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The Evaluation of 16-Channel Hybrid ASE and LED WDM-PON System Performance

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Introduction

The worldwide demand of bandwidth has led to the expansion of fiber optics access technologies. EPON, GPON (Ethernet/Gigabit Passive Optical Network) and even 10G GPON systems were proposed to provide this growth of demand. However, TDM-PON (Time Division Multiplexing PON) concept has its limitations due to the concept of time division. Another way of increasing the bit rate is WDM-PON (Wavelength Division Multiplexing PON) solution [1-3]. To satisfy the growing demand the system must have high bit rate and be cost-effective. Spectral-slicing technique can achieve this aim. ASE-source (Amplified Spontaneous Emission) as the OLT (Optical Line Terminal) and colorless LED (Light Emitting Diode) as ONU (Optical Network Unit) hybrid solution is proposed in this paper [4, 5]. The paper contains the investigation of 16-channel system with and without gain flattering filter on OLT side and LED on ONU side.

In this paper is demonstrated 16 channel WDM-PON system with optical slicing technique. The ASE source was chosen due to its power characteristics for bit rate increasing. The lack of power of LED sources is compensated with decreased bitrate in uplink, however LED has the advantage of less price and minimized operating cost [3]. The ONU also can be colorless, it means that each source has the same central wavelength. All the central wavelength conversions are made with the help of spectral slicing in the AWG (Arrayed Waveguide Grating) with FSR (Free Spectral Range).

The analytical part of the investigation was done using a software simulator. All the system components were simulated using OptSim software.

System Design and Simulation

Fig. 1 shows the schematic of proposed system with an EDFA generating broadband ASE. ASE-source can have also GFF (Gain Flattering Filter), which leads to the rise of attenuation, but from another point of view it flattens the power spectrum of all the channels (Fig. 2). ONU side consists of LED and circulator, that divides uplink and downlink signals. Spectral slices are made with a help of AWG with FSR both for LED and ASE-source. Free spectral range of AWG in this case equals to 24 nm for optimal utilization of spectrum. Combined spectrum of ASE and ONU is seen in figure 3 with and without GFF.

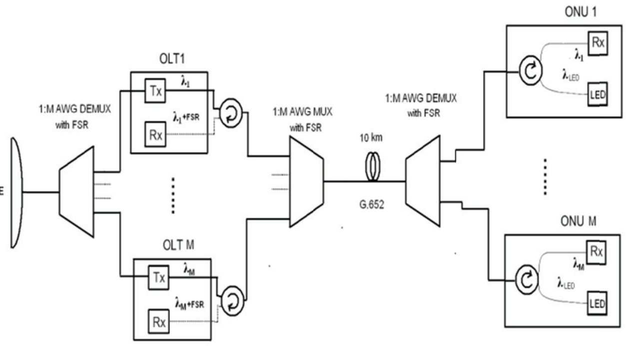


Fig. 1. A schematic diagram of N-channel system

The length of fiber is 10 km. Standard single mode fiber (G.652) was chosen for the proposed simulation transmission because this type of fiber is the most popular

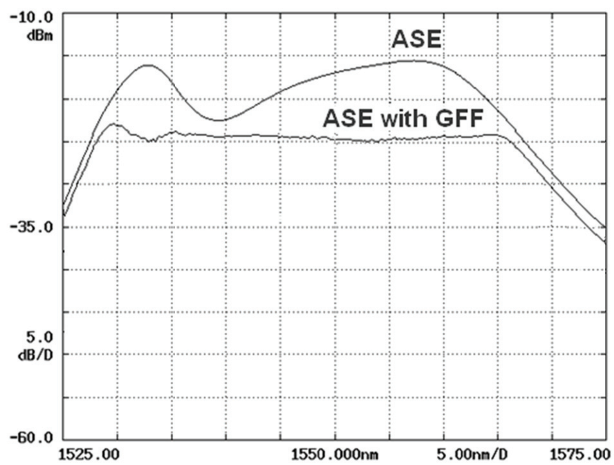


Fig. 2. ASE-source power spectrum

among already installed infrastructure of optical distribution networks. This configuration uses only one fiber to satisfy minimization of infrastructure's cost. The common power spectrum is shown in figure 3. ASE-source is without GFF. The power difference for the best and the worst channels in this case can achieve 4 dB. Each slice has the width of 0.9 nm and distance between channels – 1.6 nm (200 GHz) that is optimal for this solution due to the effect of dispersion. Adjacent channel isolation is not less than 15 dB. At the OLT side each slice is modulated using Mazh-Zehnder modulator and pseudorandom bit sequence. NRZ (Non-Return to Zero) format was chosen for coding due to its simplicity.

