Spectrum Sliced Sources AMOOFDM Modulated for WDM&TDM PON

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Abstract *We experimentally demonstrate the use of AMOOFDM format as a cost effective solution for colorless source WDM-PONs based on spectrally sliced ASE source (SLED, RSOA and pre-selected RSOA).*

Introduction

The Wide Division Multiplexing - Passive Optical Network (WDM-PON) is a prospective candidate for the future broadband access network. This architecture using spectral slicing of the light from broadband incoherent sources such as Light Emitted Diodes (LED)[1-6] is proposed to implement WDM-PON due to its robustness to the optical crosstalk from Rayleigh backscattering. On the other hand, the Adaptively Modulated Optical Orthogonal Frequency Division Multiplexing (AMOOFDM) is a cost effective and upgradeable solution for next generation PON (NGPON)[7-8]. The main advantage of AMOOFDM is that it can transmit parallel data at low rate on each sub-carrier simultaneously. Therefore a frequency selective channel is transformed into a collection of flat channels, which is robust to fiber chromatic dispersion. In addition, the AMOOFDM can be integrated with forward error code (FEC) to improve transmission. In this paper, we propose to combine the AMOOFDM modulation with the spectrum sliced sources generated by three directly modulated devices: 1) Superluminescent LED (SLED), 2) Reflective Semiconductor Optical Amplifier (RSOA), 3) Pre-selected spectrum RSOA source.

Experimental setup

The experimental scheme of a hybrid PON architecture is shown in Fig. 1. The upstream (or downstream) data is an AMOOFDM signal, which is constructed mathematically using MATLAB™ and then injected into an arbitrary waveform generator which is used to convert the digital data sequence into an analogue signal waveform. The signal consists of 1024 sub-carriers. Among them, 1023 sub-carriers carry m-QAM symbol and the first one contains no power. The signal has an electrical bandwidth of 500MHz with a cyclic prefix of 8 samples. The AMOOFDM symbol duration is thus 2.056 µs. Three spectrum sliced sources are modulated by this AMOOFDM:

- The SLED emits around 1550 nm (35 nm optical bandwidth at 3dB), is biased at a current of 110 mA and sliced it at 1551.20 nm.

- The RSOA (700 µm chip length with 20% confinement factor) emits around 1570 nm at 10°C for a bias current of 60 mA and was sliced at 1571.44 nm.

- The pre-selected spectrum RSOA source is constituted by an SOA (180mA bias current) where one of the output fibers is connected to a selective mirror. Typically this selective mirror returns only the Coarse WDM 1551 nm optical spectrum window. This scheme allows increasing the optical power (cf. Fig. 2) inside a potential slicing band (here sliced at 1551.17nm). In this work, the length of the half cavity (SOA to mirror) is around 2 meters. This length could be reduced in the future by a coating on the chip to optimize the modulation quality. The optical output of these three devices were spectrum-sliced, multiplexed in a 100 or 200 GHz optical multiplexer, and finally sent into the transmission link. We utilised typically Gaussian shaped multiplexer with 100 GHz channel spacing, 24 and 60 GHz half-bandwidth at 3 and 20 dB excess loss correspondingly with an adjacent channels crosstalk <-35dB. The link consists of SMF (Single-Mode Fibre) and an optical variable attenuator used to simulate the loss of splitter. The optical signal was detected by an avalanche photodiode at the centre office (CO). The received AMOOFDM signal is captured by a real time digital sampling oscilloscope (DSO).

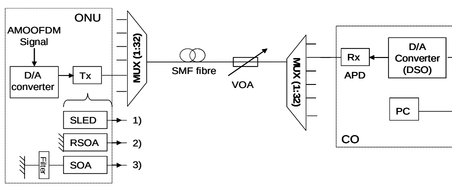

Fig. 1: Experimental setup of a Hybrid PON with SLED, RSOA and pre-selected spectrum RSOA sources

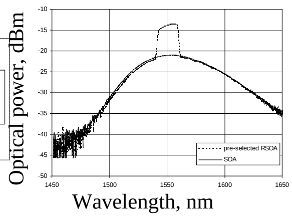

Fig. 2: Spectrum of SOA without and with pre-selected spectrum mirror

Experimental results and discussion

To maximize the throughput transported in the spectrum-sliced system, the Levin-Campello (LC) adaptive power-bit loading algorithm [9] is introduced for channel capacity optimization over AMOOFDM modulation. The Bit Error Rate (BER) performance is measured from the computation of the Error Vector Magnitude (EVM) of the different sub-carriers, and the BER is 10^{-4}. Fig. 3 shows the resulting bit rate as a function of a) the received optical power and b) optical budget for the three ASE sources at 20°C. The optical budget is defined as the losses between the spectrum sliced source and the photo-receiver. We present the performance of :

- SLED without slicing and with slices of 100GHz and 200GHz respectively.
- RSOA with slice of 100GHz.
- Pre-selected spectrum RSOA without slicing and with slice of 100GHz.

