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Design of L-Band Multiwavelength Laser for TDM/WDM PON Application

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Abstract:

This paper presents on the design of L-Band Multiwavelength laser for Hybrid Time Division Multiplexing/ Wavelength Division Multiplexing (TDM/WDM) Passive Optical Network (PON) application. In this design, an L-band Mulltiwavelength Laser is designed as the downstream signals for TDM/WDM PON. The downstream signals ranging from 1569.865 nm to 1581.973 nm with 100GHz spacing. The multiwavelength laser is designed using OptiSystem software and it is integrated into a TDM/WDM PON that is also designed using OptiSystem simulation software. By adapting multiwavelength fiber laser into a TDM/WDM network, a simple and low-cost downstream signal is proposed. From the simulation design, it is found that the proposed design is suitable to be used in TDM/WDM PON for up to 64 Optical Network Units (ONUs).

Keywords: Multiwavelength laser, Passive Optical Network, Time Division Multiplexing, Wavelength Division Multiplexing

Introduction:

Passive Optical Network (PON) is becoming more favourable in optical network nowadays. Current optical network employs Time Division Multiplexing (TDM) or Wavelength Division Multiplexing (WDM) PON architecture. However, due to higher capacity network, TDM/WDM is proposed as the future technology. In WDM, multiwavelength lasers are used as the downstream signal. Currently, an array of Distributed Feedback (DFB) Laser is used as the downstream signal in WDM.

Hao Chen et al. in [1] has presented a low-cost L-band multi-wavelength laser (MWL). The 16-channel laser with 100GHz wavelength spacing was manufactured using a hybrid method. This device can be used on a wide fiber-to-the-home (FTTH) access network. It contains of four 4-channel semiconductor optical amplifier (SOA) arrays and a silica-based AWG array. The laser activity of 16 channels is shown and the fiber-coupled output power may reach up to 1.8mW while the threshold current is as poor as 22mA. Direct laser modulation at 1.25GHz provides an open eye with an extinction ratio of 5.4dB.

In 2009, Wang Zhaoying et al. have created multiple wavelength laser fiber relaying on cascade semiconductor optical amplifiers (SOAs) by utilizing high-birefringence fiber loop mirror (Hi-Bi FLM) as wavelength filter. Then, the configured of 0.6 nm homogeneous widening linewidth of the SOA allowed laser to oscillate along DWDM ITU Grid spacing and SOAs with low frequency gain as a gain medium in the laser for laser oscillating in C+L band. The specified multiple wavelengths provided by the cascaded SOAs of the C+L band could have a wider bandwidth and flattened gain range than a single SOA[2].

T. Subramaniam[3] introduced a unique optical gain clamped enhancer based on the typical ring-laser configuration by using a single Fiber Bragg Grating (FBG) and serves as a wavelength laser to a dismissal network. The conventional erbium doped fiber amplifiers (EDFA) has non flat gain spectrum which differs greatly because of saturation if the incoming signal power is high. An optical feedback laser signal powered by the amplifier will achieve a gain-clamping effect. As the waveform and laser circulate in the amplifier network, a gain-clamped amplifier that used ring-laser cavity was found to have greater noise figures.

According to A. Bekker[4], multiwavelength fiber lasers are significant for several applications in fiber sensors, optical communication, and optical testing. The wavelength is defined by applying the appropriate mode-locking frequency of the multi-length laser cavity produced by consecutive multiple fibers grating reflectors with a different Bragg-wavelength. This enables high-speed conversion between wavelengths that could be relevant for dynamic Wavelength-Division-Multiplexing (WDM) in optical fiber communication networks. Other than that, the necessity for multiwavelength laser resources like Dual Wavelength Fiber Lasers (DWFLs) with unique application amplifiers has developed tremendously, offering a fascinating mechanism for generating dual-wavelength laser outcome as it reveals inhomogeneous extension as a medium gain[5].

A multiwavelength thulium-doped fiber laser based on a micro fiber-optic Fabry-Perot interferometer (FPI) and a nonlinear optical loop mirror (NOLM) has been presented[6]. A multiwavelength erbium-doped fiber laser based on random distributed feedback which produced 24 laser lines has been demonstrated in S. Saleh et al.[7]. In M. N. M. Azhan et al.[8], a multiwavelength Brillouin-erbium fiber laser has been demonstrated with five laser lines and wide tunability from 1530 nm to 1565 nm. A stable room-temperature multiwavelength erbium doped fiber laser by employing 45° tilted fiber gratings (TFGs) which produced more than 60 lasing lines has been demonstrated[9]. In addition, a tunable multiwavelength random fiber laser with half-open cavity has been presented[10].

