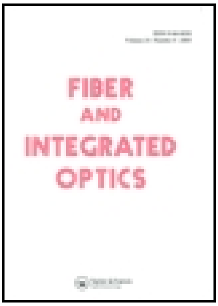

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Fiber-Grating-Based Optical Limiting Amplifier Module for Dual-Wavelength, Hybrid Data Rate Transmission

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Fiber-Grating-Based Optical Limiting Amplifier Module for Dual-Wavelength, Hybrid Data Rate Transmission

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A multichannel fiber-grating-based optical limiting amplifier module is proposed. Dual-wavelength, hybrid data rate transmission is demonstrated with 30 dB input dynamic range. For 5.0 and 2.5 Gbit/s dual-channel transmission in a 200 km single-mode fiber, power penalty due to gain competition between channels and backreflection noise is less than 0.6 dB compared to the receiver sensitivity of 0 km, 5.0 Gbit/s single-channel operation.

Keywords dispersion compensating, fiber Bragg grating, input-power dynamic range, optical limiting amplifier, wavelength division multiplexing

Erbium-doped fiber amplifiers (EDFAs) rapidly increase the progress of 1.55 μm optical fiber transmission, since they overcome the link loss caused by branching and/or tapping and fiber transmission [1]. For maintaining receiver sensitivity in high-speed/long-haul transmission, fiber chromatic dispersion compensation using dispersion compensation fiber (DCF) [2] or chirped fiber gratings (CFGs) integrated optical circulators (OCs) [3] is necessary. However, fiber span may be limited by optical loss of single-mode fiber (SMF), or insertion loss of CFG(s) integrated OC(s). Optical limiting amplifiers (OLA) providing high-input dynamic range are potential candidates for solving these problems [4]. In this letter, we propose and demonstrate a grating-based dual-pass EDFA acting as an OLA to amplify dual-channel, hybrid data rate (5.0 and 2.5 Gbit/s) modulated signals. Input dynamic range and bit-error-rate (BER) performance of the grating-based OLA are measured and discussed.

Experimental Setup

The experimental setup is depicted in Figure 1. For the first experiment, one distributed feedback (DFB) laser source at 1548.5 nm is externally modulated by 5.0 Gbit/s $2^{15} - 1$ pseudorandom bit sequence (PRBS) non-return to zero (NRZ)

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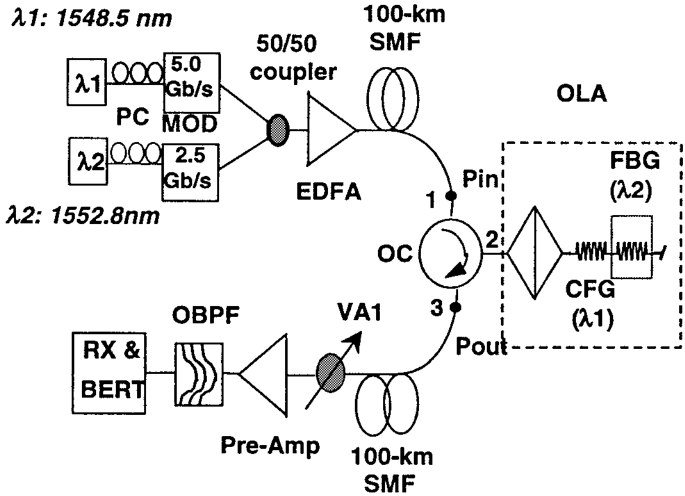

Figure 1. Experimental setup: PC, polarization controller; MOD, external modulator; OBPF, optical bandpass filter; RX, optical receiver; BERT, bit-error-rate test set.

data stream. The signal is then amplified by a boost EDFA and then followed by a 100 km SMF with optical loss of 0.22 dB/km. Another 100 km SMF is arranged after the OLA module. An EDFA (without isolator) is located after port 2 of the OC in the OLA module. A CFG is used for both signal reflection and fiber chromatic dispersion compensation. The interport isolation is 50 dB, and the insertion loss is 1.0 dB for the OC. The CFG has 95% reflectivity and 0.4 nm full width at half maximum (FWHM) at 1548.5 nm. The circulator-grating combination exhibits a total insertion loss of about 3 dB. The amplified spontaneous emission (ASE) was greatly reduced because of the narrow-band filtering effect of the CFG. The saturation signal output power of this OLA is about 9.5 dBm. For the second experiment, to confirm the feasibility of OLA for dual-channel or multichannel operation, another DFB laser source at 1552.8 nm is externally modulated by a 2.5 Gbit/s $2^{23} - 1$ PRBS NRZ data stream for dual-channel operation. A fiber Bragg grating (FBG) has 99.9% reflectivity, and 0.2 nm FWHM at 1552.8 nm is connected in series with the CFG, as shown in Figure 1.

