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Burst-mode Bidirectional Optical Amplifier with single-EDF configuration for L-band use in 10Gbit/s-PON systems

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1. Abstract

We propose a novel burst-mode bidirectional L-band optical amplifier with single-EDF configuration, show its gain characteristics, and clarify the impact on downstream transmission properties of the gain deviation caused by upstream burst signal amplification.

2. Introduction

There has been increasing interest in broadband optical access services using PON (Passive Optical network) systems due to their cost-effectiveness; the transmission fiber and the central office equipment are shared by many subscribers. GE-PON(Gigabit Ethernet PON)[1] and G-PON(Gigabit-capable PON)[2] systems, which can provide gigabit-capable FTTH services, have been deployed in Japan and North America, respectively. Moreover, the next generation PON systems with 10Gbit/s capacity are being discussed in IEEE and FSAN [3, 4]. In these associations, coexistence with current PON systems has been recognized as indispensable to achieve smooth migration. A wavelength allocation plan for next-generation PON systems in the L-band wavelength region (1560 to 1625 nm) has been proposed for realizing coexistence because the L-band wavelength region is not used by existing PON systems that comply with current standards.

Optical amplifiers bring some benefits to PON systems such as long-reach, high splitting ratios, and high-sensitivity. For existing PON systems that comply with current standards, we have investigated a bidirectional optical amplified PON repeater that consists of an O-band (1260 to 1360 nm) optical burst-mode amplifier and an S-band (1460 to 1530 nm) optical amplifier [5]. This amplifier utilizes gain-clamping to suppress optical surges; such surges can well cause failure of the optical receiver as well as interfering with the reception of normal signals at the OLT due to gain dynamics.

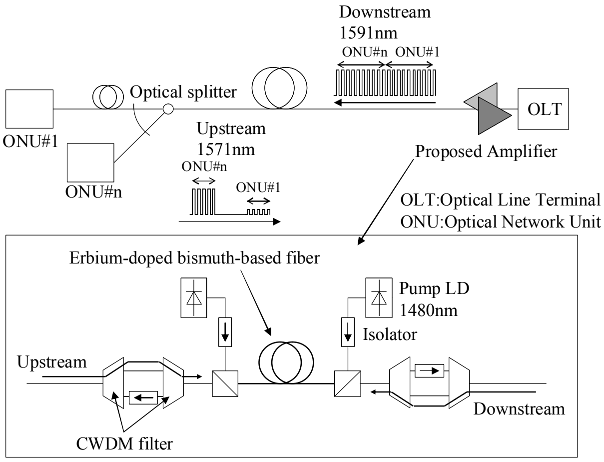

Fig.1 Configuration of bidirectional optical amplifier with single-EDF

In this paper, we propose a novel burst-mode bidirectional optical amplifier with single erbium-doped fiber (EDF) configuration for L-band amplification. The proposed amplifier employs downstream optical signals as the gain-clamp light to suppress optical surges. This eliminates the additional gain-clamp light source and simplifies the optical amplifier because we can use the same gain medium to amplify both upstream and downstream optical signals. We also show the gain characteristics of the proposed optical amplifier and clarify the impact on downstream transmission properties of the gain deviation due to upstream burst signal amplification.

3. Proposed burst-mode bidirectional optical amplifier with single-EDF configuration

Figure 1 shows the configuration of the optical access system with the proposed amplifier and the structure of the amplifier. To suppress optical surges, the downstream optical signal is stronger than the burst-mode signal light, so proposed amplifier is allocated near the OLT. The proposed amplifier consists of just an erbium-doped bismuth-based fiber [6] to amplify upstream and downstream signals in the L-band wavelength region. Downstream optical signals are utilized to suppress optical surges, which are usually triggered in the upstream optical burst signals by optical amplification. Therefore, the proposal yields a simple bidirectional optical burst-mode amplifier that does not need any additional LD for gain-clamping and thus offers significant cost benefits. On the other hand, the gain variation caused by the upstream burst-mode optical signal may degrade the downstream optical signals.

4. Experiment

We conducted an experiment to clarify the influence of upstream and downstream signals as well as basic gain properties. Figure 2 shows gain properties as a function of input power. Both forward and backward pump powers were set at 500 mW. The downstream signal was set at the relatively high power of 0 dBm to realize gain clamping of the upstream signals. The wavelengths of upstream and downstream signals were 1571 nm and 1591 nm, respectively, these wavelengths lie on the ITU-CWDM grid [7].