In this project, an L-band multiwavelength laser is proposed to replace the use of DFB lasers. The multiwavelength laser is used as the downstream signal for a TDM/WDM PON. The TDM/WDM PON design has been proposed whereas WDM PON is embedded with current TDM PON[11]. By employing a multiwavelength laser as the WDM PON transmitter, a lower cost downstream signal is proposed.

Methodology:

This project is mainly focusing on the design and simulation using OptiSystem software. The first phase of this project is to design an L band multiwavelength laser for PON. The second phase is to implement the L band multiwavelength laser in the TDM/WDM PON. Then, the proposed design is simulated using the OptiSystem software for simulation verification. Once the design has been successfully generated, the data analysis data will be conducted.

The simulation layout of the multiwavelength laser for TDM/WDM PON is illustrated in Figure 1. Figure 2 shows the architecture of TDM/WDM PON which deploys the multiwavelength laser. The design comprises of a Continuous-Wave laser with central wavelength of 1575.92 nm and a power of 10 W, 5-meter length of Erbium-Dope Fiber Amplifier (EDFA), 1x2 Power Splitter, 2x1 Power Combiner and Optical System Analyzer (OSA). In this design, WDM PON is deployed to the current TDM PON. By incorporating WDM PON, lower attenuation is expected as WDM PON does not deploy optical splitter which will produce higher loss, but instead WDM PON is using optical multiplexer/demultiplexer with lower loss.

The simulation design for the multiwavelength source which is the source for the OLT is as shown in Figure 1. It is equipped with an electrical component part whereby a synthesized signal generator that is 150 GHz sine generator corresponds to a wavelength spacing of 0.8 nm, an amplitude of 0.448 a.u. and 0 a.u. bias. The dual port dual drive Mach-Zehnder Modulator (DMZM) connect both the optical and electrical part of component system together that is biased at the minimum output power, the odd-order optical sidebands could be curb by the splitting ratio of 1.3 and carry out with a modulator phase shift type. The design parameter described above was applied to the proposed design that is applicable to downstream multi-wavelength laser applications for channel capacities up to 100Gbit / s. Lastly, its transmitted power, optical and electrical power received, and laser wavelength spectrum will be measured to the designated ring laser. The findings will be observed using an Optical Spectrum Analyzer (OSA) and optical power meter.

