Bidirectional 1.25Gbps WDM RoF Wired Wireless Optical Transmission using Multiple SSB Carriers in FP LD by Multiple Mode Injection Locking

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Abstract

A new bidirectional SSB WDM-RoF system to simultaneously transmit both 1.25Gbps wired and 15GHz wireless signals is proposed. For downlink, only one MZM modulating a FP-LD and multiple mode injection locking were used to serve multiple Base Stations. For uplink, remodulation technique by RSOA was used. We demonstrated this scheme by measuring BER for three channels after 23 km transmission.

Introduction

Wavelength-division-multiplexing radio-over-fiber (WDM-RoF) has been regarded as a promising system that can meet the increase and varied demands of broadband multimedia services for wireless users [1]. In WDM-RoF system, Base Stations (BSs) should be simple, colorless, and cost-effective [1]. Furthermore, lightwave and RF signal processing functions are centralized at a Central Office (CO), so that the CO should use simple structures and cost-effective methods to generate downlink signals. Recently, RoF technique for the WDM-PON has been researched to make optical network unit (ONU) support both wired and wireless services [2-3]. The WDM-PON systems using RoF technique can both reduce the cost of BSs and serve as many users as possible. However, in these systems, using one DFB laser and one Mach-Zehnder modulator (MZM) in the CO for one BS make the overall system become costly and can not take the advantages of the low cost WDM-PON using spectrally-sliced Fabry-Pérot laser diode (FP-LD) [4] and colorless BSs are not supported [2].

In this paper, we propose and demonstrate a new simple structure for a low-cost bidirectional WDM-RoF system supporting both wired and wireless services. The proposed scheme also supports colorless BSs, and is compatible with the conventional WDM-PON system. For downlink, we generated multiple Single Side Band (SSB) optical carriers by using only one MZM modulating a FP-LD and multiple mode injection locking (MM-IL) technique. For uplink, a Reflective Semiconductor Optical Amplifier (RSOA) was used in the BS to realize a colorless and simple BS. BER of both the downlink and the uplink for three channels after 23 km transmission were measured to demonstrate our scheme.

Operation Principle

The operation principle of the proposed scheme is shown in Fig. 1. For MM-IL, two FP LD having the same mode spacing and optical spectral region are used. All modes of the master FP- LD are modulated by MZM in Double Side Band (DSB) format then

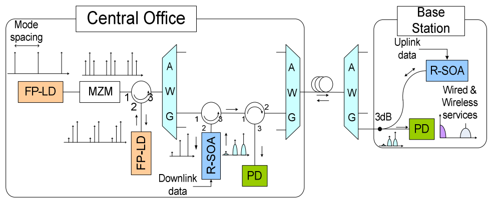

Figure 1: The schematic of proposed system

injected to a slave FP LD. All modes of the slave FP-LD are locked to the side modes of injected optical signal (lower or higher side mode group) by adjusting its temperature. In this condition, one locked side mode group is amplified and other side mode group is suppressed. The optical power of center carrier group also is reduced but still high enough to form the SSB signals to avoid dispersion induced carrier suppression (DICS) problem [5]. Each of these carriers is separated by an AWG and enters into a RSOA. The RSOA reduces the MPN induced by the spectrally sliced FP LD because it acts as a high pass filter in gain saturation condition [6] and then it modulates optical carrier with 1.25Gbps signal. At the BS, optical signal is split into two paths. One path entered the PD to detect both wired and wireless signals, the other one enter another RSOA for the uplink. This RSOA in gain saturation condition erases the downlink signal and modulates 1.25Gbps uplink signal, simultaneously [1]. The remodulated signal is transmitted back to the CO and detected by a PD.

Experiments and Results

The experimental setup for the proposed system is illustrated in Fig. 2. Two FP–LDs had the mode spacing of 1.08nm and spectral region of about 1535-1555nm. The master FP LD was with an isolator whereas the slave one was without an isolator. All mode of the master FP LD were modulated by a MZM biased at 6.0V (Vπ/2) and driven by 15GHz/20dBm

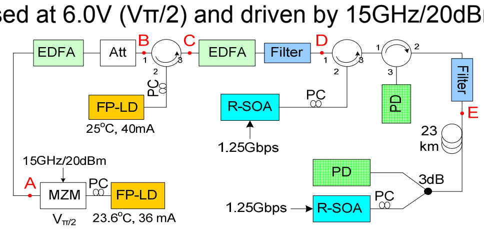

Figure 2: Experimental setup

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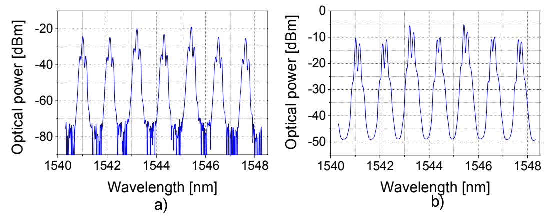

