Semiconductor Optical Amplifier Transceivers for WDM Access Systems

Yuji Akatsu
NTT Photonics Laboratories
3-1 Morinosato Wakamiya, Atsugi-shi, Kanagawa Pref., 243-0198 Japan
akatsu@aecl.ntt.co.jp

Abstract

The wavelength-division multiplexing (WDM) passive optical network (PON) is one of the promising access network systems that can satisfy cost-effectiveness, inter-operability, and providing simultaneously of various services. Semiconductor optical amplifier (SOA) transceiver is an attractive devices achieving inter-operability which corresponds to wavelength independency in each optical network unit (ONU). This paper reviews the configuration of the WDM access systems and the performance of the SOA transceivers applied to the systems.

Keywords: semiconductor optical amplifier, transceiver, WDM access

1. Introduction

The expansion of broadband services requires the development of a high-capacity optical access network system in recent years. In the design of the access network system, cost-effectiveness, inter-operability, and providing simultaneously of various services are indispensable. The wavelength-division multiplexing (WDM) passive optical network (PON) is one of the promising access network systems that can meet these requirements.

Many optical components for optical access network applications are being investigated with a view to reducing their cost. Spectrally sliced spontaneous emission from a semiconductor optical amplifier (SOA) [1, 2], and from an Er-doped fiber amplifier (EDFA) [3, 4], spectral slicing of an light-emitting diode (LED) [5], an integrated-optic multifrequency laser (MFL) [6], an injection-locked Fabry-Perot laser [7], and a fiber grating semiconductor laser (FGL) [8] have been proposed for use as WDM sources.

Semiconductor optical amplifier (SOA) transceiver is an attractive devices achieving inter-operability which corresponds to wavelength independency in each optical network unit (ONU). This paper reviews the configuration of the WDM access system and the performance of the SOA transceivers applied to the system.

2. Concept of WDM-PON System using SOA Transceiver

We have developed an ONU that employs a semiconductor optical amplifier transceiver (SOAT-ONU). A concept of the proposed WDM-PON system is schematically shown in Fig. 1. In the access node, there are CW-LD transmitters whose wavelengths are λ1, λ2, λ3, and λ4. Launched λ1, λ2, λ3, and λ4 CW lights reach

Optical Transmission, Switching, and Subsystems, edited by Cedric F. Lam, Chongcheng Fan, Norbert Hanik, Kimio Oguchi, Proceedings of SPIE Vol. 5281 (SPIE, Bellingham, WA, 2004) · 0277-786X/04/$15 · doi: 10.1117/12.530108

SOAT-ONU-1, -2, -3, and -4, respectively, through filter-1, an access line, filter-2, and each upstream subscriber line and are incident to a reflective SOA in each SOAT-ONU. The reflective SOA is modulated by the electrical signal, is amplified, and forms the upstream signal light. The λ1, λ2, λ3, and λ4 upstream signals reach receivers of Rx1, Rx2, Rx3, and Rx4, respectively. Since the wavelength of the upstream signal is the same as that of the incident CW light, wavelengths can be assigned flexibly without any adjustment of the ONU. In addition, since the SOAT has a gain over a wide range of wavelengths, one SOAT-ONU can handle multiple wavelengths. On the other hand, the downstream signals of λ5, λ6, λ7, and λ8 are launched from LD1, LD2, LD3, and LD4, respectively. They reach the SOAT-ONU-1, -2, -3, and -4, respectively, and are incident to the receiver in each SOAT-ONU.

The main advantages of this WDM-PON system are as follows:

1) Since the uni-directional upstream and downstream lines are installed between the subscriber node and each user, a SOAT-ONU can be developed cost-effectively by only replacing the LD of a normal ONU with a reflective SOA.
2) Since the wavelength filters are dissociated from the users, network security can be achieved in the optical layer.
3) Since the LD sources are installed only in the access node, it is easy to control the launched power and wavelength.

