

Simultaneous ER Enhancement and Light Reuse Scheme for RSOA-Based WDM-PONs

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Abstract

A simultaneous extinction-ratio enhancement and light reuse scheme was proposed for RSOA-based WDM-PONs to enhance 10/1.25-Gbps downstream and upstream transmissions. This scheme greatly reduces the power penalty for both downstream and upstream transmissions.

Introduction

The latest development in passive optical network (PON) systems is evolving toward higher data rates and long-reach transmission distances, where WDM-PONs can be very attractive solutions [1,2]. The re-modulated reflective semiconductor optical amplifier (RSOA) is a very popular colorless source to be utilized in an optical network unit (ONU) [3]. At the optical line terminal (OLT), directly modulated DFB lasers (DMLs) are frequently used to transmit downstream signals at high data rates. However, the transmission distance is limited by the chirp effects if the DMLs are modulated with high extinction ratio (ER) [4,5]. For example, to obtain good transmission performance by using DMLs at 10 Gbps over distances of tens of kilometers, the ER is usually 3 dB or lower. To avoid power penalty from such a low ER, a Fabry-Perot etalon (FP etalon) or a filter is usually added before the receiver at the ONU to reshape the signals [3,5].

In this paper, we propose a simultaneous ER enhancement and light reuse scheme built in the OLT to enhance the downstream transmission for multiple DML channels and provide reusable lights, whose downstream data are erased, to the ONUs for re-modulating the upstream data. This RSOA-based WDM-PON architecture can use only a single FP etalon at the OLT rather than one at each ONU. Performance enhancement on the downstream and upstream transmission can be simultaneously achieved because the ER value is improved for each downstream signal and the intensity noise caused by downstream signal can be greatly reduced for each upstream signal.

Architecture and Operation Principle

The RSOA-based WDM-PON architecture is shown in Fig. 1. The downstream and upstream data propagate via different feeder fibers and distribution fibers such that

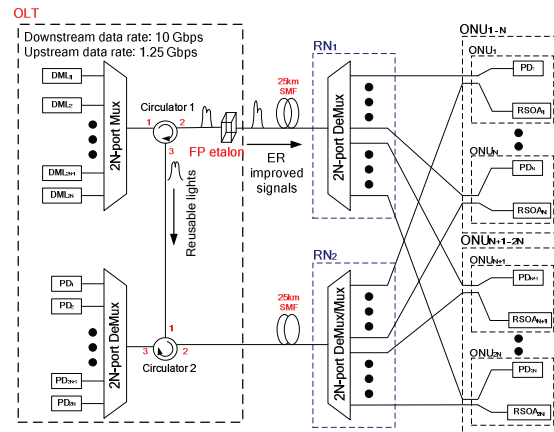


Fig. 1 Architecture of the proposed RSOA-based WDM-PON.

upstream channels can use the same light sources at OLT without suffering from the Rayleigh scattering and/or Fresnel reflection effects. Multiple DMLs of DWDM channel spacing are modulated at 10 Gbps and combined by a 2N-port wavelength-division multiplexer (Mux). The DWDM signals are then fed into the first circulator (circulator-1), which directs the reflected lights from the FP etalon to the RSOAs at the ONUs. The FP etalon erases the downstream data so its reflected light can be reused as the pilot light for remodulation. Meanwhile, the downstream lights are reshaped to enhance ER by the same FP etalon and directly propagated along the upper feeder fiber to the first remote node (RN₁), where the 2N-port de-multiplexer (DeMux) routes the lights to their corresponding receivers through the distribution fibers. For the upstream transmission, the same way is used to distribute reusable lights among the RSOAs at the ONUs. The RSOA re-modulates the upstream data on the pilot light and transmits along the same path to the OLT via the second circulator (circulator-2). The data rate for the upstream signals is 1.25 Gbps.

The key component, an FP etalon, performs two opposite spectral filtering functions: suppression of the spectral peak of bit "0" for the transmitted lights, leading to ER enhancement, and suppression of the spectral peak of bit "1" for the reflected lights, leading to data erasure. To provide the functions to multiple DWDM channels,

the free spectral range (FSR) of the FP etalon must match the channel spacing.