In the case of using SLED source, we obtained an optical power of -14.11dBm inside the slice of 100GHz. By increasing the width of a slice by 200GHz, the bit rate rose. Consenquently, a 30 dB optical budget up to 100Mbit/s is possible.

The quality of the modulation is improved by the use of the RSOA which allows higher bit rate. But the optical budget is limited by the lowest optical power (-18.5dBm/100GHz slice). The budget reached 22dB at a data rate of 100Mbit/s.

When the pre-selected spectrum RSOA is used, the optical power increase (-9.5dBm/100GHz slice) but the modulation quality is degraded due to the long half-cavity. However, we obtained a bit-rate of 100Mbit/s for 30dB optical budget.

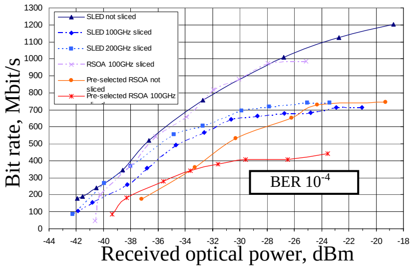

Fig. 3a: Bit rate as a function of received optical power

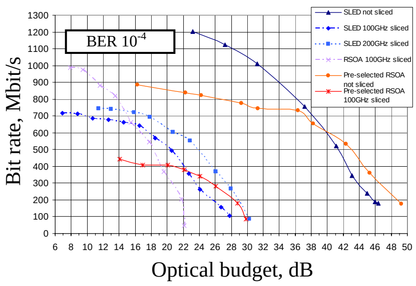

Fig. 3b: Bit rate as a function of optical budget

Referring to Fig. 4a, in the case of the SLED source with 100GHz slice at 20°C, it is noted that bit rate curve has the same behaviour when the distance of fiber varies from 0 to 60km. The impact of chromatic dispersion in the fiber is negligible until 60km. The temperature of the SLED was changed in order to analyze the output signal features. The bit rate in function of the optical budget is shown in Fig. 4b with the sliced wavelength of 100GHz when the distance of the fiber is 20km. The temperature variation has a great impact on the bit rate performance, and the optimal value is obtained at 20°C.

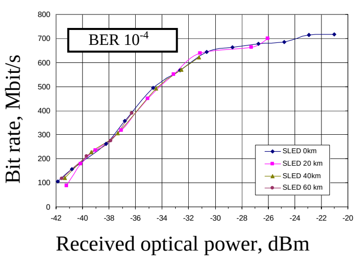

Fig. 4a: SLED source as a function of the transmission distance

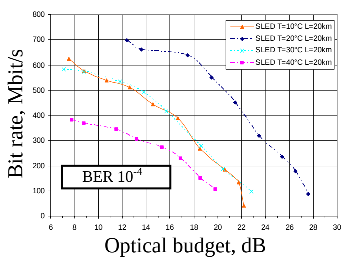

Fig. 4b: SLED source as a function of temperature

The Fig. 5 shows the curves of bit rate vs. optical budget when the temperature of the pre-selected RSOA source is varied. The results are similar at the temperatures of 10°C and 20°C.

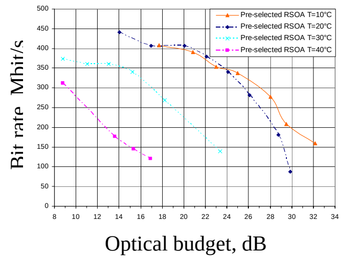

Fig. 5: Pre-selected RSOA source as a function of temperature

The optical crosstalk[3] has a degrading impact on the WDM PON using spectrum sliced light source, but we will not discuss it in detail in this paper. Due to the fact that AMOFDM employs adaptive bit-loading according to the channel conditions, the effect of adjacent channel crosstalk is optimized.

Conclusion

With a view to achieve low-cost and upgradeable colorless ONU modules, for the first time, we experimentally demonstrated the use of AMOOFDM modulation over three spectrum sliced light sources. This choice guarantees robustness to the chromatic dispersion effect in the fiber. We achieve for a BER of 10^{-4}:

- 30dB optical budget for 100 Mbit/s,
- 18dB optical budget for 700 Mbit/s,
- 8dB optical budget for 1 Gbit/s

The 30dB optical budget allows the use of these devices with AMOOFDM signal over a standard G-PON class B+ infrastructure and is a potential solution for Hybrid PON in the future. In our opinion, the pre-selected spectrum RSOA is good candidate device to reach 1Gbit/s for the highest optical budget when the length of the half cavity is reduced.

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