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COLORLESS AND SOURCELESS OPTICAL NETWORK UNITS IN PASSIVE OPTICAL NETWORKS

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ABSTRACT

Colorless and sourceless optical network units are efficient techniques to implement a scalable optical networks which provide high speed and large bandwidth for the increasing demand for internet services. In this paper, we review and analyze in details colorless and sourceless optical network units. First, we review colorless optical network unit types. After that, we discuss the sourceless optical network units. Then, the issues and the limitations of SOA-based ONUs are analyzed and discussed, with simulation results demonstrating the effects of the change in the seeding power on the upstream performance of the remote seeded ONU at wave 1540 nm.

Keywords: *Semiconductor Optical Amplifier, Colorless Optical Network Unit, Passive Optical Networks, Sourceless Optical Network Unit.*

1. INTRODUCTION

the high data rate and wide band networks are required as the services through Internet have become growing market [1-2]. The services such as content delivery, video on demand and IP TV services increase with time [3]. Besides, high definition HD video services are growing with a demand of higher data rate and symmetric bandwidth [1]. interactive gaming is also becoming an attracting object these days, which requires a large bandwidth and high data rate.
All these services need scalable access networks. The WDM-PON network can provide high data rate with wide bandwidth to improve personal communications [4]. It is capable to improve the capacity of the network by applying several wavelength .[3]. The huge capacity network becomes more scalable when passive optical network is applied (PON), because PON has no active elements in the outside plant. Therefore, WDM has been applied in PON to achieve a high capacity [1].

As the IP traffic is increasing, customers do not want to pay extra cost for the improved network. thus, the cost has become the main issue for the service provider to upgrade the network [1]. The improvement of the capacity and data rate of the network must respect the cost effect to meet the desired QoS with minimal cost.

colorless optical network units and sourceless optical network units are cost solution for passive optical networks. In this scheme, the ONU is nonspecific wavelength. In other words, the optical network unit (ONU) does not depend on a particular wavelength in the network. This property gives the network flexibility in operation and maintenance. Besides flexibility, colorless is a cost solution. Hence every ONU has the same equipments and mass production is possible. The mass production decreases the cost of the unit which makes it cost effective. There are many studies on colorless schemes to make it more efficient. In this paper, we review the colorless techniques.

2. COLORLESS OPTICAL NETWORK UNITS

In colorless technology, ONU must not be wavelength dependent. also it must be taken in account the cost of the ONUs and some technical issues, like the back reflection, beat noise and SNR. Therefore, realizing a scalabal and efficient

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colorless ONU is the main scope of many researches [1, 3, 5-6].
The main two categories of colorless are self-emitting scheme and seed light scheme. The first scheme, self emitting, can be realized either by tunable laser diode approach or based on spectrum slicing. The other scheme, seed light scheme can be achieved by injection locking, Remote seedingor based on re-modulation. In this section, we will describe the principles of these categories.

In self-emitting category, as in any typical ONU, the optical unit emits the upstream wavelength by a light source in the unit. The process of selecting the wavelength takes place externally by either filtering the light spectrum in the remote unit or through configuration during the installation. The two schemes of self-emitting category have been proposed in many literatures [3, 6-7].

2.1 Based on Tunable laser Diode

The easiest scheme to realize a wavelength independent ONU is to use a tunable laser diode as a light source. the wavelength of the ONU is configured in the installation, which provides a sufficient scalability to the network. the modulation scheme in this case is preferred to be external. While the direct laser modulation is not used.
On the other hand, the cost of the tunable laser diode as a component is high, even if the performance of this scheme is considered the best, whereby the performance of this scheme can reach up to 10Gbps [1,6].

2.2 Based on Spectrum Slicing

Spectrum slicing is a scalable and low cost scheme for colorless technologies [7-10]. The light source in the ONU is a broadband light source. The light spectrum is sliced into a narrowband channels. Then, this spectrum passes through either a WDM or a filter at the remote node to pass only one channel. The rest of the spectrum is wasted as shown in Figure 1.

