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# CHANNEL MONITORED CHANNEL DUPLEXER FOR OPTIMIZATION OF BIDIRECTIONAL PASSIVE OPTICAL NETWORK

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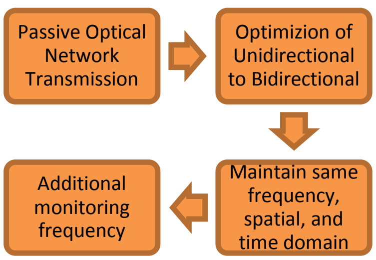
## Graphical abstract




## Abstract

Method of optimizing the optical network transmission in access network has been investigated in many years. Unidirectional optical transmission system is the earliest method of delivering the information. In recent years, bidirectional optical transmission system is the most popular network and shall be the first right of refusal to deploy nowadays. It is justify enough by the massive deployment of the popular state-of-the-art network named Passive Optical Network (PON) in Fiber To The Home (FTTH) technologies. Combining 3 wavelengths includes (1) 1310nm, (2) 1490nm, and (3) 1550nm within a fiber is the method used on Gigabit Capable Passive Optical Network (GPON) or Gigabit Ethernet Passive Optical Network (GEPON/EPON). Combining 2 different wavelengths for uplink and downlink on Small Form Pluggable (SFP) lasers also has been a method used to optimized and saved the fiber infrastructure. Compared those techniques, the research optimization focusing on introducing a passive optical duplexer that combined the same wavelength from both end with the element of monitoring via different wavelength to confirm the network availability. In the design, a unidirectional converter able to operate at a nominal 1310nm or 1550nm windows shall be demonstrated up to 10Gbps Ethernet signal.

*Keywords*: PON, WDMPON, channel duplexer, monitored channel duplexer

## Abstrak

Kaedah untuk mengoptimumkan jaringan komunikasi menggunakan gentian optik didalam rangkaian akses telah dikaji bertahun lamanya. Pada awalnya, komunikasi menggunakan satu arah komunikasi dalam gentian optik telah digunakan untuk menghantar maklumat. Sejak kebelakangan ini, kaedah menggunakan dua arah komunikasi dalam satu gentian optik menjadi satu pilihan utama selain daripada kaedah yang sedia ada. Ia dibuktikan dengan pembangunan yang begitu besar melibatkan satu jaringan yang dinamakan '*Passive Optical Network (PON)*' atau Rangkaian Optik Pasif didalam teknologi '*Fiber To The Home (FTTH)*'. Menggabungkan tiga panjang gelombang yang berlainan iaitu (1) 1310nm, (2) 1490nm, dan (3) 1550nm didalam satu gentian optik ialah kaedah yang digunakan didalam '*Gigabit Capable Passive Optical Network (GPON)*' atau '*Gigabit Ethernet Passive Optical Network (GEPON/EPON)*'. Teknik menggabungkan dua panjang gelombang juga digunakan dalam teknologi pembuatan '*Small Form Pluggable (SFP)*' yang akan dipasang pada alat telekomunikasi untuk tujuan mengoptimumkan dan menjimatkan penggunaan gentian optik. Didalam kajian ini, teknik mengoptimumkan penggunaan gentian optik yang akan digunakan ialah melalui penukaran komunikasi dua arah kepada satu arah yang menggunakan panjang gelombang yang sama pada arah yang bertentangan dan ditambah dengan panjang gelombang yang unik untuk tujuan pemantauan. Didalam reka bentuk yang digunakan, alat penukar satu arah komunikasi boleh beroperasi pada panjang gelombang 1310nm dan 1550nm serta menggunakan isyarat Ethernet sebesar 10Gbps.

*Kata kunci*: PON, WDMPON, penggabung saluran, pemantau penggabung saluran

## 1.0 INTRODUCTION

The demand on bandwidth throughout all network layers leads to the finding on the method to optimize the usage of physical fiber infrastructure. Based on recent statistics by Malaysian Communication And Multimedia Commission (MCMC) (2013), in Malaysia itself, there are about 1.4 millions new fiber ports with a 45,600 Km span that has been installed nationwide up to the end of 2013 [1]. That is not inclusive the existing infrastructures from Small Medium Enterprise (SME) and Corporate users that requires a fastest and stable connectivity that only possible via fiber optic infrastructure.