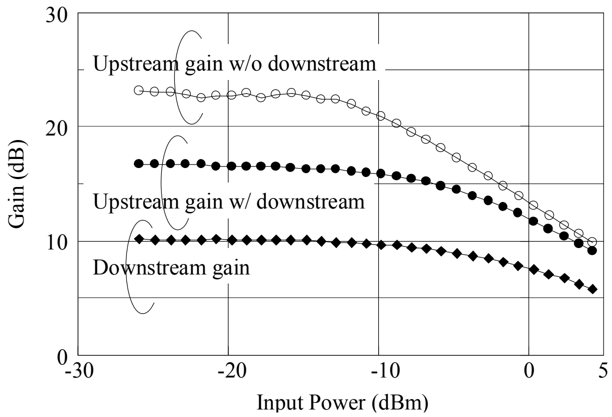

Fig.2 Upstream and downstream gain characteristics

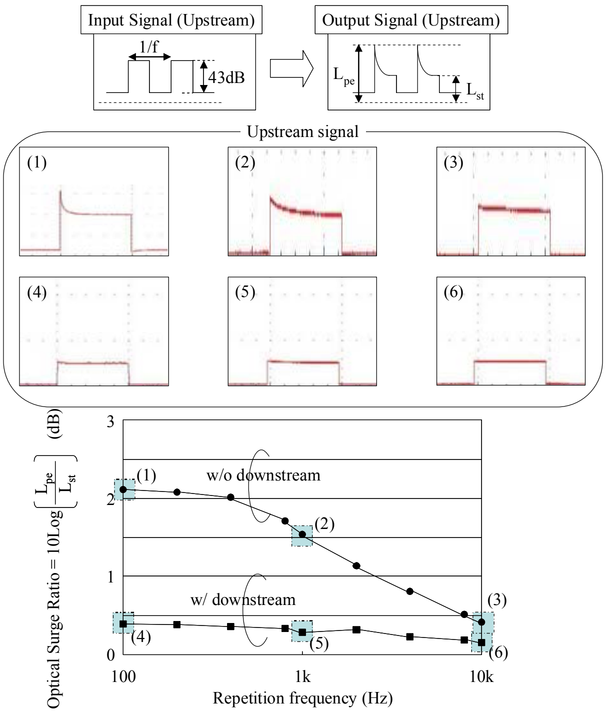

Fig.3 Optical surge ratio versus burst repetition frequency

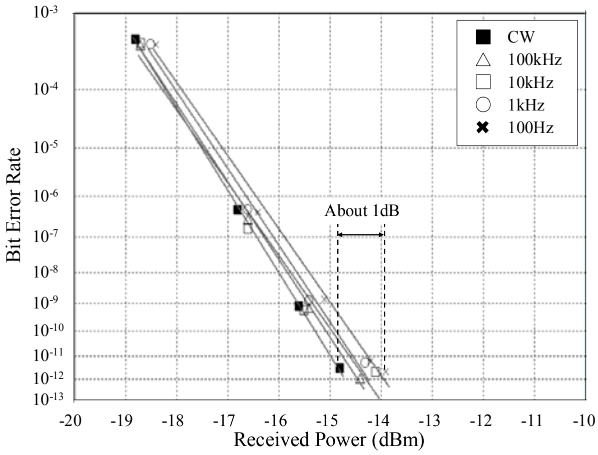

Fig.4 Bit error rate versus repetition frequency

As shown in Figure 2, although the downstream signal suppress the upstream gain from 23dB to 16dB, good gain linearity is obtained because the 1 dB gain suppression point is improved to -10 dBm and gain deviation of the upstream signal is suppressed compared to upstream signal amplification (unidirectional amplification). The downstream signal gain is around 10 dB at input powers less than -10 dBm while the downstream gain is decreased with upstream signal input powers greater than -10 dBm. These results show that the proposed bidirectional optical amplifier works well at upstream averaged signal powers under -10 dBm.

Next we confirmed that the downstream signal could suppress optical surges in the upstream signal. Figure 3 shows the optical surge ratio (OSR) as a function of burst repetition frequency. We define OSR as the ratio of optical surge peak level to restored normal signal level. Bidirectional amplification well suppresses OSR compared to unidirectional amplification, see Figure 3.

Figure 4 shows the bit-error rate (BER) as a function of averaged receive power of upstream signal at the optical receiver; the parameter is burst repetition frequency. We evaluated the power penalties at the BER of 10^{-12} for each burst repetition frequency. In the experiment, downstream 10.3125 Gbit/s (PRBS was 2^{31}-1) signals were generated by a $LiNb_3$ intensity modulator; extinction ratio was 9.8 dB and averaged power was -3 dBm. A PIN-PD was used in the optical receiver. The maximum power penalty of only 1 dB is observed at the burst repetition frequency of 100 Hz and averaged optical input power to the amplifier of -13 dBm.

5. Conclusion

We proposed a novel burst-mode bidirectional L-band optical amplifier with single-EDF configuration, and demonstrated its gain characteristics. First we confirmed the effect of optical surge suppression using gain-clamp light. We also clarified the impact on downstream transmission properties of the gain deviation caused by upstream burst signal amplification. Measurements showed that the upstream signal had no significant influence at averaged optical input powers to the optical amplifier of under -13 dBm which confirms the validity of our proposed bidirectional amplifier.

Reference

[1] IEEE 802.3ah
[2] ITU-T Recommendation G.983 series
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[4] FSAN NGA http://www.fsanweb.org/nga.asp
[5] K.I.Suzuki, et al., ECOC2006, Mo.4.5.3.
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[7] ITU-T Recommendation G.694.2