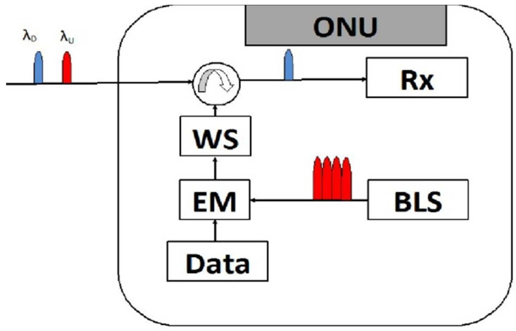

Figure 1 Colorless Topology Based On Spectrum Slicing

The wavelength on every ONU is decided by the remote node. The light source in this scheme is mostly a LED. the broadband light source in this scheme was proposed by the earliest researches [11]. Then, the researchers proposed a centralized scheme which implements the light source in the central office CO [12]. In a centralized scheme, the ONU receives the sliced upstream channel from the OLT. The advantages of this scheme are the flexibility and the low cost of the LED light source.
On the other hand, spectrum slicing has some weaknesses. First, it suffers from beating noise from the broadband light source. Besides, dispersion degrades the transmission rate. These weaknesses make this scheme performs in data rate of 1Gbps [4], which can be acceptable for a low cost architecture.
Based on injection locking
In injection locking scheme, the ONU has Fabry-Perot laser diode (FP-LD) as a light source. When the seed light is injected into the FP-LD, it locks the wavelength of the upstream signal (Figure 2). The seed light can be either laser or a narrow channel from the sliced spectrum [1, 6, 13-14].

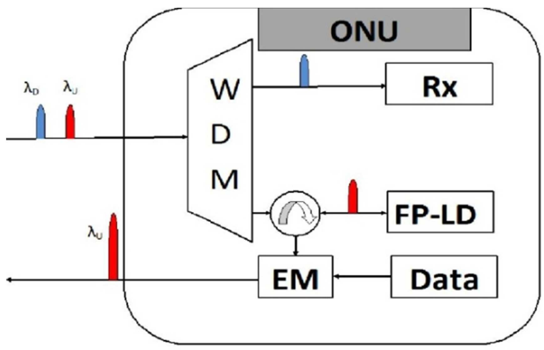

Figure 2 Injection Locking Scheme Using FP-LD

The injected light decides the coherency of the light generated by FP-LD. Besides, the coherency of the upstream light depends on the locking conditions [6]. This scheme has some weaknesses such as back

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reflection, SNR of the seed light and insufficient locking [3]. The data rate of this scheme can achieved about 1.25Gbps based on the results published in [1].

3. SOURCELESS OPTICAL NETWORK UNITS

3.1 Based on Remote Seeding the Seed Light

Remote seeding scheme scheme is based on modulating the seed light received from the OLT and sending it back as upstream signal. In other words, OLT sends the downstream wavelength and a continuous wavelength to the ONU. The ONU receives these wavelengths and divides them by WDM to demodulate the downstream data and modulate the upstream data. In the ONU side, there are two stages which the wavelength supply goes through: (i) amplification and (ii) modulation. Reflective semiconductor optical amplifiers (RSOA) can be the amplifier and the modulator is electro-absorption modulator (EAM). Other researches use RSOA itself as a modulator because of its low cost [15-18]. the remote seeding scheme is affected by back reflection and the SNR of the seed light. However, using RSOA as modulator can upgrade the performance up to 5Gbps or even 10Gbps with EAM.

3.2 Based on Re-Modulation

Re-modulation scheme has been known as a low cost solution, see Figure 3 [6,19-32]. Similar to the remote seeding scheme, re-modulation scheme also loops back the wavelength coming from the OLT. The difference is reusing the downstream wavelength instead of sending different wavelength as a supply.
In ONU side, there is a power splitter to split the downstream signal into two parts, one for the receiver and the other for the upstream modulator. Two different modulation schemes must be used here, one for downstream signal at the OLT and another one for upstream signal at the ONU, to avoid the effect of downstream data on the upstream data. Some researches uses saturated semiconductor optical amplifiers SOA to recycle the downstream wavelength and produce continues wavelength (CW) as shown in Figure 4. [6].

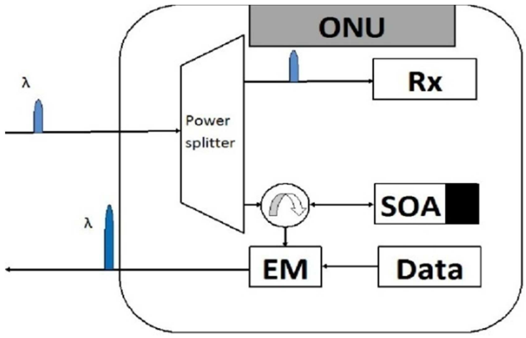

Figure 3 Re-Modulation Scheme

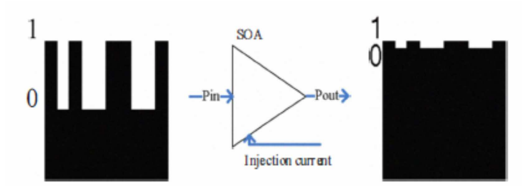

Figure 4 Recycling The Downstream Wavelength (Source [16])

the extinction ratio of the downstream signal is high, which affects the modulation of upstream signal. By passing the downstream signal through a saturated SOA, the low logic level becomes close to the high logic level, which make the signal continues wavelength for upstream modulation [6,16].