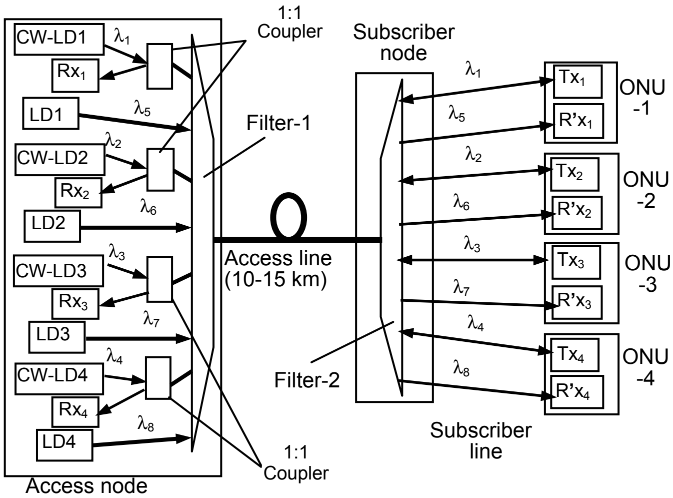

Fig.1 Schematic diagram of the WDM-PON system.

3. Performance of SOA transceiver

The reflective SOA module is installed in the Tx part of the SOAT-ONU. The SOAT gain is 12 -14 dB and the SOAT-ONU will operate in a wavelength range of 1520 – 1590 nm. As for the reflective SOA, front and rear facets are anti-reflected (AR) coated facet and uncoated cleaved facet, respectively.

We constructed a WDM-PON system that is similar to that in Fig. 1. The transmission characteristics between the SOAT-ONU and ONU for the access node (AN-ONU) were investigated using a 100 Base-X analyzer. Fig. 2 shows the experimental setup for transmission characteristics. The access node consists of an ONU and a DFB LD. The LD emits 1.5 μm CW light with a power of 0 dBm. The light passed through a 10-km-long single-mode fiber and illuminated an SOAT module, where it was modulated, amplified, and reflected as an upstream signal. This upstream signal was received by the receiver module in the ONU. On the other hand, the downstream signal, which had a wavelength of 1.3 μm, was output from the ONU and transmitted to the receiver module in the SOAT-ONU.

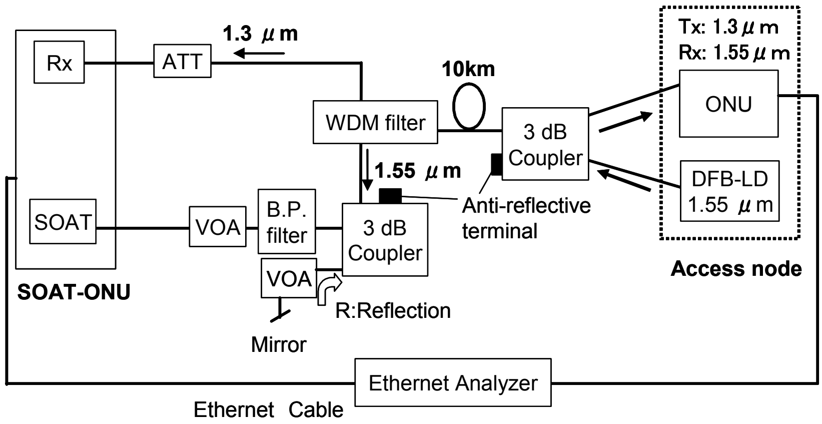

Fig. 2 Experimental setup for transmission characteristics.

Fig. 3 shows measured relationship between received optical power of the upstream signal and packet errors while varying the intensity of the background reflection. The number of the packet errors rises sharply as the background reflection increases. The upstream signal eye diagrams for background reflections of -46 dBm and -36dBm are shown in Fig. 4(a) and (b), respectively. These results indicate that the main factor causing errors is the interference between the background reflection and the upstream signal. To reduce the interference, we attempted to broaden the linewidth of the CW-LD source by the dithering [9]. We dithered the CW-LD by piling the 500-MHz clock signal on its DC bias. The receiver sensitivity improves with increasing modulation depth, which is defined by the ratio of the amplitude of the clock signal to the total amplitude. We have clarified the importance of dithering to prevent interference between the background reflection and the upstream signal.

