Demonstration of data remodulation for upstream traffic in WDM access networks using injection-locked FP laser as modulator

L. Y. Chan, *C. K. Chan, +D. T. K. Tong, S.Y. Cheung, F. Tong, and L. K. Chen
Information Engineering Dept., The Chinese University of Hong Kong, Shatin, Hong Kong, China
**Bell Laboratories, Lucent Technologies, 791 Holmdel Keyport Road, Holmdel, NJ 07733, USA*
+Tellium, Inc., 2 Crescent Place, P. O. Box 901, Oceanport, NJ 07757-0901
Tel: +852-2609-8479, Fax: +852-2603-5032, Email: lychan@ie.cuhk.edu.hk

Abstract: We propose and demonstrate an upstream-traffic remodulation scheme based on injection locking of a FP laser diode on the downstream wavelength. The original 10Gb/s downstream data are largely suppressed, allowing simultaneous direct modulation of 1-Gb/s upstream data with improved signal quality.

OCIS codes: (060.2360) Fiber optics links and subsystems; (060.4080) Modulation

1. Introduction

The application of WDM in local access networks [1] can be a promising approach to meet with the increasing bandwidth demand from enterprises and households. But the relative high cost of the transmitters with distinct wavelengths has hindered the general market acceptance. For this reason, network architectures with data remodulation on the downstream wavelength channel for upstream traffic back to the central office were proposed, including remodulation on the blank time slots from the downstream signals via either an optical modulator [2] or a semiconductor optical amplifier [3]. The main advantage of data remodulation technique is the centralized wavelength sources at the central office, which eliminates any wavelength–registered source at the optical network unit, thus enhances stocking management and eases maintenance. In [4], an ASE injected Fabry-Perot laser diode (FP-LD) was proposed as a WDM source at the ONU to transmit upstream data traffic. However, it required completely unmodulated ASE wavelengths from the central office and thus could not support downstream traffic with the same set of wavelengths.

In this paper, we propose and demonstrate a novel data remodulation scheme for upstream traffic, based on injection-locking of a FP-LD with the downstream data wavelength channel. The proposed scheme only requires a FP-LD at the ONU and thus is potentially low-cost. Experimental results show that the scheme can largely suppress the original 10-Gb/s downstream data stream, allowing reuse of optical power and simultaneous direct modulation of 1-Gb/s upstream data. The injection-locked FP-LD offers single-mode operation and thus greatly reduces the dispersion-induced penalty. We have demonstrated that the upstream signal can be transmitted over a 50-km fiber span with error-free operation.

2. Data Remodulation Scheme

Fig. 1 shows the architecture of a typical WDM local access network. A wavelength grating router (WGR) is used to route different wavelength channels to different ONUs. Our scheme employs a FP-LD at the ONU (see Fig. 1 inset). At the ONU, the downstream wavelength channel is partially tapped off for downstream data reception while the rest of the wavelength power is injected into the FP-LD for injection locking. The injection locking will greatly improve the side-mode suppression ratio (SMSR) of the FP-LD, which is necessary for DWDM environment. Under the condition that both the ones and zeros power levels of the injected downstream signal are above a certain power threshold, the injection-locked FP-LD will emit the same wavelength as the downstream signal with the original data content largely suppressed. Thus, by direct-modulating the injected-locked FP-LD with the upstream data simultaneously, a potentially low-cost upstream data transmitter with improved signal quality can be realized.

