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Real-time 10Gbps Polarization Independent Quasicoherent Receiver for NG-PON2 Access Networks

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Abstract: A real-time 10Gbps polarization independent quasicoherent receiver for NG-PON2 access networks is proposed and experimentally validated. The sensitivity of this receiver is -33dBm and making feasible a 35dB power budget (required for E2 class).
OCIS codes: (060.1660) Coherent communications; (040.0040) Detectors; (060.4510) Optical communications

1. Introduction

During the recent years, data traffic over the access networks is growing exponentially due to new streaming media, Internet of Things (IoT), cloud computing and the convergence between wireless and optical communications in the new 5G paradigm [1]. In order to address these traffic necessities, new standards for new generation passive optical networks such as NG-PON2 have been released [2,3]. NG-PON2 provides an aggregated data rate of 40Gbps employing time and wavelength division multiplexing (TWDM), which therefore requires 10Gbps colorless and tunable Optical Network Units (ONU) and Optical Line Terminals (OLT). NG-PON2 also requires an optical distribution network (ODN) with high splitting ratios and transmission distances up to 40km. These requirements increase the complexity and the cost of the ONUs and OLTs due to the necessity of tunable optical filters, Avalanche Photodiodes (APD) and high optical power lasers.

In the last years, several coherent technologies have been studied in order to fulfill all these requirements and reduce the cost of the ONUs [4-6]. In this paper, we propose and experimentally validate a real-time 10Gbps polarization independent quasicoherent receiver. This 10Gbps quasicoherent receiver can solve these NG-PON requirements reducing the cost of the ONUs and OLTs in real time, i.e. without digital signal processing (DSP) to obtain the real data. This real-time 10Gbps quasicoherent receiver increases the sensitivity, which allows use reduced optical power laser and cheap photodiodes instead of expensive APDs, and enables wavelength selection without optical filtering, which allows to dispense with expensive tunable optical filters.

2. Experimental Setup

Fig. 1 shows the schematic of the real-time 10Gbps polarization independent quasicoherent receiver, denoted as Bifrost Quasicoherent Receiver, and the experimental setup used in this work.

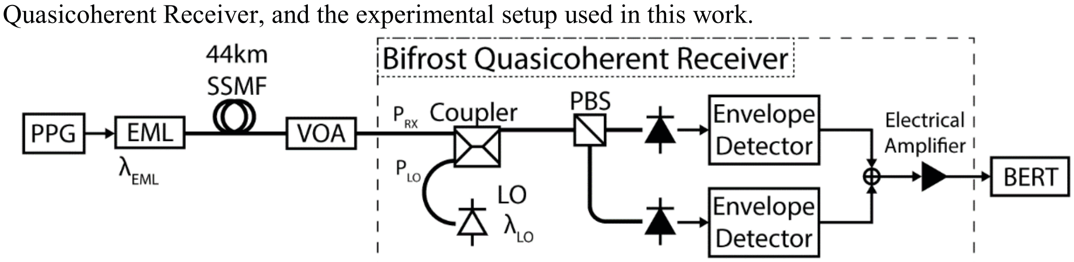

Fig. 1. Experimental setup.

The proposed receiver consists of optical coupler followed with a Polarization Beam Splitter and two PIN photodiodes with an electrical bandwidth of 23GHz. The coupler is fed with the received signal and a local oscillator (LO), which is a TLS. The LO wavelength (λ_{LO}) is tuned to a wavelength that is shifted away the value of an intermediate frequency f_{IF} from the wavelength of the received signal (λ_{EML}), so f_{IF} is placed in a desired range of 9 to 16GHz. Both IF signals at the photodiodes are downconverted to baseband employing an ultra-wideband Schottky diode based envelope detector for 10Gbps signals similar as the one presented on [7]. Finally, both signals are physically added and electrically amplified. Therefore, the proposed 10Gbps quasicoherent receiver does not requires DSP for the real-time operation. The Bit Error Rate (BER) is measured with real-time BER test (BERT).