4. SOA SEEDING SCHEMES

Semiconductor optical amplifiers are widely used as light sources for optical network units. The advantage of using SOA is its low cost. Using SOA-based ONUs in passive optical network improves the flexibility of the network because of the wavelength allocation, while the seeding light decides the wavelength of the output signal. There are two types of SOA-based ONUs: one with centralized light source called Remote seedingscheme and the other one without centralized source called self-seeded as shown in Figure 5. [3-4, 33].

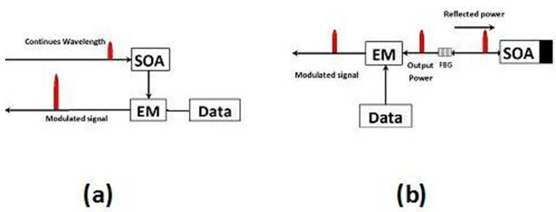

Figure 5 (A) Remote Seeding Scheme (B) Self Seeding Scheme

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Remote seeding scheme is based on modulating the seed light received from the OLT and sends it back to the ONU. In other words, OLT sends the downstream wavelength, in the same time sends the upstream wavelength supply to the ONU. The ONU receives these wavelengths and divides them by WDM to demodulate the downstream data and modulate the upstream data. In the ONU side, there are two stages which the wavelength supply goes through: (i) amplification and (ii) modulation. Reflective semiconductor optical amplifiers (RSOA) can be the amplifier and the modulator is electro-absorption modulator (EAM). Other researches use RSOA itself as a modulator because of its low cost [34-39].

As in injection locking, the Remote seeding scheme is affected by back reflection and the SNR of the seed light. However, using RSOA as modulator can upgrade the performance up to 5Gbps or even 10Gbps with EAM.

Re-modulation scheme has been known as a low cost solution. Similar to the Remote seeding scheme, re-modulation scheme also loops back the wavelength originating from the OLT. The technical difference is reusing the downstream wavelength instead of sending different wavelength as a supply.

In ONU side, there is a power splitter to split the downstream signal into two parts, one for the receiver and the other for the upstream modulator. Two different modulation schemes must be used here, one for downstream signal at the OLT and another one for upstream signal at the ONU, to avoid the effect of downstream data on the upstream data. Some researches uses saturated semiconductor optical amplifiers SOA to recycle the downstream wavelength and produce continues wavelength (CW).

The extinction ratio of the downstream signal is high, which affects the modulation of upstream signal. By passing the downstream signal through a saturated SOA, the low logic level becomes close to the high logic level, which make the signal continues wavelength for upstream modulation.
Self-seeded RSOA, on the other hand, does not need centralized light source. This scheme is based on seeding the RSOA with its own ASE. The concept of this scheme is amplifying one wavelength from the ASE spectrum by returning this wavelength back to RSOA. Some researches realize self seeding scheme by using a coupler and a band pass filter to return one wave length, another research uses FBG to achieve self seeding. The result of self seeding scheme is incoherent light, which suitable for low speed data. The advantage of this scheme is making the RSOA saturated to suppress the noise generated by the amplifier. To make the ONU colorless, many researches place the wavelength selection at the remote node, in this case they call it remote self seeding, while the RSOA seeded with its own ASE power remotely [40-45].

However these two schemes, Remote seedingand self seeding, present a cost solution and flexibility, they still have some limitations. Remote seedingscheme only works with good seeding power from OLT. The downstream loss budgets due to distance and splitting ratio also reduces the seeding power and the RSOA will not be saturated. Self seeding scheme overcomes this issue because it does not include centralized light source and RSOA is always saturated, however, the incoherent light power is not suitable for high data rate.

5. SIMULATION RESULTS AND DISCUSSION

Figure 7, Figure 8, Figure 9 and Figure 10 show the performance of the upstream signal for the remote seeded optical network unit (ONU) when the semiconductor optical amplifier operates at wavelength 1540 nm. The figures show the effect of the bias current on the upstream performance in different seeding power values.

Figure 7 shows the performance when the seeding power is -14 dBm. In this seeding power value, the semiconductor optical amplifier SOA is saturated. Therefore, the performance is sufficient. The bias current change does not have significant effect on the performance. Because the amplified spontaneous emitted power (ASE) is suppressed, the change in the bias current does not affect the generation of the amplified spontaneous emitted power (ASE).

Figure 8. shows the performance when the seeding power is -17 dBm. In this seeding power value, the semiconductor optical amplifier SOA is less saturated. Also in this case, the performance is accepted, but not as sufficient as the performance of -14 dBm seeding power. The bias current change has no notable effects on the performance while the amplified spontaneous emitted power (ASE) is

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suppressed, because the change in the bias current does not affect the generation of the amplified spontaneous emitted power (ASE) in this case either.