Performance Demonstration

We demonstrate the proposed scheme by using a DML modulated by 10-Gbps nonreturn-to-zero (NRZ) signals to transmit the downstream signals. The data is of $2^{31}-1$ pseudorandom bit sequence (PRBS). An RSOA is used at the ONU to re-modulate the downstream pilot light to transmit the upstream NRZ signals at a data rate of 1.25 Gbps. The DML is temperature controlled at 25 °C. Its bias current and modulation current are 82 mA and 35 mA, respectively. It has an output wavelength of 1557.54 nm and an average optical power of 6 dBm. The RSOA, which has the specifications of 20 dB optical gain and + 3 dBm saturated optical power, was biased at 60 mA and driven by 40-mA modulation current. The FP etalon used in the experiment has an insertion loss of 1.68 dB, finesse of about 10, and FSR of 100 GHz. When the original DML signal with 3-dB ER passes through the FP etalon, two output lights are generated. The transmitted signal has an improved ER value of 8 dB, while the reflected signal has a null ER value (0 dB). Thus, the FP etalon provides ER enhancement to the transmitted signals but data erasion to the reflected signals.

The incident optical power to the RSOA was fixed at -10 dBm for the measurements. The ER for the downstream signals is enhanced from 3 dB to 8 dB after the FP etalon. The eye pattern is still wide open after 25-km transmission. The transient chirp of the DML signal can also be filtered out by the FP etalon [3,5]. Here we achieve simultaneous ER enhancement and data erasion by using a single FP etalon. With this scheme, the upstream signals based on the reusable light, whose downstream data were erased, can have much better quality than the ones without using the FP etalon.

The bit-error-rate (BER) measurement verifies the performance enhancement to the downstream and upstream signals, as shown in Fig. 2 and Fig. 3. After transmission of 25 km and at the requirement for $BER=10^{-9}$, for 10-Gbps downstream signal the decrease in the power penalty is better than 1.8 dB and for 1.25-Gbps upstream signal only 0.5 dB power penalty is observed by comparing the result with the re-modulated upstream signals using an additional CW pilot light. Compared to the transmission without data erasion, our scheme reduces the power penalty by about 1.4 dB.

Conclusions

We demonstrate a simultaneous ER enhancement and light reuse scheme using a single FP etalon for RSOA-based WDM-PONs. It can enhance the downstream ER value for multiple DWDM channels and simultaneously provide multiple reusable lights for ONUs. This scheme can reduce system cost by eliminating the use of CW pilot lights.

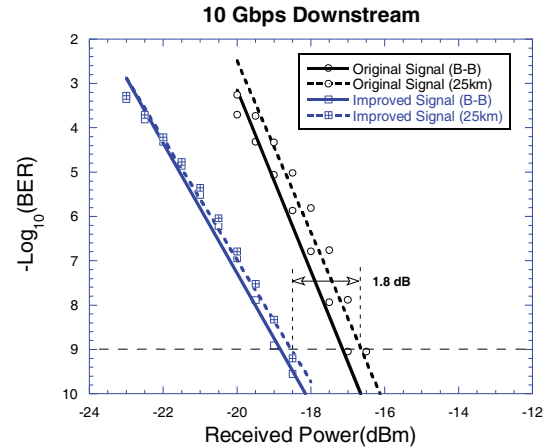


Fig. 2 Measured downstream BER with and without using an FP etalon for ER enhancement.

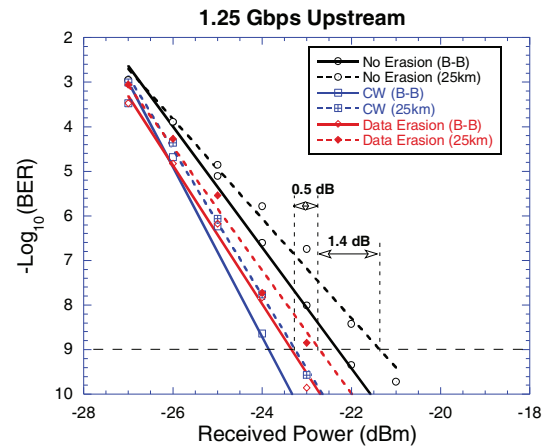


Fig. 3 Measured upstream BER with and without using an FP etalon for data erasion.

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