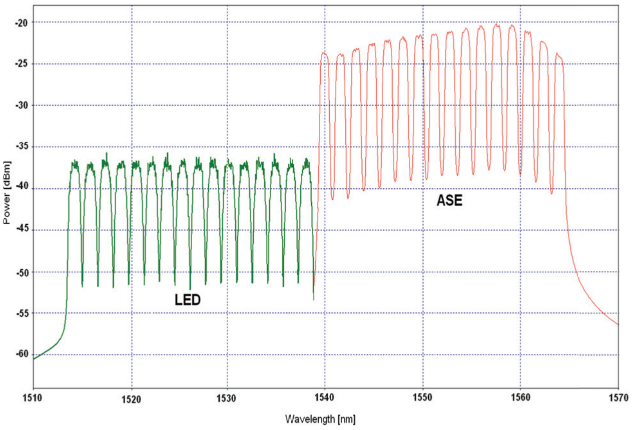
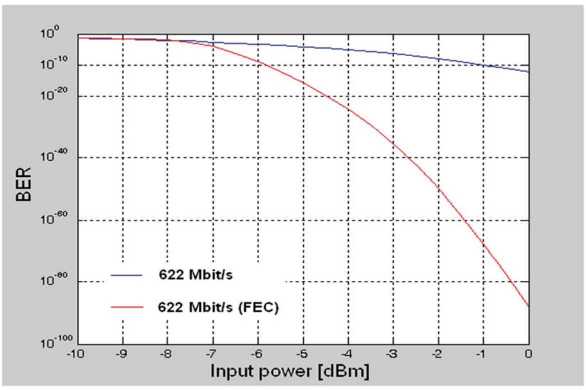
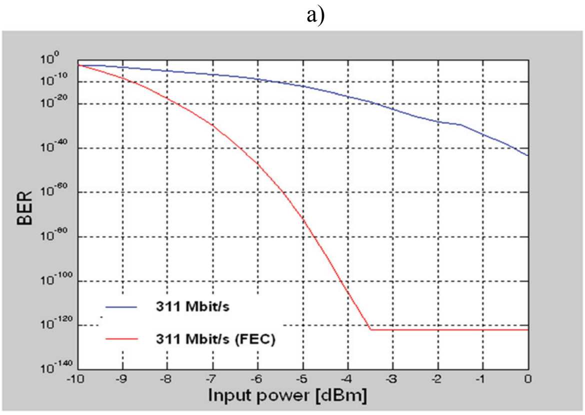


Fig. 3. Spectrum of Hybrid ASE and LED system

Due to nonflatness of the spectrum, the level of slices is different on side channels. At ONU side is used direct



a)



b)

Fig. 4. BER dependence of LED output power: a – 622 Mbit/s; b – 311 Mbit/s

modulation and spectral slicing after it. The configuration of multiplexer and demultiplexer is the same.

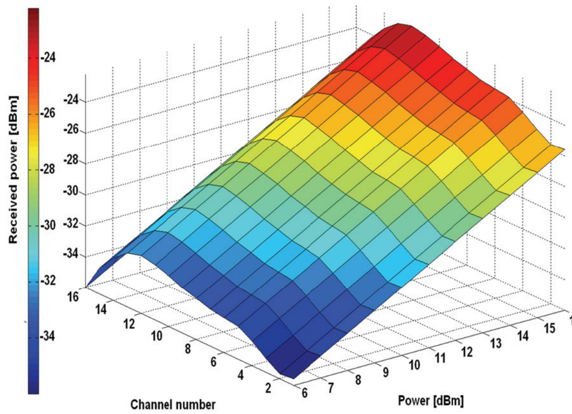
The strategy of simulation both for uplink and downlink is the rise of LED or ASE output power with the direct step (0.5 and 1 dB) where the BER level is controlled. The target BER level is < $1 \cdot 10^{-10}$. LED central frequency is 1526.4 nm with FWHM (Full Width at Half Maximum) of 80 nm. ASE-source full width at half maximum using GFF is 42 nm, without GFF is used the region between 1540-1568 nm.