In order to test the sensitivity of the proposed real-time 10Gbps quasicoherent receiver, a 10Gbps Externally Modulated Laser (EML) has been employed with an emitting power of 0.44dB. This EML is modulated using a 10Gbps Non-Return-to-Zero (NRZ) signal generated with a Pulse Pattern Generator (PPG). The modulated signal is transmitted through 44km of Standard Single Mode Fiber (SSMF) and a Variable Optical Attenuator (VOA) is used to introduce losses in the channel.

3. Results

The sensitivity has been defined as the minimum received power with a maximum BER of 10^{-3} as required by NG-PON2 with FEC [2]. The variation of the sensitivity of the proposed receiver versus LO optical power is shown in Fig. 2. The sensitivity of the polarization independent proposed receiver for two different order pseudorandom binary sequences (PRBS) is shown in Fig. 3. Finally, Fig. 4 shows the sensitivity of the proposed receiver compared to a direct detection (DD) scheme.

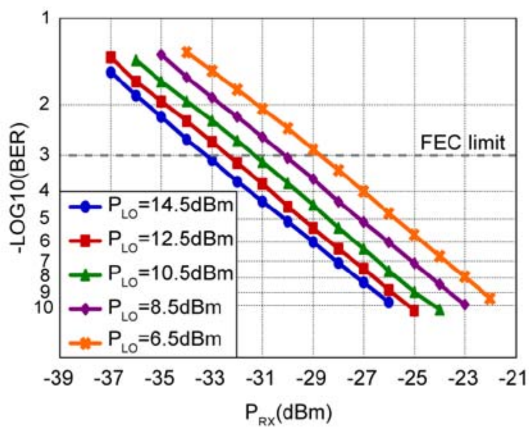

Fig. 2. BER versus received power for 10Gbps Bifrost Receiver for different LO power.

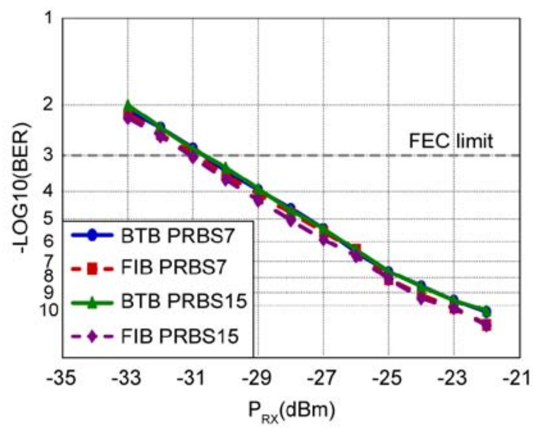

Fig. 3. BER versus received power for 10Gbps Polarization Independent Bifrost Receiver for different PRBS patterns.

In Fig. 2, the variation of the sensitivity of the proposed receiver for different LO powers is shown. The sensitivity of the proposed receiver is -29dBm with a LO power of 6.5dBm. When the LO power is increased to 14.5dBm the sensitivity improves to -33dBm. The sensitivity improvement is 1dB for each 2dB increment of the LO power. This improvement starts to get saturated with a LO power of 10.5dBm when the sensitivity improvement decays to 0.5dB for each 2dB increment of LO optical power.

The optical back-to-back and the 44km SSMF transmission sensitivity for P_{LO}=10.5dBm and two different order patterns (PRBS7 and PRBS15) are shown in Fig. 3. As can be observed, there is no penalty due to 44km fiber propagation and the use of different patterns, i.e. PRBS7 and PRBS 15, exhibit the same BER behavior. Therefore, the receiver is pattern independent, as can be seen in Fig. 3. All the measurements have been implemented without polarization control, which shows the polarization independent operation.

The sensitivity of the proposed real-time 10Gbps quasicoherent receiver is -33dBm while the sensitivity of the 10Gbps Direct Detection (DD) with a PD with the same characteristics of the PIN used by the Bifrost Receiver is -20dBm, as is depicted in Fig. 4. Thus, the proposed quasicoherent receiver provides an improvement of 13dB compared with DD receivers.