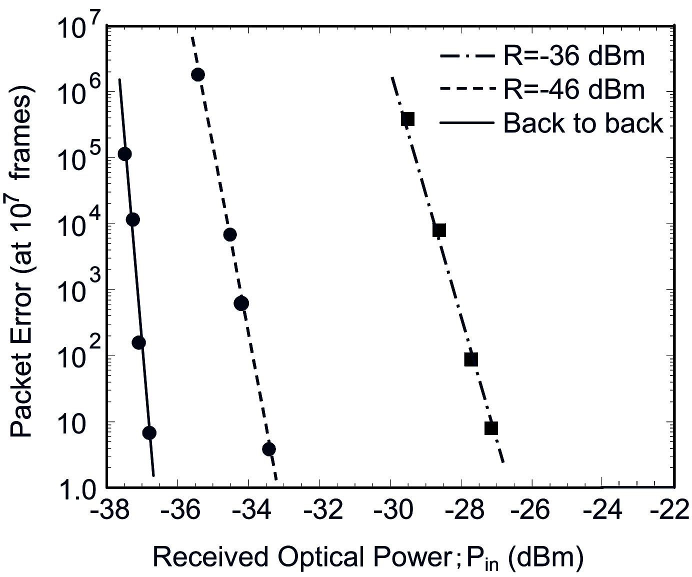

Fig. 3 Measured relationship between received optical power of the upstream signal and packet errors.

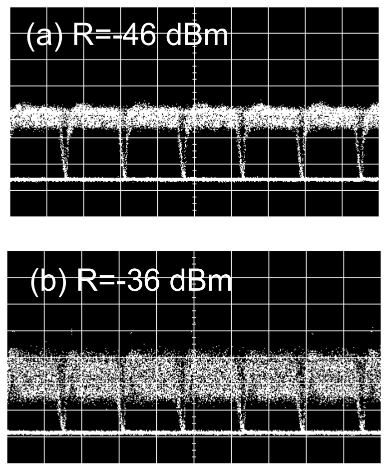

Fig. 4 Upstream signal eye diagrams for background reflections of (a) -46 dBm and (b) -36dBm.

4. Conclusion

We have proposed a novel WDM-PON system that can provide cost-effective and inter-operable optical access network system for the next generation and developed its key components, a SOAT-ONU (Semiconductor optical amplifier transceiver-ONU). This component showed the good performance for application to an actual WDM-PON system.

References

1. K. Akimoto, J. Kani, M. Teshima, and K. Iwatsuki, "Spectrum-sliced, 25-GHz spaced, 155 Mbps X 32 channel WDM access," CLEO/Pacific Rim 2001, ThB1-5, pp. II-556-557.
2. P. Healey, P. Townsend, C. Ford, L. Johnston, P. Townley, I. Lealman, L. Rivers, S. Perrin, and R. Moore, "Reflective SOAs for Spectrally Sliced WDM-PONs," in Conf. Optical Fiber Communications, 2002, WW4, pp. 352-353.
3. D. K. Jung, H. Kim, K. H. Han, and Y. C. Chung, "Simultaneous WDM and Digital Video Transmission over Spectrum-Sliced Bidirectional WDM PON," OECC/ IOOC 2001 Conf. Incorporating ACOFT, MB Access Networks 1, pp.16-18.
4. W. T. Holloway, A. J. Keating, and D. D. Sampson, "Multiwavelength Source for Spectrum-Sliced WDM Access Networks and LAN's," IEEE Photon. Technol. Lett., vol. 9, pp. 1014-1016, 1997.
5. K.-Y. Liou, U. Koren, E. C. Burrows, J. L. Zyskind, and K. Dreyer, "A WDM Access System Architecture Based on Spectral Slicing of an Amplified LED and Delay-Line Multiplexing and Encoding of Eight Wavelength Channels for 64 Subscribers," IEEE Photon. Technol. Lett., vol. 9, pp. 517-519, 1997.
6. R. Monnard, M. Zirngibl, C. R. Doerr, C. H. Joyner, and L. W. Stulz, "Demonstration of a 12 X 155 Mb/s WDM PON Under Outside Plant Temperature Conditions," IEEE Photon. Technol. Lett., vol. 9, pp. 1655-1657, 1997.
7. L. Y. Chan, C. K. Chan, D. T. K. Tong, F. Tong, and L. K. Chen, "Upstream traffic transmitter using injection-locked Fabry-Perot laser diode as modulator for WDM access networks," Electron. Lett., vol. 38, pp. 43-45, 2002.
8. R. J. Campbell, J. R. Armitage, G. Sherlock, D. L. Williams, R. Payne, M. Robertson, and R. Wyatt, "Wavelength stable uncooled fibre grating semiconductor laser for use in an all optical WDM access network," Electron. Lett., vol. 32, pp. 119-120, 1996.
9. M. Okayasu, Y. Suzuki, N. Yoshimoto, R. Iga, H. Sugiura, and J. Yoshida, "Bi-directional Transmission Experiment using a Semiconductor Optical Amplifier Transceiver Module for WDM-PON and WDM-LAN Applications," Proc. of the European conference on Network and Optical Communications 1999, pp. 278-283.