Mutually injected Fabry-Perot laser diodes for injection seeded WDM-PON with low injection power

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Abstract: We demonstrate an injection seeded WDM-PON by using a low noise broadband light source based on mutually injected Fabry-Perot laser diodes. The proposed injection source enables to transmit 1.25 Gb/s/channel with a low injection power.

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1. Introduction

In order to guarantee bandwidth delivery for next generation access network, a wavelength division multiplexing passive optical network (WDM-PON) is considered as an ultimate solution because of its large bandwidth, high security, and protocol transparency [1]. However, implementation of WDM-PON requires a cost-effective WDM source. Recently, the wavelength locked Fabry-Perot laser diode (F-P LD) with an external cavity has been widely adopted for high bandwidth delivery [2]. To implement WDM-PON based on the wavelength locked F-P LD, a cost-effective source was proposed [3], [4]. The LED cannot provide enough output power and transmission data rate is limited by the amplified spontaneous emission (ASE)-ASE beating noise. On the other hand, MI F-P LD attracts a strong attention due to its low noise characteristics. However, the data rate was limited to 622 Mb/s by the periodic noise peak of the MI F-P LDs.

In this paper, we demonstrated 1.25 Gb/s/channel injection seeded WDM-PON based on the MI F-P LD. This MI F-P LD was proposed to transmit high-speed signal [5]. The periodic noise peak of the MI F-P LDs was shifted to higher frequency by reducing length of the external cavity. Furthermore, we investigated noise characteristics of the MI F-P LD after it was injected into a polarization independent F-P LD (PI F-P LD). We could achieve error-free transmission at the injection power of -18 dBm.

2. Experiment setup and results

The experiment setup based on the wavelength locked F-P LDs to demonstrate 1.25 Gb/s transmission is shown in Fig. 1(a). The MI F-P LDs in the dashed box of Fig. 1 (a) as the low noise BLS is shown in Fig. 1(b). The cavity length and the front facet reflectivity of F-P LD 1 and 2 were 400 μm and 0.1%, respectively. Thus, the mode spacing of each F-P LD was 0.8 nm (100 GHz). The length of the external cavity (between two F-P LDs) was 9 cm. We realized an un-polarized BLS by polarization multiplexing with two polarization controllers (PCs) and a polarization beam combiner (PBC). The output of the MI F-P LDs was transmitted through 20-km single mode fiber (SMF) and filtered by an arrayed-waveguide grating (AWG) with 3-dB bandwidth of 0.64 nm (80 GHz) and channel spacing of 0.8 nm (100 GHz). Then, it was injected into the PI F-P LD located at the ONT. We used another AWG at the central office (CO) for optical de-multiplexing with same specifications of the AWG at the remote node (RN).

Fig. 1. Experiment setup for WDM-PON with proposed BLS.

Fig. 2. Measured optical spectra of the MI F-P LD injection.
Fig. 2 shows measured optical spectrum in the proposed experiment setup. We could observe the multi-wavelength light output (spectrum A) and broad linewidth with wavelength detuning of 0.4 nm to achieve low noise characteristics [6]. The wavelength detuning is defined by the wavelength difference between the lasing modes of the F-P LDs. After the output light of the MI F-P LD was spectral sliced by the AWG at the RN (spectrum B), it was injected into the PI F-P LD with the injection power of -18 dBm. The measured spectral ripple was about 8 dB for both best and worst case (spectrum C). The bias current of the PI F-P LD was set at 45 mA.

To investigate the noise characteristics of the MI F-P LDs, we measured the RIN spectrum according to the injection power at the receiver (Rx) after passing through two AWGs as shown in Fig. 3(a). The periodic noise peak which is determined by the external cavity length was observed at intervals of 1.1 GHz. It can be explained by the external cavity length of 9 cm of the MI F-P LDs. As injection power was increased, the RIN was decreased over the whole frequency range. Therefore, the average RIN from 50 kHz to 750 MHz was also decreased as shown in Fig. 3(b). Above the injection power of -18 dBm, we could achieve the RIN of -110 dB/Hz. The measured RIN is sufficient for error free transmission of a 1.25 Gb/s non-return to zero (NRZ) data without a forward error correction.

To investigate the transmission performance, we measured the bit error rate (BER) at the Rx in Fig. 1(a) with and without the transmission fiber of 20-km. The upstream signal was modulated with the 1.25 Gb/s NRZ. The pseudorandom bit sequence (PRBS) pattern length was $2^{11}-1$ which is a simulation of 8B/10B 1.25 Gb/s Ethernet signal. The bias current and modulation current of the PI F-P LD were set 20 and 45 mA (peak to peak), respectively. As shown in Fig. 4, we could achieve error free transmission within power penalty of 0.5 dB. The maximum power penalty (between best case and worst case) by the wavelength detuning (difference between mode of PI F-P LD and spectrum sliced MI F-P LD) was about 1 dB since spectral ripple was relatively large by 8 dB as shown in Fig. 2 at the low injection power of -18 dBm. The measured eye diagrams also show the high level noise at worst case compared with the best case as shown in the inset of Fig.4. It should be noted that we utilized a high pass filter with bandwidth of 1 MHz at the optical receiver to decrease 1/f noise since there is no signal component (DC ~ 10MHz).

3. Conclusion

In conclusion, we successfully demonstrated the 1.25 Gb/s/channel injection seeded WDM-PON by using a single MI F-P LDs. The usable bandwidth of MI F-P LD can be increased by optimizing the MI F-P LDs and/or by using an F-P LD with quantum dot active region that provides a very broad lasing spectrum. We believe that the MI F-P LDs can be used to accommodate the high-speed WDM-PON cost effectively.

4. References