On the receiver side of the system are avalanche photodiodes (APDs) to detect signals with 4-order electrical Bessel filtering, BER (Bit Error Rate) meters and eye-diagram analyzers to evaluate performance of each channel. FEC (Forward Error Correction) is used to minimize the output power of LED with coding gain not less than 3 dB without slicing.

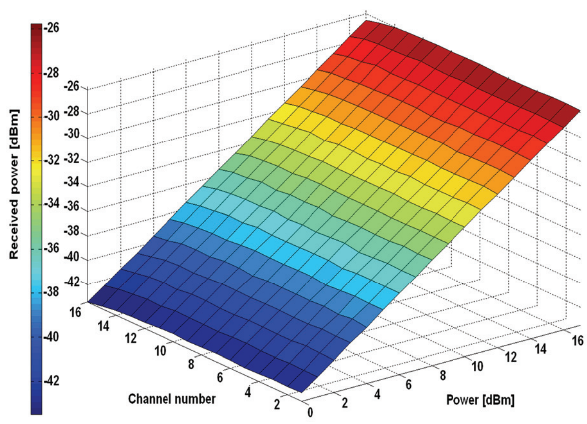
Table 1. Uplink subsystem results

Bitrate (Mbit/s)	311	311(FEC)	622	622(FEC)
Power (dBm)	-5.8	-8.9	-1	-5.9

The OLT side simulation scenario consisted of 2 bitrates: 1 and 2.4 Gbit/s. The sensitivity of APD in this simulation is -33.5 dBm for 1 Gbit/s and -30 dBm for 2.4 Gbit/s for BER < $1 \cdot 10^{-10}$. The BER target level was the same as in Uplink subsystem. However, BER difference was huge (See Figure 5). The received power difference without GFF is 3.5 dB and 0.7 dB with it.



a)



b)

Fig. 5. Received power: a – ASE-source; b – ASE-source with GFF

The total power difference between ASE-source and ASE with GFF in the same configuration can achieve 5.5 dB, however slicing loss also will be different. The power budget for downlink (without slicing loss) is 26 dB. For Uplink it achieves 15.2 dB (polarizer and extra AWG for slicing is not needed). Sensitivity degradation due to ASE noise also exists both for uplink and downlink [5]. It achieves 2.6 dB for 1 Gbit/s system. FEC was not used in this case. Fig.6-8 shows us the BER dependence of output power for ASE-source. The minimal acceptable power is 9 dBm for 1 Gbit/s per one channel and 11 dBm with GFF. The configuration for 2.4 Gbit/s per one channel is not available for the proposed system due to the poor BER level.

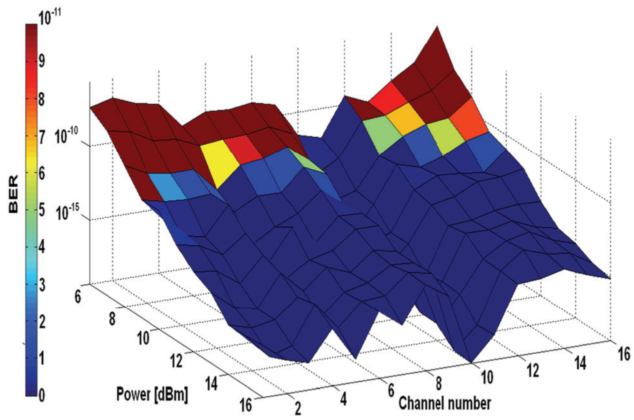


Fig. 6. BER dependence of ASE power for 1 Gbit/s per channel

32-channel system using the same channel bandwidth and step between them (0.9 nm and 1.6 nm respectively) is not possible due to the lack of LED power for the increased loss budget and the total width of available spectrum for ASE-source and LED both.