Results and Discussion

Figure 2 shows the measured signal output power as a function of input power for a one-channel (at 1548.5 nm) conventional EDFA and OLA, and two-channel OLA by adding the 1552.8 nm channel. For single-channel OLA operation the input dynamic range of the OLA is as high as 30 dB because the signal is amplified before and after (i.e., twice) being reflected by the CFG. Here the input dynamic range is defined as the input power range that maintains a power level within 3 dB down from its peak power value. The link budget of OLA is improved from 2 to 20 dB when the input power level is decreased from −10 to −40 dBm. The result is similar for dual-channel operation. For the OLA the relative ASE power is much larger at lower input power than that at higher input power because the gain of OLA is suppressed in the latter case, and the ASE power decreases accordingly. The measured BER performance of the 5.0 Gbit/s signal in back-to-back, 200 km

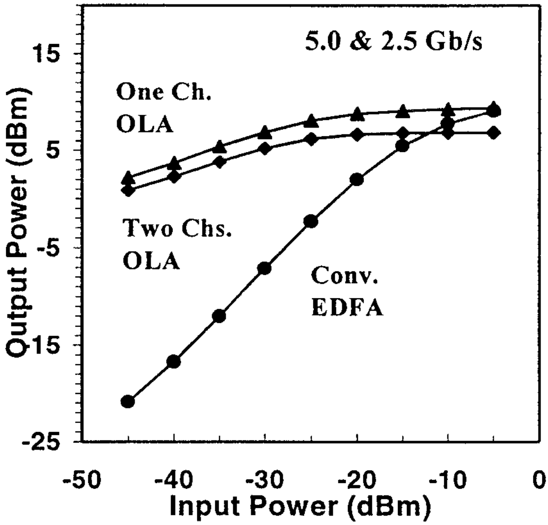

Figure 2. Measured signal output power as a function of signal input power for a one-channel (at 1548.5 nm) conventional EDFA and OLA, and dual-channel (at 1548.5 and 1552.8 nm) OLA.

transmission without or with the 2.5 Gbit/s modulated channel signal is shown in Figure 3. The received sensitivity at 10^{-9} BER for the baseline is -39.6 dBm. When only the 5.0 Gbit/s channel is transmitted, the performance degradation is 0.9 dB for a 200 km SMF transmission with a CFG-integrated OLA compared to that of the 0 km baseline condition. The power penalty is mainly due to the

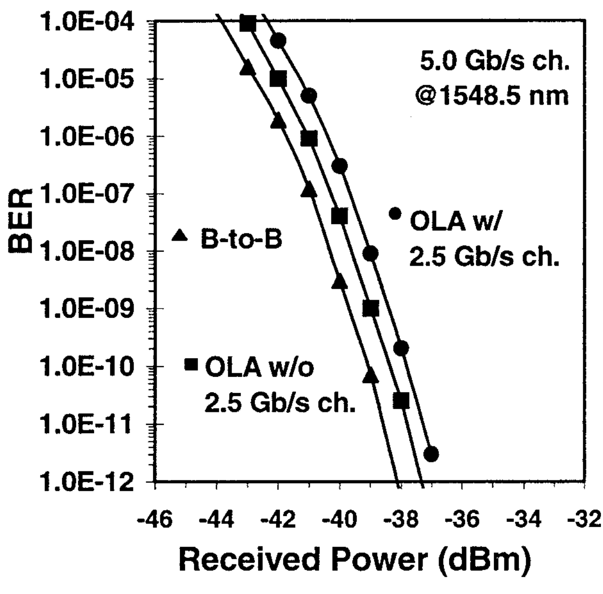

Figure 3. Measured bit-error-rate (BER) performance of the 5.0 Gbit/s channel signal in back-to-back and 200 km single-mode fiber transmission with and without the 2.5 Gbit/s channel signal.

