First Demonstration of Fast Automatic-Gain-Control (AGC) PDFA for Amplifying Burst-Mode PON Upstream Signal

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Abstract

The effectiveness of installing fast AGC in a PDFA for amplifying burst mode PON upstream signals is reported for the first time. The technique has the potential to realize high-gain/high-power burst-mode PON repeaters.

Introduction

Passive Optical Network (PON) access systems, characterized by their fiber-shared point-to-multi-point configuration, are used for providing broadband multimedia services in Japan. Nowadays, gigabit-class PON based access services are being provided (GE-PON/G-PON) and 10 gigabit-class PON (e.g. 10GEPON) systems are being standardized. A PON system adopts a star network topology; its user-side terminals (i.e. ONU: Optical Network Unit) are connected to the central-office-side terminal (i.e. OLT: Optical Line Terminal) by optical splitters and fibers. To encourage PON penetration (lower costs), each OLT should support long-reach operation and/or many more ONUs. This is possible with optical amplifying PON repeaters that can compensate the splitter and fiber losses and so increase the transmission distance and/or the ONU-accommodation number.

Optical amplifying PON repeaters are, however, difficult to realize, because of the bursty nature of upstream signals. These signals dynamically disturb the gain of fiber amplifiers yielding upstream signal waveform distortion (i.e. optical surge). Our solution was to propose the gain-clamp (GC) technique to stabilize the gain of PON amplifying repeaters [1]. Our proposal injects a high-power (stronger than the signal light) and continuous light generated by an outside DFB-LD into a Praseodymium Doped Fiber Amplifier (PDFA) that has gain in the 1.31μm wavelength region; this technique reduces the small signal gain but expands the linear amplification region of the PDFA. It achieved 17dB gain and good gain linearity (its deviation is held to less than 1dB over the input power range of up to -10dBm).

High-gain type optical amplifying PON repeaters (26dB gain) are beginning to be demanded [2]. Therefore, burst-mode amplification methods other than the GC technique (which reduces signal gain) are needed to achieve the high-gain and/or high-power burst-mode amplifiers. Our solution is to apply the fast automatic-gain-control (AGC) technique [3] to PDFAs. It has the possibility of achieving a burst amplifier that offers high gain and high power, because the pump power is only used for signal amplification (not wasted to amplify the GC light at all). This paper reports the first demonstration of the fast AGC PDFA for amplifying burst-mode PON upstream signals.

Fast Automatic-Gain-Control (AGC) PDFA

The fast AGC PDFA (Figure 1) adopts feed-forward pump-power and feed-back optical-attenuation controls. The linear amplification region is expanded by fast adjustment of the pump light power to suit the input signal light power. In addition, fast VOA control extinguishes the optical surges created by the gain response in the amplification medium. This technique has been applied to EDFAs [3] for optical packet networks with the relatively relaxed burst condition compared to that of PON upstream signals.

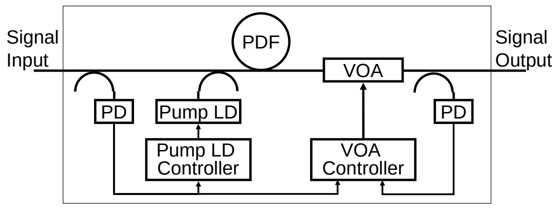


Figure 1: Architecture of Fast AGC PDFA

Experiment: Static Characteristics

First, we measured the static input-output characteristics of the fast AGC PDFA (Figure 2). When the pump power is constant (i.e. independent of the signal light power) (ACC mode, Figure 2(a)), the linear amplification region (i.e. gain deviation is held to less than 1dB) covers the input power range of up to -11dBm. On the one hand, when the pump power is controlled by the fast AGC technique (Figure 2(b)), the linear gain region can expand up to -6dBm without any drastic small signal gain decrease (the

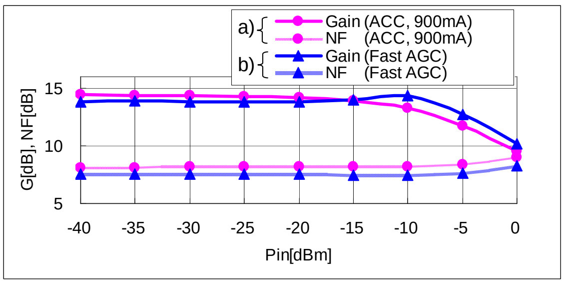


Figure 2: Static Input-Output Characteristics

difference in small signal gain between the ACC and fast AGC is only 0.5dB).

Experiment: Dynamic Characteristics

Next, we measured the dynamic input-output characteristics of the fast AGC PDFA to confirm its ability of the optical surge suppression (Figure 3). The burst signal generated by an acousto-optic modulator (AOM) or 500-ps response burst-mode 10Gbit/s transmitter [4] (50% duty rectangle) was amplified by the PDFA, and we measured its normalized surge intensity (i.e. *Cs=Ps/Pout*, *Ps*; surge power, *Pout*; output signal light power) using an oscilloscope. When *Cs* was being measured, the peak power of the input burst light was kept constant at -10dBm.