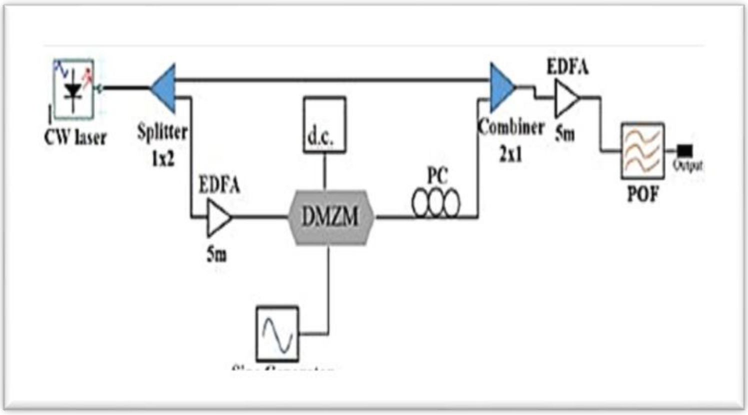


Figure 1. The proposed design of multiwavelength laser for WDM-PON

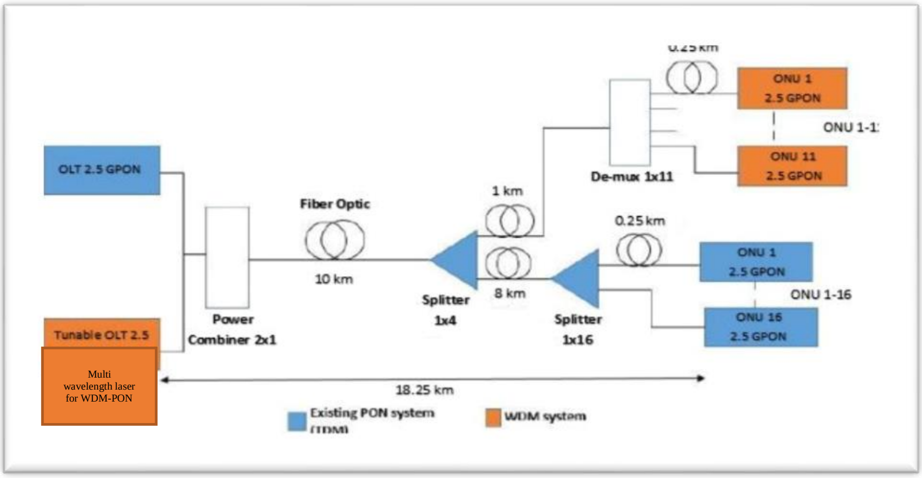


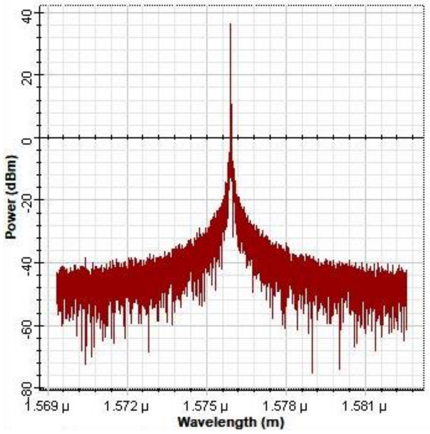
Figure 2. The proposed design of TDM/WDM Passive Optical Network (PON) architecture employing multiwavelength laser for WDM PON

Result and Discussion:

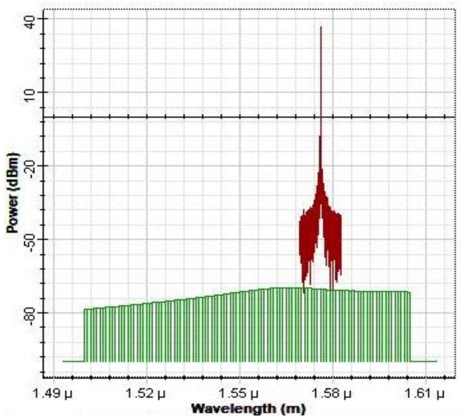
During the project simulation, several laser cavities can be selected when designing a fiber laser. The ring cavity is one of them. To facilitate, ring cavity has been selected for its simplest form factor on generating multi-wavelength outputs. Based on the analysis of the simulated ring cavity setup, a noise spectrum is produced after a single input wavelength spectrum shifts to EDFA in reverse to another splitting laser which does not create any noise.

The dual drive Mach-Zehnder Modulator (DMZM) was utilized in this design. The EDFA-generated carrier signal laser transmitted to the dual drive Mach-Zehnder Modulator (DMZM) for the generation of phase-coded carrier signal. The DMZM operates by either changing the amplitude of the signal generator, changing the synthesize generator's phase difference, or controlling the bias applied to the DMZM. Indicating DMZM in this system is important because it biases with minimal output power that can suppress odd order sidebands. Following DMZM, polarization regulator was set to regulate the polarization condition of this ring cavity.

Based on Figure 3, the outcome spectrum of the L-band multi-wavelength layout is naturally source of noise in amplifier due to a spontaneous emission enhanced in a fiber medium once the CW laser being transmitted pre and post EDFA. The spectrum of ASE is indeed quite broad. This wavelength has a free spectral range of 0.8 nm. This ring design laser was proposed to achieve cost-effective implementation for L-band on Passive Optical Network as the other alternative method of multiple wavelength transmission rather than using array laser. It would also help users by providing steady gain, lower signal-to-noise ratio and improved bandwidth capacity.



(i)



(ii)

Figure 3. (i) CW laser before passing the EDFA (ii) CW laser after passing the EDFA