The NG-PON2 standard [2] indicates that the TX lasers should provide a minimum emitting power of 2dBm and a maximum emitting power of 9dBm, so the proposed 10Gbps quasicoherent receiver power budget is between 35dB and 42dB. Consequently, the proposed 10Gbps quasicoherent receiver allows to work with all the optical path loss classes of NG-PON2, because the most restrictive class (Extended 2 o E2) is defined by a minimum optical path loss of 20dB and a maximum optical path loss of 35dB [2], which are easily fulfilled using the proposed 10Gbps quasicoherent receiver and any of the possible NG-PON2 laser types.

In the case of employing a DD scheme with the PD, the power budget would be between 22dB and 29dB, which means that it would only be able to fulfil the optical path losses of the less restrictive NG-PON2 class (Nominal 1 o N1) by employing the most powerful laser type. Moreover, measurements in this case have been made without using an optical filter at the receiver, which would be necessary in a multiwavelength scheme as NGPON2 and would introduce additional losses. Therefore, the DD with a PIN PD would not be feasible in a transceiver because it will not be able to fulfil the optical path losses of any of the NG-PON2 classes and more expensive 10Gbps APD are required.

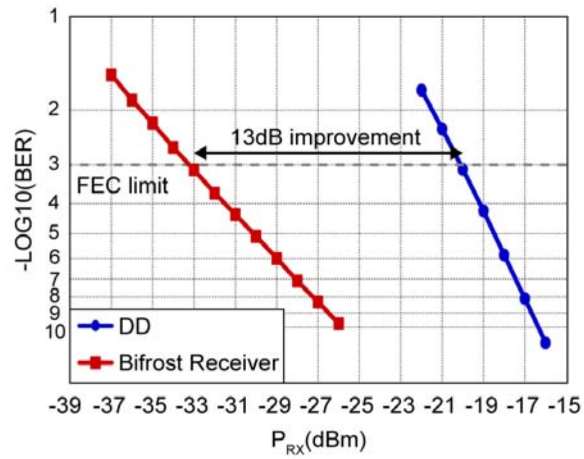

Fig. 4. BER versus received power for 10Gbps Bifrost Receiver and 10Gbps Direct Detection (DD).

Consequently, the high sensitivity of this 10Gbps quasicoherent receiver will allow to employ lasers presenting lower emitting powers. In order to fulfil the required maximum optical path losses for class N1 (29dB), a laser with an emitting optical power of -4dBm may be employed. In the case of a ODN class Extended 1 (E1) with a required maximum optical path losses of 33dB, a laser with 0dBm emitting optical power may be used. The possibility of employing low optical power lasers is a great advantage of this real-time 10Gbps quasicoherent receiver because the wavelength variation in a switching process is smaller for smaller emitting powers, which will favor the fulfillment of the frequency requirements of NG-PON2.

4. Conclusions

In this paper, a real-time 10Gbps polarization independent quasicoherent receiver has been proposed and experimentally validated for NG-PON2 networks. The real-time operation of this 10Gbps quasicoherent receiver has been tested and shows a pattern independent operation. In addition, the real-time 10Gbps quasicoherent receiver exhibits an extremely low power penalty due to 44km SSMF transmission employing an EML as transmitter and a polarization independent operation.

The proposed real-time 10Gbps quasicoherent receiver has a sensitivity of -33dBm and can provide a power budget between 35dB and 42dB, fulfilling the maximum path losses for all the NG-PON2 classes. In addition, the receiver will allow a reduction of cost and complexity of the transmitters because it can operate with low emitted optical power. For example, a -4dBm emitting power EML would fulfill the maximum optical path losses of a class N1 of NG-PON2.

In conclusion, the real-time 10Gbps quasicoherent receiver is an attractive candidate to solve the main implementation problems of the NG-PON2 and to reduce the cost and the complexity of the ONUs.

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