Figure 3: Optical spectrum at a) point A, b) point C

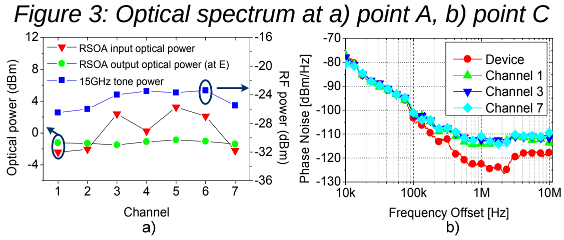

Figure 4: a) RSOA power input and output and 15GHz tone; b) 15GHz carrier phase noise

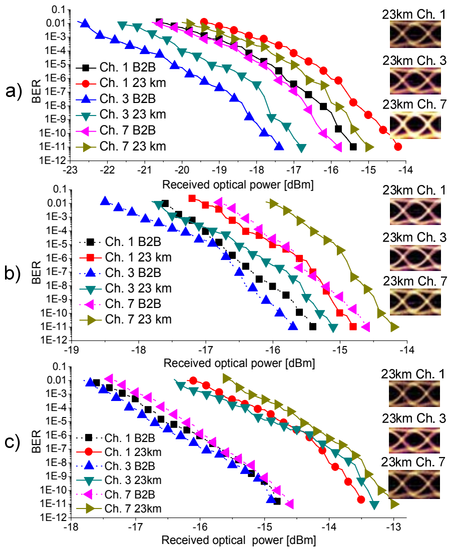

Figure 5: BER and eye-diagram of three channels a) 15GHz band DL b) Baseband DL, c) Baseband UL

RF signal to generate DSB signal. All modes of slave FP LD are controlled to lock to the upper side mode group of DSB signal by adjusting its temperature and the polarization controller (PC). Fig. 3 shows the optical spectra after MZM and after the slave FP LD. Optical signal from the slave FP LD entered into an EDFA to satisfy gain saturation requirement of the RSOA. A tunable optical filter was used to separate a certain optical carrier. Up to 7 optical carriers with maximum peak power difference of about 10dB could be selected for performance evaluation. The average input (at point D), output power of the RSOA and 15GHz tone peak power (at point E) were measured for all channels and shown in Fig. 4(a). Ch. 1, 3 and 7 were selected to measure BER. Phase noises of 15GHz carriers of these channels are shown in figure 4(b). Compared to local 15GHz tone; it is shown that proposed scheme guarantees RF carrier quality. For each channel, the RSOA was modulated by NRZ $2V_{pp}$ 1.25Gbps signal. The modulated optical signal was transmitted through 23km SMF and divided into two paths; one entered into a PD and the other one

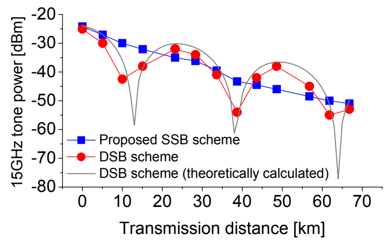

Figure 6: 15GHz tone power after transmission

entered into another RSOA for the uplink. This RSOA remodulated $2V_{pp}$ 1.25Gbps uplink data. Input optical powers to the RSOA for channel 1, 3 and 7 were -11.5, -11.2 and -11.7 dBm, respectively. The BER curves of the downlink and the uplink were shown in Fig. 5; the insets are eye diagrams after 23 km transmission. We can see that the maximum power differences to achieve the same BER for three channels were about 0.7dB for baseband, 2dB for 15GHz band of the uplink and 0.5dB for the uplink. The difference for 15GHz band was because of the difference of the locking efficiency as shown in Fig. 4(a). Power penalties after 23km transmission were 1dB for the baseband and 15GHz band of the downlink and 1.5dB for the baseband of the uplink.

15GHz tone power of Ch. 3 after different transmission lengths is shown in Fig. 6. To verify that our scheme could mitigate DICS, the temperature of the slave FP LD was adjusted to 21^{0}C so that its modes locked to center carrier group of the injected optical signal and two side modes still had the same power level. 15GHz tone power depended on the transmission distance in this case is also shown in Fig. 6. As shown in the figure, the proposed system kept the RF signal from degradation due to dispersion because the injection locking made optical carriers become asymmetric.

Conclusion

A new cost effective bidirectional WDM-RoF system was proposed. In this scheme, MM-IL technique was used to generate SSB carriers to mitigate DICS for multiple BSs. RSOAs were employed to reduce MPN and modulate data for the downlink and to remodulate data for the uplink. Error-free transmission for 1.25Gbps wired data and 15GHz wireless one was achieved after 23 km transmission for three channels with the power penalties were about 1dB for the downlink and about 1.5dB for the uplink.

References

1. Y.Y. Won et al, J. Lightwave Technol., Vol. 25 (2007), pp.3472-3478.
2. G.K. Chang et al, MWP (2007), 24 – 28
3. H.C. Kwon et al, ICTON (2007), 9-11
4. S.L. Woodward et al, IEEE Photon. Technol. Lett., Vol. 10, (1998), 1337-1339
5. H.S. Ryu et al, MWP (2003), 223-226
6. K. Sato et al, IEEE J. of Quantum Electron, Vol. 7 (2001), 328-333