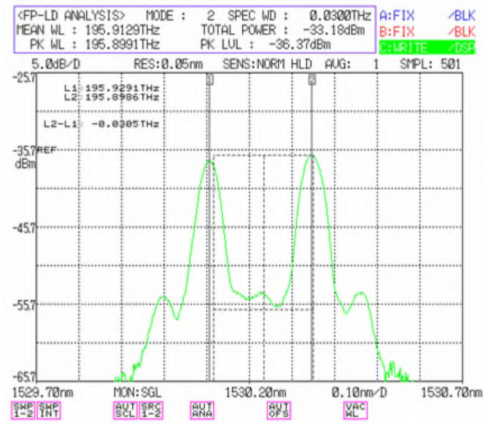

Fig. 7. The optical spectrum of subcarrier after pass through FBG.

The optical spectrum of the subcarrier and the central carrier for downstream transmission are shown in Figs. 8 and Fig. 9, respectively. To compare with intensity modulation and phase modulation, we reuse part of the downstream optical signal with phase modulation for the upstream signal.

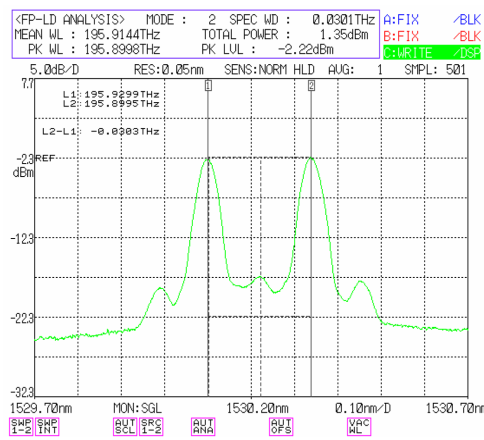

Fig. 8. Optical spectrum of subcarrier amplified by EDFA and 25km SMF transmission.

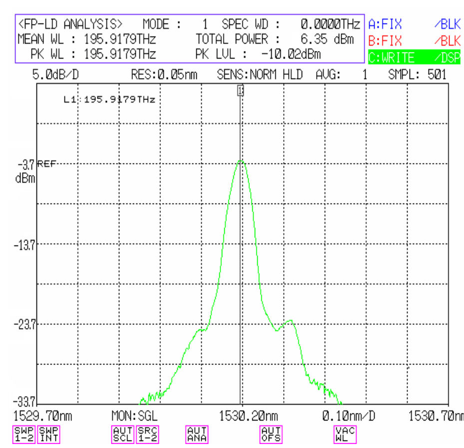

Fig. 9. Optical spectrum of central carrier after 25km SMF transmission.

The optical spectrum of the central carrier is remodulated by the phase modulator then amplified by EDFA, which is shown in Fig. 10. The central carrier via 25 km SMF is presented in Fig. 11.

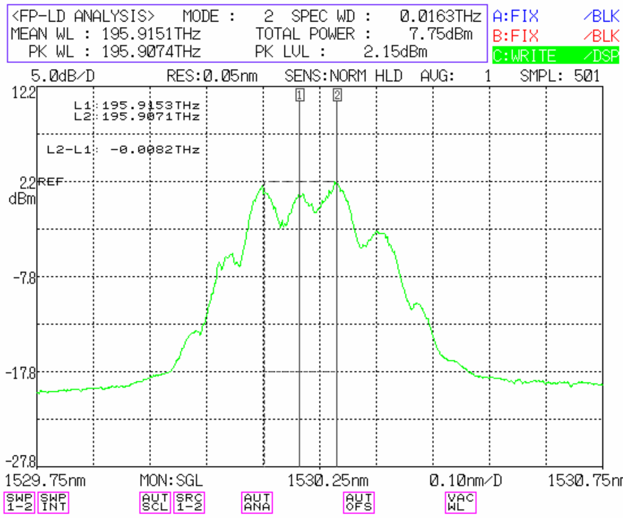

Fig. 10. The optical spectrum of central carrier remodulation by phase modulator and amplify by EDFA.

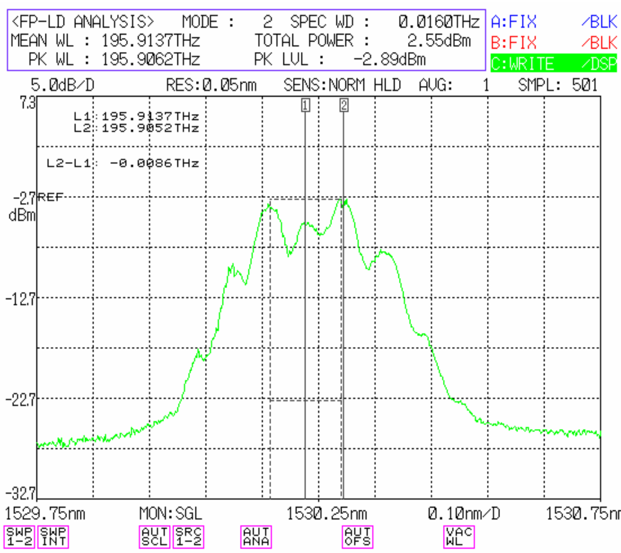

Fig. 11. The optical spectrum of remodulated central carrier used for upstream data after 25km transmission.

Figs. 12-14 illustrate the eye diagrams of downlink and uplink transmissions. Fig. 12 shows the eye diagram for the central carrier downstream data while Fig. 13 shows it for the subcarrier downstream data. Fig. 14 depicts the eye diagram for the central carrier upstream data. From these eye diagrams observation, we see that phase modulation is better than intensity modulation. The system power penalty of the central carrier for downlink and uplink is seen to be < 0.5 dB. The downlink and uplink transmission of BER values are lower than 10^{-9}.