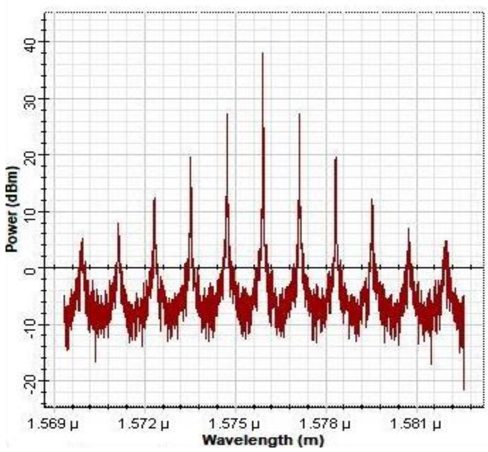
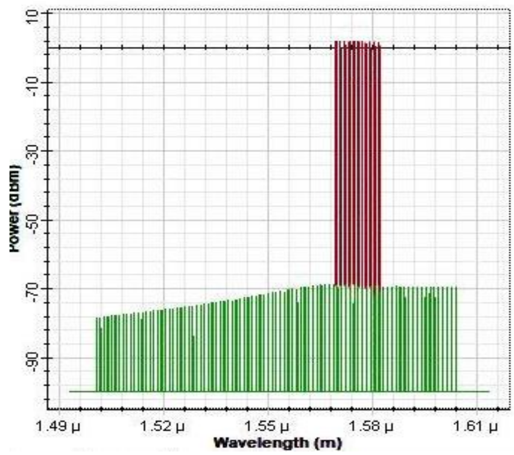
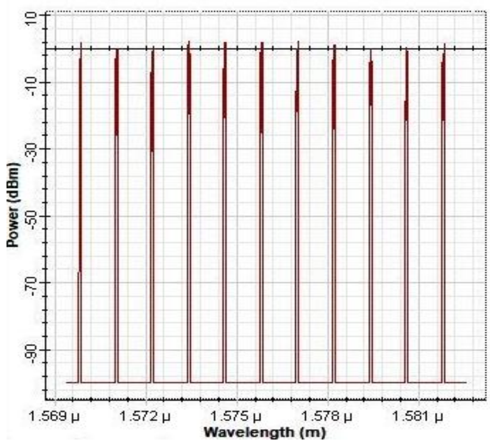


Figure 4. Multiwavelength laser spectrum after tuning the symmetry factor

The laser spectrum displayed in Figure 4 illustrates the trend and alterations in wavelength amplitude. This is caused by tuning of symmetry factor at the polarization controller. The polarization controller has been set by the parameter of 0.6 symmetry factor, as it gives extra flatness in the output spectrum. On the other hand, the tuning technique were needed to modify the narrower and linearity of the wavelength. However, it depends on the kind of analysis and experimental conditions used. Thus, the polarization is regulated to achieve full wavelength spectrum efficiency.



(i)



(ii)

Figure 5. (i) Multiwavelength laser spectrum output evaluated after optical filter (spectral resolution of 0.01 nm) (ii) Expanded sample of laser spectrum of (i) showing 11 simultaneous wavelength lasing oscillations

When optical filters are used, numerous waveforms may be easily produced. There are 3 filter options that could be utilized in the optical filter. In this design, Gaussian filter was chosen because it provided better output spectrum flatness than other filters in the simulation. A bandwidth of 10 GHz and a free spectral range of 0.8 nm with frequency of 1585 nm are successfully developed. The results of the simulation are illustrated in Figure 5.

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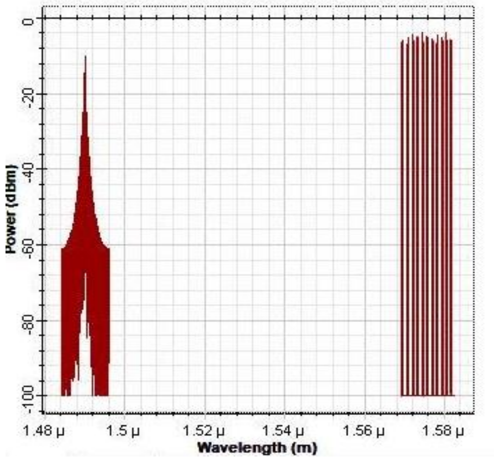

Figure 6. Downstream signal with 1490 nm for TDM and 1569.87 to 1581.87 nm for WDM PON

Figure 6 shows the spectra of the downstream signals deployed in this TDM/WDM PON. For TDM PON, the downstream signal is at wavelength of 1490 nm while for WDM PON, the downstream signals range from 1569.87 to 1581.87 nm. Figure 7 shows the downstream received power obtained at the ONU for TDM and WDM PON. It can be perceived that TDM PON suffers higher losses as compared to WDM PON as TDM PON requires optical splitter in the network. As the number of channels increase, the power received at ONU terminals is reduced due to high losses generated mostly by the splitter for TDM PON. WDM PON suffers less loss as it uses a demultiplexer which is lower loss as compared to an optical splitter. This network is essentially capable of serving up to 64 ONUs, and the power obtained at the ONU for TDM PON is -27.113 dBm which is higher than the ONU sensitivity of -28 dBm.