Based on the recent demands, the strategy on optimizing the consumption of fiber optic infrastructure and bandwidth has been researched and developed in 2 categories includes (1) active devices and (2) Passive Optical Network (PON). Hyo-Hook Park *et al.,* (2008) conclude that there are numbers of method that has been introduced in active devices such as upgrade the transceiver transmission method to bidirectional transmission using different wavelength [2]. Most of the challenge with the method was the complexity of the algorithm and stable materials to comply the mission. Another method is optimizing the fiber infrastructure via PON where this would be the famous state-of-the-art that has been implemented most of the country. Using PON, the transmission capacity is share within a single fiber. The transmission method in GPON/GEPON/EPON uses a different transmission wavelength but within the same spatial domain and in full duplex mode. As mentioned by ITU-T, G.984.1 (2013), the larger the split ratio is for GPON, the more attractive it is for operators. However, a larger split ratio implies greater optical splitting which creates the need for increased power budget to support the physical reach. Split ratio up to 1:64 are realistic for the physical layers, given current technology [3].

There are 2 optical transmission network that includes (1) Active Optical Network (AON) and (2) Passive Optical Network (PON). Sungwi Kim *et al.,* (2003) state that both of the optical networks will have different set of demand in physical fiber infrastructures. AON however, did not share their bandwidth as what the normal PON does [4]. AON is much more direct and consume more fiber infrastructure compare to PON. The needs to optimize the fiber consumption become very crucial when it involved mass deployment to the users.

The proposed fiber infrastructure optimization in this paper is by convert the existing unidirectional into bidirectional fiber transmission network. It converts the legacy unidirectional transmission into a bidirectional transmission in one fiber in which the opposite travelling signals share similar frequency, spatial and time domains. The addition of monitoring channel in duplexer converter shall be part of the design. By having the converter, fiber optic infrastructure can save 50% of the fiber consumption that legacy unidirectional transmission can offer. In addition, converter is expected to operate with most of network transmission protocol.

Existing optical network infrastructure requires for an optimization to save the invested Capital Expenditure (CAPEX) and increase the revenue of operators. This optimization however requires for integration on external passive converters to the network that suffer a small link loss budget allocated. Freshnel effect also one of other element that need to have a control measure to reduce the light reflected back to origin. Since the proposed bidirectional converter were converting the same wavelength on both end, the reflected light travels can be visibly read by the terminal that transmit the laser. The reflection signal may create a Upstream (UP) and Downstream (DS) signals cross-talk and interferometric beat noise. As proposed by Kwangsoo Park and Moonsoo Park, (2014), these reflections however can be mitigated using APC type connector that resulting a very significant Optical Return Loss (ORL) [5].

## 2.0 BIDIRECTIONAL

In Quantum Field theory, E.H.Carlson, (2000) support that light having both wavelike and particle-like properties – that is, incorporating "wave-particle dualism" [6]. Todorka L. Dimitrova and Antoine Weis, (2007) summarize that in the 17th century was mark by the two opposing views interpreting light in term of particles (Newton) or in terms of waves (Huygens). In the 19th century the experiments of Th. Young and A.Freshnel and later Maxwell's theory, supported by the experiments of H. Hertz, confirmed the wave concept of light and the subject seemed to have been settled at the turn of the 19th to the 20th century. Einstein's interpretations of the photoelectric effect in terms of particles of light and later define as photon [7]. Later, K.O. Greulich, (2011) conclude that a photon has no electric charge, stable, and relatively massless [8]