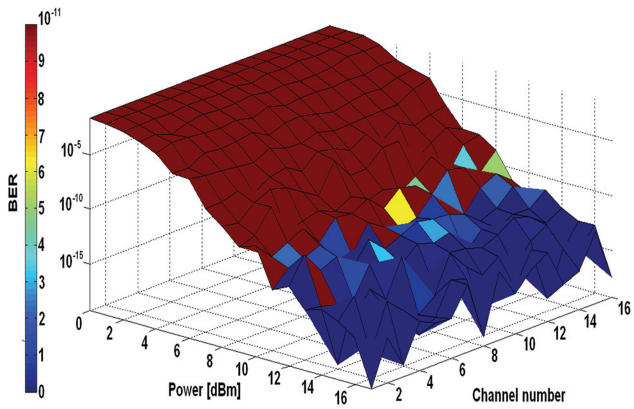


Fig. 7. BER dependence of ASE power for 1 Gbit/s per channel with GFF

8-channel system configuration is possible for 1 Gbit/s with and without GFF with minimal ASE power of 7 and 9 dBm. 2.4 Gbit/s realization for 8-channel system is also not achievable. The manufacturer can choose between 8 and 16 channel realization depending on its needs.

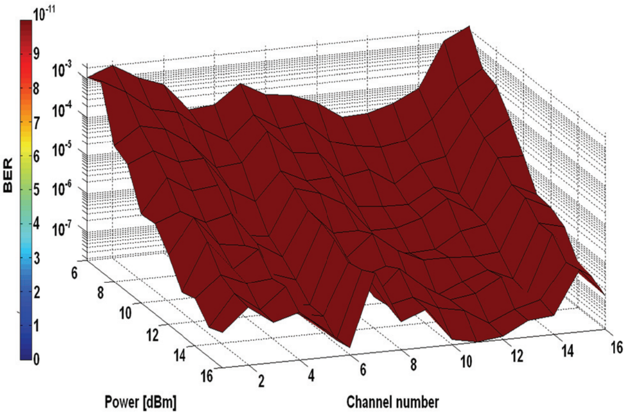


Fig. 8. BER dependence of ASE power for 2.4 Gbit/s per channel

Table 2. Downlink subsystem results

ASE type		With GFF	Without GFF
Power (dBm)	Min	-32.5	-32.7
	Max	-31.8	-29.2
BER	Min	$1.1 \cdot 10^{-11}$	$1.7 \cdot 10^{-13}$
	Max	$1.6 \cdot 10^{-11}$	$1.9 \cdot 10^{-11}$

Conclusions

The proposed system can achieve error free transmission at bitrate of 622 Mbit/s per user with minimal uplink LED power of -5.9 dBm (FEC). The power –1 dBm is only achievable for SLED, that doesn't have such modulation bandwidth as the proposed low power LED. The error free transmission for 322 Mbit/s per user configuration is achievable at optimal power for market LED solution at -8.9 dBm. The FEC "gain" is 4.2 dB for this scenario. 1 Gbit/s per one user is not available for this type of LED.

The downlink scenario consists of two possible editions: with and without GFF. The configuration without GFF has extra power margin, however, the difference between channel powers can achieve 3.5 dB. With the use of GFF the difference decreases to 0.7 dB, which is more preferable for network operating. The minimal ASE-sorce power for 1 Gbit/s per channel is 9 and 11 dBm (without and with GFF). The bitrate of 2.4 Gbit/s is not achievable in this network topology. Non standardized bitrates like 1.5 Gbit/s can be used to increase downlink bandwidth. The use of FEC in bitrate increasing scenario is obligatory. 32-channel system is not possible using proposed network topology.

Acknowledgement

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I. Lasuks. Sustiprintos savaiminės spinduliuotės ir šviestukų našumo įvertinimas 16 kanalų WDM-PON sistemose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 33–36.

Poreikis padidinti duomenų pralaidumą sudarė prielaidas sukurti naujas duomenų perdavimo optiniais tinklais technologijas. TDM-PON technologijai būdingi laiko apribojimai. Pagrindiniai reikalavimai, didinant perdavimo spartą, –minimaliomis sąnaudomis pasiekti didelį bitų perdavimo greitį. Tokia yra WDM-PON technologija. Minėtus reikalavimus galima patenkinti taikant spektrines technologijas. Pasiūlytas naujas metodas, pagrįstos sustiprintos savaiminės spinduliuotės ir šviestuko taikymu tuo pačius metu. Il. 8, bibl. 5, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).