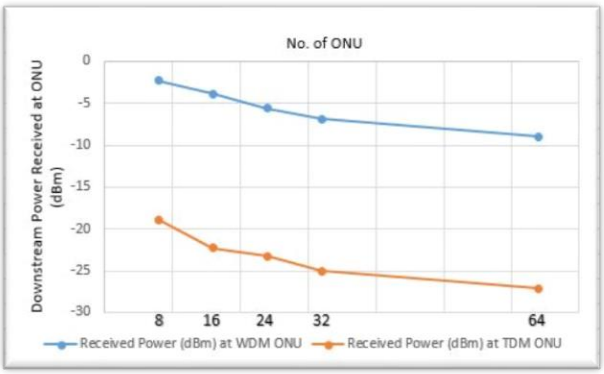

Figure 7. Graph of downstream received power versus number of ONU

The optical power budget is to determine the viability of the system proposed. Figure 8 shows the excess power margin produced by TDM PON as it suffers higher losses as compared to WDM PON. Using an optical power meter in the OptiSystem software, the optical losses of the devices are measured, and the values are shown in Figure 8. In this design, typical values of insertion loss for the optical splitter are used. The transmitted power is set at 0 dBm and the ONU sensitivity is -28dBm. The excess power decrease as the number of ONUs increases mainly due to the high losses produced by the optical splitter. Based on the measured power budget, it found that the excess power margin is greater than zero for TDM system to be viable for up to 64 ONUs.

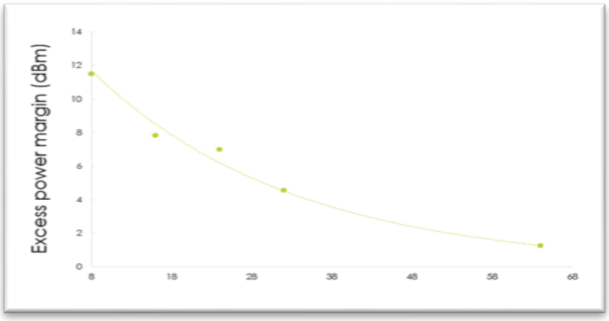

Figure 8. Graph of Excess power margin versus number of ONU for TDM PON

Conclusion:

In conclusion, the design of multiwavelength laser for TDM/WDM PON was successfully developed by using OptiSystem software. Based on the simulation, the design of L-band downstream signal has a range of 1569.865 nm to 1581.973 nm for WDM and 1490 nm for TDM with 100 GHz spacing has been demonstrated. The purpose of multiwavelength laser design is to replace the usage of single DFB laser for each user in WDM PON. Based on the design, it can be concluded that the proposed system is suitable to be deployed for up to 64 ONUs or customers. The advantage of the design is a simple and cost efficient multiwavelength laser as the downstream signal for the TDM/WDM PON application.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.

- The author has signed an animal welfare statement.
- Ethical Clearance: The project was approved by the local ethical committee in University of Teknologi MARA (UiTM).

Authors' contribution:

Nani Fadzlina Naim, Muhammad Amirul Hafiz Mohamed Hashim, Suzi Seroja Sarnin, Norsuzila Ya'acob and Latifah Sarah Supian contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript

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تصميم الليزر متعدد الموجات L-Band لتطبيق TDM/WDM PON

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الخلاصة:

يقدم هذا البحث عن تصميم ليزر L-Band متعدد الطول الموجي لتطبيقات الشبكة البصرية المنفعلة (PON) بتقسيم الوقت الهجين / تعدد الإرسال بتقسيم الطول الموجي (TDM / WDM). في هذا التصميم ، تم تصميم ليزر الطول الموجي ذو النطاق L ليكون بمثابة إشارات المصب لـ TDM / WDM PON. تتراوح إشارات المصب من 1569.865 نانومتر إلى 1581.973 نانومتر مع تباعد 100 جيجا هرتز. تم تصميم الليزر متعدد الطول الموجي باستخدام برنامج OptiSystem وهو مدمج في TDM / WDM PON المصمم أيضًا باستخدام برنامج محاكاة OptiSystem. من خلال تكييف ليزر الألياف متعدد الطول الموجي في شبكة TDM / WDM ، يتم اقتراح إشارة بسيطة ومنخفضة التكلفة في اتجاه مجرى النهر. من تصميم المحاكاة ، وجد أن التصميم المقترح مناسب للاستخدام في TDM / WDM PON لما يصل إلى 64 وحدة شبكة بصرية (ONUs).

الكلمات المفتاحية : الليزر متعدد الطول الموجي ، الشبكة البصرية السلبية ، مضاعفة تقسيم الوقت ، مضاعفة تقسيم الطول الموجي.