Figure 9 shows the performance when the seeding power is -24 dBm. In this seeding power value, the semiconductor optical amplifier SOA is unsaturated. In this case, the performance is insufficient. The bias current change has clear effect on the performance because the amplified spontaneous emitted power (ASE) in this band is high, the change in the bias current changes the amplified spontaneous emitted power value (ASE) in this case. Therefore, the amplified spontaneous emitted power (ASE) affects the OSNR and decreases the performance of the upstream signal, the performance in this case is strongly dependent on the bias current.

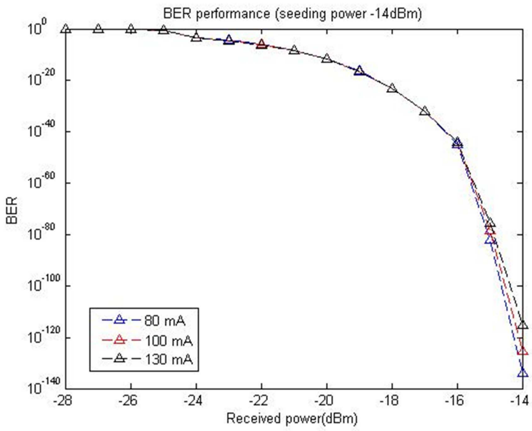

Figure 7 Ber Vs Received Power (Seeding Power - 14dbm)

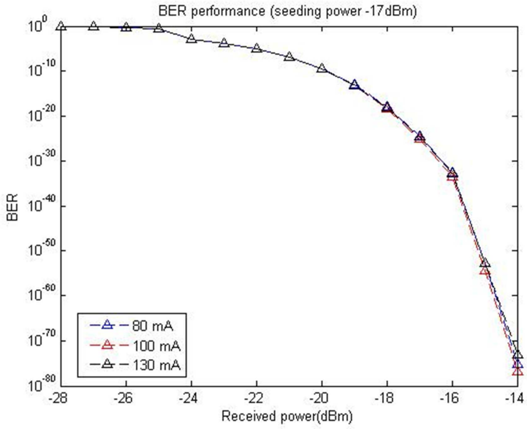

Figure 8 BER Vs Received Power (Seeding Power - 17dbm)

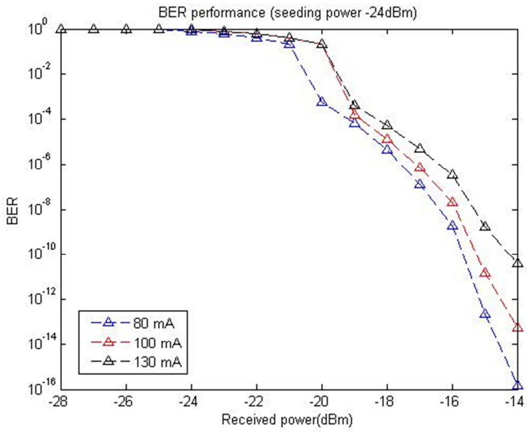

Figure 9 BER Vs Received Power (Seeding Power - 24dbm)

Figure 10 shows the sensitivity of the receiver side at bit error rate 10-9 . When the seeding power is -14 dBm, the receiver side is able to detect the upstream signal with the maximum bit error rate 10-9 at received power less than -22 dBm. The sensitivity of the receiver side at seeding power -17 dBm is lower than the -14 dBm seeding power sensitivity by about 1 dBm.

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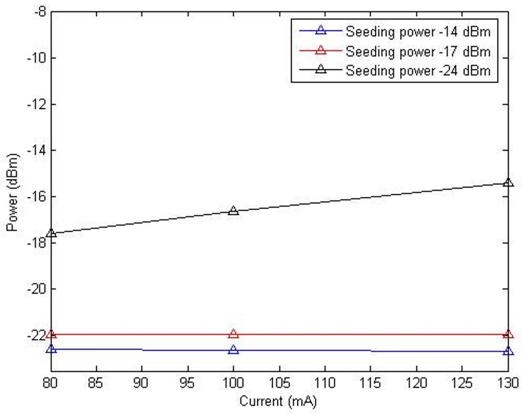

Figure 10 Sensitivity Of The Receiver

The reason is the saturation of the semiconductor optical amplifier SOA is lower, which creates more amplified spontaneous emitted power (ASE) and reduces the optical signal to noise ratio OSNR. With low seeding power, the sensitivity of the receiver side declines significantly. The reason is that the semiconductor optical amplifier SOA is unsaturated, which make the amplifier generates more amplified spontaneous emitted power (ASE). These two reasons make the optical signal to noise ratio insufficient.

6. CONCLUSION

In this paper, we review and analyze in details colorless and sourceless optical network units. First, we review colorless optical network unit types. After that, we discuss the sourceless optical network units. Then, the issues and the limitations of SOA-based ONUs are analyzed and discussed, with simulation results demonstrating the effects of the change in the seeding power on the upstream performance of the remote seeded ONU at wave 1540 nm..

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