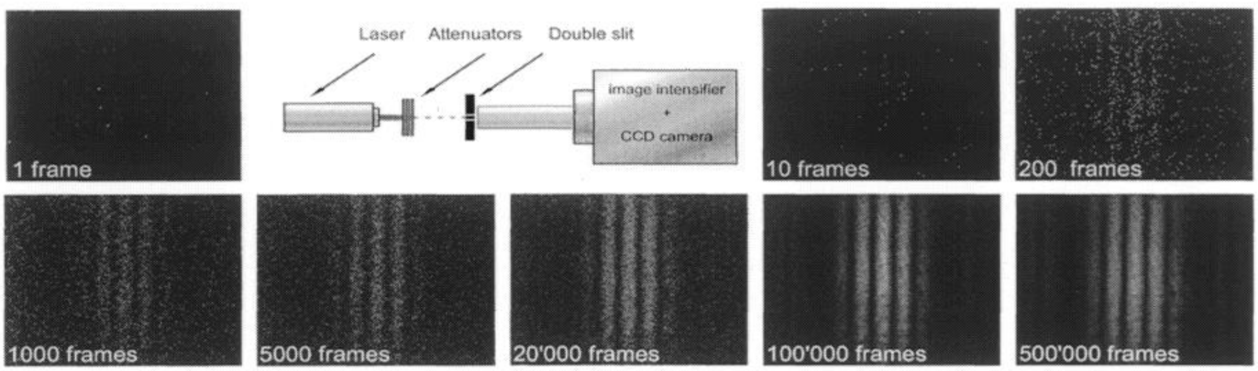



**Figure 1** Diffraction of light

From the Figure 1, Todorka L. Dimitrova's, (2007) experiment illustrate that how the light can act a wave-particle duality. The particle can be combined in area thus create a dense power that is a summation of power on particular area.

Single wavelength, bidirectional transmission (SWBiDi) system has been research by the industrial practitioner by Kwangsoo Park and Moonsoo Park, (2014). Coupling the signal has been used to split the signal with the integration of optical isolator and optical absorber. From the design proposed, the transmitter power will be splits into two equal signal (50%-50%) optical coupler with optical isolator to control the light direction. Figure 2 illustrates how the design constructed.

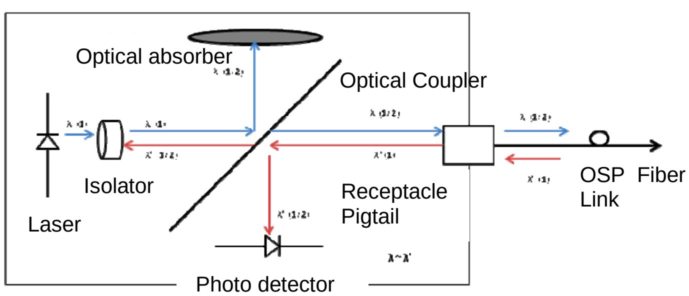



**Figure 2** SW-BOSA without any reflections

From the design, the loss of is higher than the design proposed in this paper. The higher loss shall limit the loss budget of the network that creates a significant distance limitation. 50% coupler and isolator able to introduce a 4dB loss and the converter must be placed on both transmission terminals. The total of 8dB loss and more reduces the transmission margin that installed.

Zhaowen Xu *et al.,* (2009) proposing a simultaneous triple play services transmission in single wavelength [9]. The claimed novel WDM-PON architecture is capable of delivering 10Gbps downlink and 1.25Gbps uplink. A de-multiplex wavelength injected by WDM light source will be modulate with the service and later will be multiplex with other modulated services. The multiplex signal will be circulate into optical circulator and transmit to Interferometry filter (IF). Finally the signal will be branch via AWG to every each CWDM at ONU to de-multiplex the service into their respective service. Figure 3 illustrate the setup used for the proposed design.