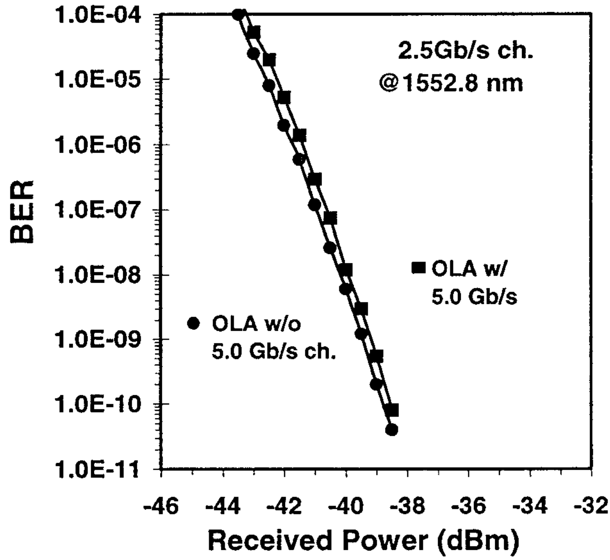

Figure 4. Measured BER performance of the 2.5 Gbit/s signal in 200 km of single-mode fiber transmission with and without the 5.0 Gbit/s channel signal.

reflection of ASE and amplified signals from connectors. When another 2.5 Gbit/s signal is added into the system, a further 0.6 dB power penalty occurs due to gain competition between the hybrid channels and multiple reflections from the connectors. Note that the 5.0 Gbit/s channel signal is reflected by the CFG, while the amplified 2.5 Gbit/s channel signal will pass through the CFG and continue its forward propagation until it is reflected by the FBG.

For the 2.5 Gbit/s signal the received sensitivity at 10^{-9} BER is −39.5 dBm, as shown in Figure 4. Negligible power penalty for a 200 km SMF transmission is observed when compared to the performance of a back-to-back condition whether the 5.0 Gbit/s channel is added or not. The measured BER results confirm the feasibility of FBG-based OLA modules for dual-channel or multichannel operation.

Conclusion

A multichannel FBG-based OLA module is proposed. Dual-wavelength, hybrid data rate transmission is experimentally demonstrated. A power penalty of less than 0.6 dB is observed when the system performance of dual-channel is compared with that of single-channel operation. The OLA module with the features of both dispersion compensation and high-input dynamic range may find potential applications in high-speed and dense wavelength division multiplexing (WDM) lightwave systems.

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Biographies

Shien-Kuel Liaw received his BSEE from National Taiwan University and his MSEE from National Tsing-Hua University, Taiwan, in 1988 and 1993, respectively. He received his Ph.D. in electro-optical from National Chiao-Tung University, Taiwan in 1999. From 1993 to 1997 he was a member of the technical staff at the Department of Applied Research of Chung-Hwa Telecommunication Laboratories in Yang-Mei, Taiwan. In 1996 he was a resident visitor at Bellcore, Red Bank, New Jersey. He is currently an assistant professor at Da-Yeh University. His research interests include optical fiber communications, erbium-doped fiber amplifiers, and fiber Bragg gratings and their related applications.

Sien Chi received his BSEE from National Taiwan University and his MSEE from National Chiao-Tung University, Taiwan, in 1959 and 1961, respectively. He received his Ph.D. in electrophysics from the Polytechnic Institute of Brooklyn, New York, in 1971, and then joined the faculty of the National Chiao-Tung University, where he is currently a professor of electro-optical engineering. From 1972 to 1973 he chaired the Department of Electrophysics; from 1973 to 1977 he directed the Institute of Electronics; from 1977 to 1978 he was a resident visitor at Bell Laboratories, Holmdel, New Jersey; from 1985 to 1988 he was the principal advisor with the Hua-Eng Wire and Cable Company, the first manufacturer of fibers and fiber cables in Taiwan, developing fiber making and cabling technology; and from 1988 to 1990 he directed the Institute of Electro-Optical Engineering. He was the symposium chair of the International Symposium of Optoelectronics in Computers, Communications and Control in 1992, which was coorganized by National Chiao-Tung University and SPIE. In 1993 he received the Distinguished Research Award sponsored by the National Science Council, Taiwan. His research interests are optical fiber communications, optical solitons, and optical fiber amplifiers. Dr. Chi is a member of the Chinese Optical Engineering Society and fellow of the Optical Society of America and the Photonics Society of Chinese Americans.

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