3. Experimental Demonstration

Fig. 2 shows the experimental setup to demonstrate the effectiveness of our proposed data remodulation scheme, for simplicity, on one particular wavelength channel. At the central office, a DFB laser at 1546.2 nm is externally modulated with a 10-Gb/s NRZ 2^{31}-1 PRBS data to form the downstream signal, which is then transmitted over a fiber span of 50 km to the ONU. The power of the ones and zeros levels are adjusted so that they are well above the locking threshold before the FP-LD at the ONU. At the ONU, 50% of the downstream signal is tapped off for data reception via an optically-amplified receiver while the rest of the signal power (-6.1dBm) is injected into a FP-LD, which is directly-modulated with a 1-Gb/s NRZ 2^{31}-1 PRBS upstream data stream. It is found that the injected power can be as low as –14 dBm, giving a dynamic range better than 8 dB, and thus offers good power budget margin for the network design. An optical circulator is used to separate the reflected and injection-locked upstream signal from the downstream signal. The remodulated upstream signal is then transmitted over another 50-km fiber span and is received at the central office. Fig. 3a shows the optical spectra of the FP-LD before and after the injection locking. It is shown the SMSR is greatly improved from 2 dB to 29.7 dB and the average output power is –4 dBm. We have also measured the bit error rate (BER) performance of both 10-Gb/s downstream (at the ONU) and 1-Gb/s remodulated upstream data signals (at the central office), and the results are depicted in Fig. 3b. It is shown that error-free operation is achieved for both signal streams after having been transmitted for 50-km. It should be noted that when a free-running FP-LD is used instead at the ONU and carries a 1-Gb/s NRZ data stream, the eye of the signal is found to be completely closed at the central office due to dispersion of the 50-km fiber span. Therefore, this proves that our scheme can also improve the signal quality to enhance transmission, in addition to effective data remodulation.

4. Summary

We have proposed and experimentally demonstrated a novel data remodulation scheme for upstream traffic in a WDM local access network. The ONU only requires a FP-LD without wavelength registration and thus it is potentially low cost and can ease the control and management. By injection-locking the FP-LD with the downstream wavelength channel, the original 10-Gb/s downstream data content is largely suppressed, allowing direct-modulation of 1-Gb/s upstream data with improved signal quality, which can be transmitted over a 50-km fiber span with error-free operation. The dynamic range of the injected power to the FP-LD is measured to be greater than 8 dB and thus offers good power budget margin for the network design.

References

1. M. Zirngibl, C. H. Joyner, L. W. Stulz, C. Dragone, H. M. Presby, and I. P. Kaminow, "LAR-Net, a local access router network," *IEEE Photon. Technol. Lett*., vol. 7, no. 2, pp. 215-217, 1995.
2. N. J. Frigo, P. P. Iannone, P. D. Magill, T. E. Darcie, M. M. downs, B. N. Sesai, U. Koren, T. L. Koch, C. Dragone, H. M. Presby, and G. E. Bodeep, "A wavelength-division multiplexed passive optical network with cost-shared components," *IEEE Photon. Technol. Lett*., vol. 6, no. 11, pp. 1365-1367, 1994.
3. H. D. Kim, S. G. Kand and C. H. Lee, "A low-cost WDM source with an Ase injected Fabry-Perot semiconductor laser," *IEEE Photon. Technol. Lett*., vol. 12, no. 8, pp. 1067-1069, 2000.
4. M. D. Feuer, J. M. wiesenfeld, J. S., Perino, C. A. Burrus, G. Raybon, S. C. Schunk, and N. K. Dutta, "Single-port laser-amplifier modulators for local access," *IEEE Photon. Technol. Lett*., vol. 8, no. 9, pp. 1175-1177, 1996.

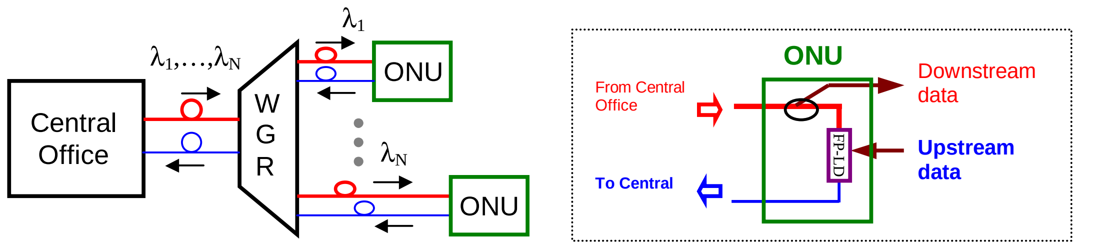

Fig. 1. A typical WDM local access network. Inset shows the proposed architecture of the ONU. FP-LD: Fabry-Perot laser diode