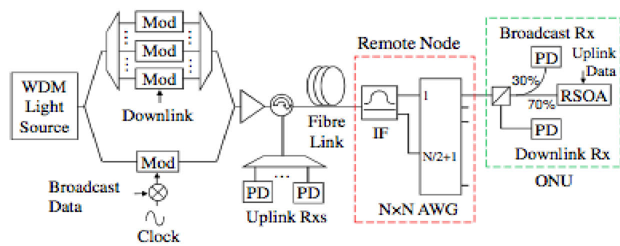



**Figure 3** Proposed triple play transmission over respective wavelength

The transmission of all the services is not as per claimed in research title. The multiplexing technique with WDM is understood to deliver numbers of spectrum in a single spatial domain

Single wavelength optical transmission in PON network however used the method of Phase modulated optical Orthogonal Frequency Division Multiplexing (OFDM) upstream with Intensity Modulation Direct Detection (IM/DD) has been proposed by J.M. Fabrega *et al.,* (2013) as illustrate in Figure 4 [10]. Reusing a downstream signal for

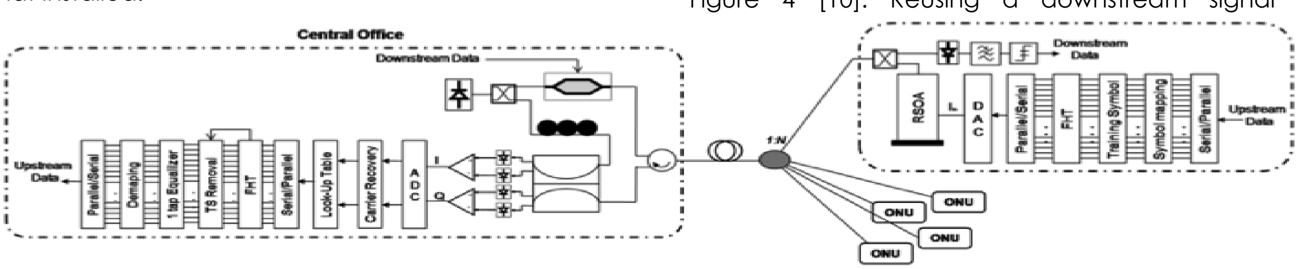
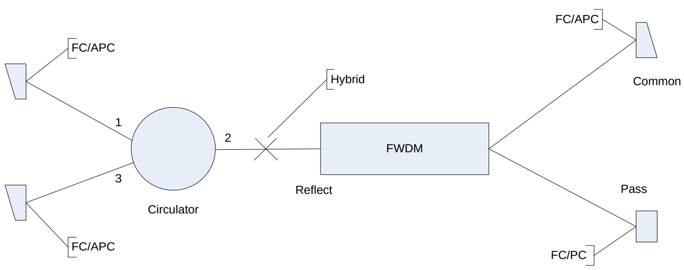



**Figure 4** Simplified Network Scheme and proposed CO-ONU design

upstream transmission by saturated Reflected Semiconductor Amplifier (RSOA) and using it to modulate the optical phase with DMT signal using low overhead (11.3%). Coherent reception is used at the CO side. The symmetric data rate can be achieved for 10Gbps downstream and upstream via the method. The complex colorless bidirectional transmission is able to meet the maximum bit rate as injected from the central office.

## 3.0 RESULTS AND DISCUSSION

An experiment setup has been done as illustrated on Figure 5.




**Rules:**
>If the circulator is 1310nm, Reflect must be 1310nm and Pass must be 1550nm
>If the circulator is 1550nm, Reflect must be 1550nm and Pass must be 1310nm

**Figure 5** Monitored Channel Duplexer

An optical circulator been used to circulate the flow of data signal that injected from port 1 will be directed to port 2 and later will be multiplex into Filter Wavelength Division Multiplexing (FWDM) to combine the monitor and data signal together and finally give an output to common port. The insertion loss of data signal is at 2.2dB loss and the reflected light power from the data signal is measure at -55dBm at port 3. This given measurement show that the crosstalk of the signal can be isolated from the receive signal on the other transmitted signal.

On the monitoring signal insertion loss however is measure at 0.7dB and the isolation loss at port 3 is measure at 45dB. The given measurement indicates that the system isolate the power of monitoring very well since the channel is not been used by the receiver.

The APC type connector has been used to eliminate the factor of reflection that increases the cross talk on the network.