The result showed that the fast AGC well suppressed the optical surges. Figure 5(a) shows measured *Cs* as a function of the burst frequency *f*[Hz]. *Cs* increased up to 1.1dB when the PDFA was operated in ACC mode. When the PDFA was operated in fast AGC mode without VOA, *Cs* became less than zero dB because the optical surge suppression was excessive and the waveform of the amplified burst was distorted. When the PDFA was operated in fast AGC mode with VOA, the absolute value of *Cs* decreased to not more than 0.2dB. The waveforms of the amplified burst signal also showed the effectiveness of the fast AGC. The optical surge and distortion disappeared when the fast AGC was active (Figure 5(b,c)). We used the 500-ps response burst-mode 10Gbit/s transmitter to confirm that there was no waveform distortion in a burst signal amplified by the fast AGC PDFA with 0.2µs time resolution.

Experiment; Amplifying PON Upstream Signals

Finally, we confirmed the power penalty of the received upstream G-PON signal amplified by the fast AGC PDFA (Figure 6). The PDFA input peak power of signals from two ONUs were set to -10dBm and -20dBm, respectively. The receiver sensitivity of the OLT was -30dBm and no degradation in receiving power was observed. This suggests that suffered no waveform distortion, and the gain is steady immediately after the passage of large power bursts. Moreover, the fast AGC PDFA successfully achieved 14dB improvement of the G-PON loss budget and over 26dB wide dynamic range operation.

Conclusion

We examined the fast AGC PDFA for amplifying burst-mode PON upstream signals for the first time. Static, dynamic, and BER characteristics suggest that it has the potential to realize high-gain/high-power burst-mode amplifiers that can lineally amplify burst upstream signals in PON systems.

References

1. K-I. Suzuki et al., ECOC2006, Mo4.5.3.
2. ITU-T Recommendation G.984.6.
3. Y. Oikawa et al., OFC/NFOEC 2008, JThA15.
4. H. Nakamura et al., OFC/NFOEC 2008, PDP26.

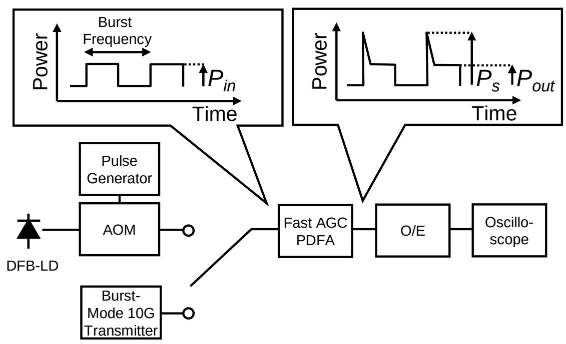
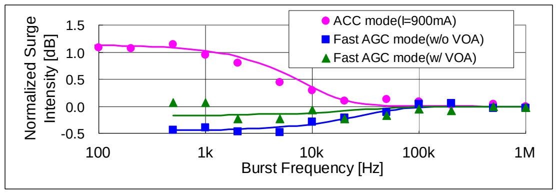
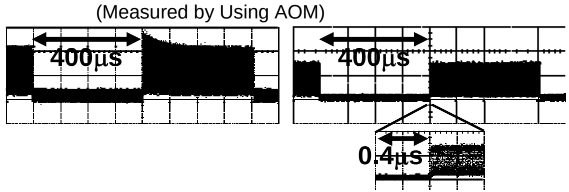


Figure 3: Setup of Optical Surge Measurement



(a) Normalized Surge Intensity vs. Burst Frequency (Measured by Using AOM)



(b) 10Gbit/s Burst Signal Trace Amplified by PDFA in ACC Mode

(c) 10Gbit/s Burst Signal Trace Amplified by PDFA in Fast AGC Mode

Figure 4: Results of Optical Surge Measurement

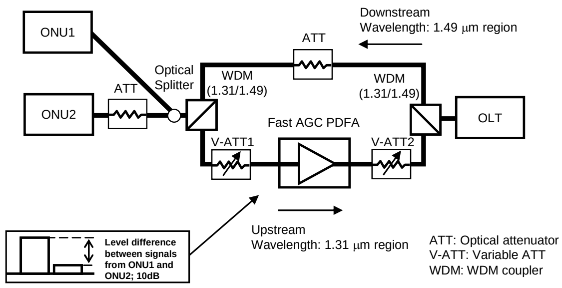


Figure 5: Setup of Power Penalty Measurement

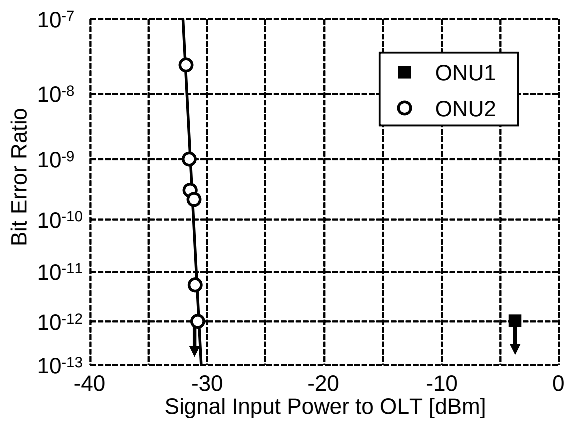


Figure 6: BER of Burst Signal Amplified by Fast AGC PDFA