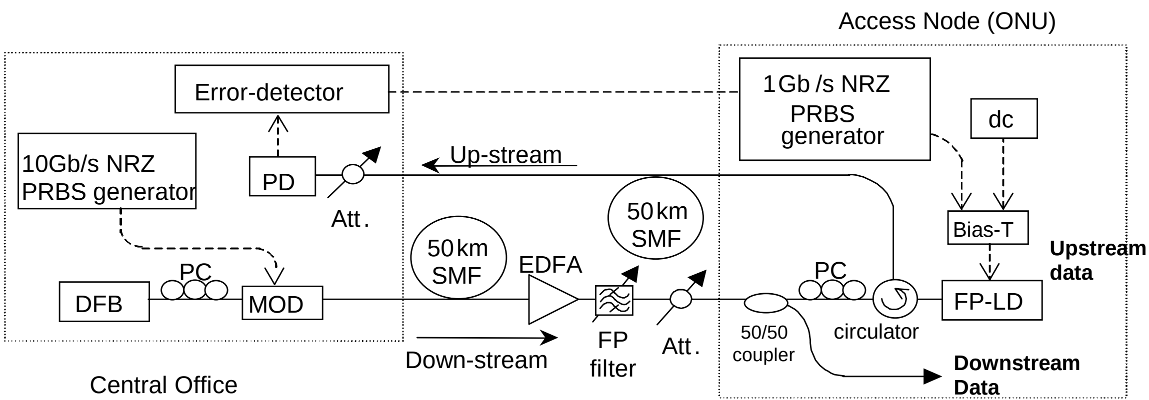

Fig.2. Experimental setup, DFB – distributed feedback laser, PC – polarization controller, MOD – external modulator, SMF – standard single mode fiber, EDFA – erbium-doped fiber amplifier, Att. – variable optical attenuator, FP-LD – Fabry-Perot laser diode, dc – dc current source, PD – photodetector .

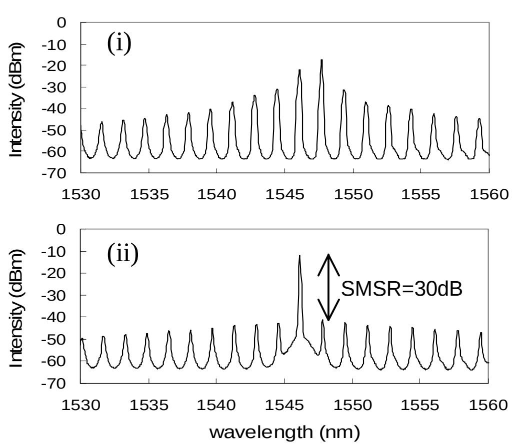

Fig.3a. Output optical spectra of (i) free running; and (ii) injection-locked by downstream wavelength (1546.2nm); of the Fabry-Perot laser diode

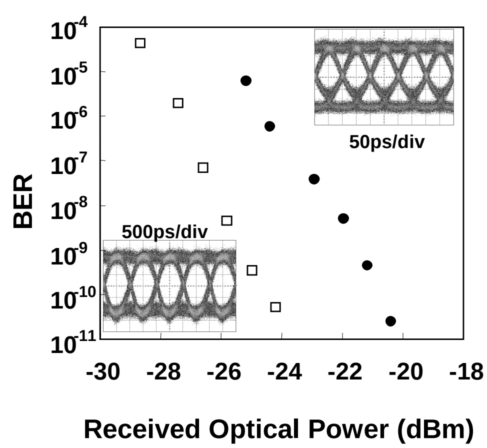

Fig. 3b. BER performance of (●) 10-Gb/s downstream data; and (□) 1-Gb/s remodulated upstream data; each after having been transmitted for a fiber span of 50 km. Insets shows the respective detected eye diagrams