On the receiving data and monitoring signal shall enter from common port and de-multiplex by the FWDM to isolate both signals. As far data signal shall be reflected to circulator component of port 2 and shall be circulate to port 3 as the receiver signal. Whereas the monitoring signal will be de-multiplex by FWDM to 'Pass" port. The insertion loss of receiving signal is measure at 2.3dB loss and the isolation power at 'Pass' port is measure at -48dBm. On the monitoring signal however is measure at 0.5dB insertion loss and the isolation power at port 3 is measure at -46dBm.

## 4.0 CONCLUSION AND FUTURE WORK

The experimental work done shows that the component satisfies the least loss that converter introduce to the network. Further simulation work shall be continue to verify the combination of light within the same frequency or wavelength from different source in fiber optic will increase the power by the summation of both lasers at state. The assumption of the hypothesis statement was the particle of photon on both laser sources would be combined into the same spatial domain.

After the combination of light at the fiber, the photon's vector will remain continue to the direction of laser that has been pre-directed from source of the laser. The assumption of the hypothesis statement was the particle of photon does not contain any charge, and therefore the photon would not repel and interact each other due to the massless of the photon itself.
This project expects the findings as below:

1. Optical bidirectional transmission using the same wavelength and injected within the same spatial and time domain is feasible with additional limitation to the network
2. Integrated network with the converter will limit the distance that it should reach and additional control measures need to be installed to ensure that the reflected light is preserve.
3. Network performance is expected to perform the same as unidirectional transmission system

The optimization of the fiber network infrastructure becomes a very important aspect in next generation networks. Therefore, the existing optical network infrastructures that run in unidirectional transmission also need to upgrade suit to the demand for fiber optic infrastructures in future. The channel duplexer converter should be one of the methods to save the consumption of fiber optic infrastructure

## Acknowledgement

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## References

[1] Malaysian Communication and Multimedia Commission (MCMC). Annual Report 2013. Lifestyle Digital. 16: 33-34
[2] Hyo-Hook Park, Sae-Kyoung Kang, Do- Won kim, Nguyen T.H.Nga, Sung-Hwan Hwang, Tae-Woo Lee. 2008. Driver-Receiver Combined Optical Transceiver Modules For Bidirectional Optical Interconnection. *Proceeding of SPIE.* 6897: 4-6.
[3] ITU-T, Series G: Transmission System and Media Digital System and Networks 2008, G.984.1. Gigabit-capable Passive Optical Networks (GPON): General Characteristics. 7.
[4] Sungwi Kim, Dohyun Nam, Gunil Yoo, Woonha Kim. 2003. An Economic Analysis on Optical Ethernet in the Access

Network. *Proceeding of SPIE: Network Architectures, Management, and Application*. 292: 292-293.
[5] Kwangsoo Park, Moonsoo Park. 2014. Single Wavelength, Bidirectional (SWBiDi) Transmission Technology. OE Solutions Co., Ltd, Publications. 5-7.
[6] E. H. Carlson. 2000. Wave-particle Duality. MISN-0-246: 1-2.
[7] Todorka L. Dimitrova and Antoine Weis. 2007. A Double Demonstration Experiment for the Dual Nature of Light. *Proceeding of SPIE 14th International School on Quantum Electronics: Laser Physics and Application.* 66040O: 1-2.
[8] K.O. Greulich. 2011. Understanding the Masses of Elementary Particles: A Step Towards Understanding the Massless Photon? *Proceeding of SPIE: The Nature of Light: What are Photon? IV*. 8120H: 1-4.
[9] Zhaowen Xu, Tee-Hiang Cheng, Yong-Kee Yeo, Yixin Wang, Xiaofei Cheng, J. Liu, D. Wang. 2009. Simultaneous Triple Play Data Transmission on a Single Wavelength. ECOC '09: 35th European Conference. 1-2.
[10] J. M. Fabrega, M. Chocol, M. Svaluto Moreolo, J. A. Lazaro, and G. Junyent. 2013. Phase Modulated Optical OFDM Upstream with IM/DD Downstream for Full-Duplex 10 Gb/s Bidirectional Transmission Over A Single Wavelength with a Reflective SOA. *Transparent Optical Networks (ICTON), 2013 15th International Conference*. 1-3.