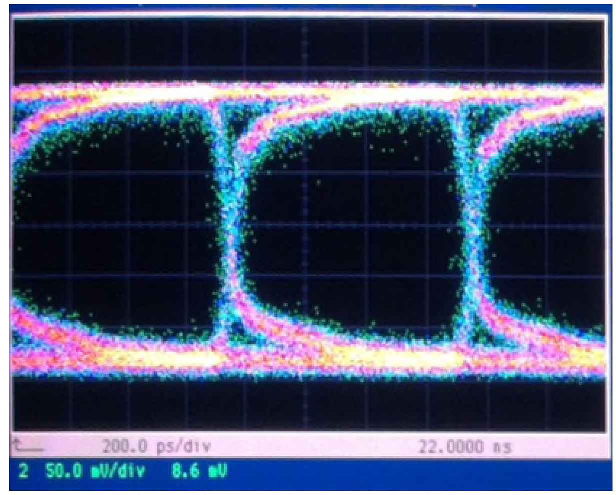

Fig. 12. The eye diagram of central carrier downstream data.

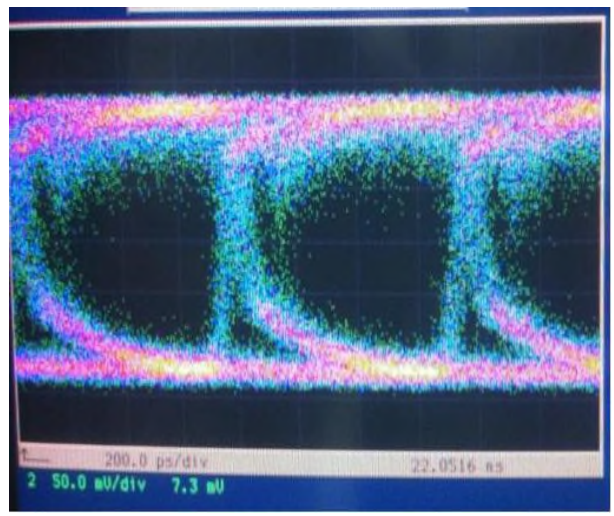

Fig. 13. The eye diagram of subcarrier downstream data.

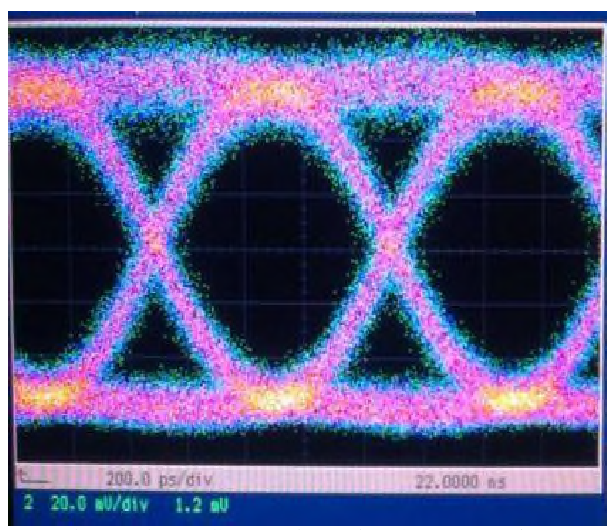

Fig. 14. The eye diagram of central carrier upstream data.

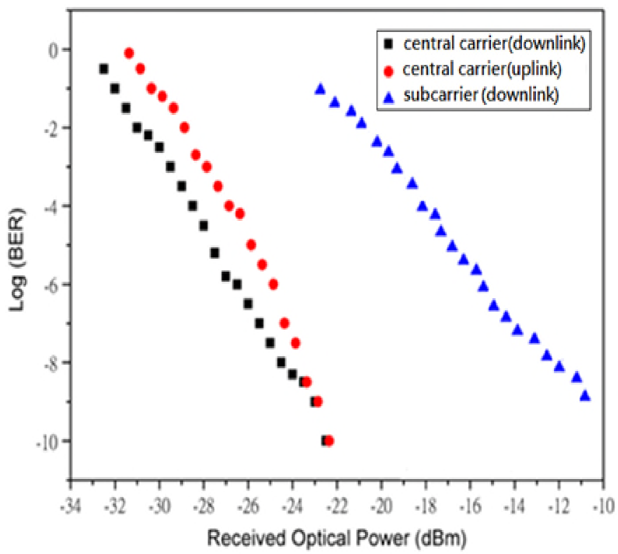

Fig. 15. The measure BER curves.

The measured BER curves of received optical power are presented in Fig. 15.The received optical power levels at the BER of 10^{-9} are −22.5dBm (central carrier downlink), −22.4dBm (central carrier uplink), and −10.6dBm (subcarrier downlink). A power penalty of approximately <0.1 dB (central carrier for downlink and uplink) for the fiber link is observed during the BER test for 25 km SMF transmission.

IV. CONCLUSION AND FUTURE WORK

We have proposed and demonstrated a bidirectional ROF-PON system. The system has simple and low cost features. Due to the RB effect, using FBG and OC achieve different transmission path to improve power fading in the OLT. We reuse part of the downstream signal as upstream optical carrier in BS to achieve low cost. Compared to phase modulation and intensity modulation for transmission, we could observe the eye diagram from high speed oscilloscope. Phase modulation is better than intensity modulation because PM has better anti-noise interference. The power penalty of the system is < 0.1 dB, downlink and uplink transmission of BER values are lower than 10^{-9}. The system can be combined with optical network and radio frequency in the future, such as fiber to the home (FTTH), Wi-Fi and antenna to implement long-haul transmission.

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