Thermal Effect Analysis of Arrayed Waveguide Grating in NG-PON2 Network

Brian Pamukti, Doan Perdana, and M.Ramdlan Kirom

Abstract—**This paper presents principles of network access Next Generation-Passive Optical Network Second Stage (NG-PON2) system and its improvement using Arrayed Waveguide Grating (AWG) with configurable wavelength. This system suitable for fluctuative bandwidth. The influence of the parameters are analysed through calculations and simulations. One of measurements in this paper is Q-factor, where Q-factor certify the quality systems that can be converted to Bit Error Rate (BER). This result has a Q-factor value of 5.71 with four wavelengths. The power of a wavelength increases with the number of wavelengths. Based on the empirical method, the transmit power has a value 9 dBm. However, the results of this simulation is not perfect, because with single wavelength transmitter has not achieved of minimal Q-factor and not suitable for this system, except for the conventional systems, e.g Time Division Multiplexing (TDM). This paper has a power consumption 10% lower than NG-PON2 planning workshop ITU-T/IEEE and 25% less power compared to DML modulation.**

Index Terms—**NG-PON2, AWG, OLT, ONU, ODN, Thermal.**

I. Introduction

THE development Next Generation-Passive Optical Network stage 2 (NG-PON2) on ITU-T G.989 is the first step for big data growth on access network. It is because this technology supports PON legacy and can use old Optical Line Terminal (OLT) as the transmission system. The Internet Service Provider (ISP) can use this technology to increase their service and bandwidth. In addition, this technology provide benefits to customers, because they do not need to replace the device. The configuration can be set via the server. A framework proposition for NG-PON2 was initiated in 2011. The system plan accomplishes fundamental configuration targets like accessible data transfer capacity, system reach and cost [1].

NG-PON 2 technology is the most recent and the newest access technology. Being the innovation leader in the field of access, high ability are expected to spend a huge cost, especially for providers, but several sides can be taken to reduce the cost. In March 2013, standard ITU-T G989 have been characterised which is consist of general necessities. However the Physical Media Dependent (PMD) and Transmission Convergence (TC) layer prerequisites can be provided for support improvement this technology. The rapid development of this standard is not missing from problems or issues that arise continuously.

Reference [2] brings research directions to low cost issues. By using the transmitter Directly Modulated Laser (DML) and with 0.2 nm-FSR DI, a reshaping spectra, this paper compares the performance up to 100 km. In addition to the relatively long access network distance, splitters used up to 256. High scalability that carried shortcomings, the achievement namely of the minimum BER is 10^{-3}. The different segment of this research are transmitter and distance. This research use EML transmitter, and the distance up to 40 km. To overcome the dispersion, the research adds Dispersion Cable Fibre (DCF) and not use the Delay-Interferometer (DI) as previous papers

Researchers [3] experiment with 80 Gbps bit rate optical networking standards and achieve the BER less than 10^{-9}. Experiments start from the OLT combines 8 distribution of laser diode with 10 dBm power. Used ranges 1570.4 nm-1576 nm wavelength with channel spacing 0.8 nm, and externally modulated using a Mach Zehnder Modulator (MZM). OLT is transmitted on a link with a distance up to 50 km and given a booster Semiconductor Optical Amplifier (SOA) prior to photodetector device.

Meihua Bi et al. [4] proposed 40 Gbps Time Wavelength Division Multiplexing Passive Optical Network (TWDM-PON) system for four 10-Gbps wavelengths with 256 downstream ratio along the 50 km. Several other references discuss NG-PON2 ratio, aggregate NG-PON, distance and cost budget. This paper showed the high bit rate transmission to link downstream of TWDM-PON for total capacity 40 Gbps by using Array Waveguide Grating (AWG) and an aggregate of four 10-Gigabit-PON (XGPON).

The problem in the NG-PON2 is bandwidth efficiency or wavelengths utility that are not optimum. One of problems arise when some of the area prepared apply for this technology to aggregate four wavelengths, but some areas are still using two wavelengths. There was waste of bandwidth and have an impact on power consumption disadvantage. In addition, the imposition of customer could be a result of provider does not want to lose too much.

Beside that, bit rate 40 Gbps has evolved gradually, its means that the entire request will not be fully 40 Gbps. One is the system Mux/Demux is initially 2 static devices, into one dynamic device with Arrayed Waveguide Grating (AWG) [5]. One of the AWG advantages on NG-PON2 technology is adjustable wavelength. The smaller segments are needed to increase demands and availability. For example when total of network access only requires bitrate of 20 Gbps, its means that area just need two wavelengths. This excess of AWG with a adjustable filter is four stacked X-GPON can be broken down into two wavelengths. It could be an advantage for providers in the provisioning bandwidth and

Brian Pamukti was with the School of Electrical Engineering, Telkom University, Bandung 40257, Indonesia. He is now Lecturer in Telkom University.(e-mail: brianp@telkomuniversity.ac.id).

Doan Perdana was with the School of Electrical Engineering, Telkom University, Bandung 40257, Indonesia. He is now as Head of The Expertise in Network and Multimedia. Telkom University.(e-mail: doanperdana@telkomuniversity.ac.id).

M. Ramdlan Kirom was with the School of Electrical Engineering, Telkom University, Bandung 40257, Indonesia. He is now as Head of Engineering Physics, Telkom University. (e-mail: mramdlankirom@telkomuniversity.ac.id).

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traffic efficiency. The reason that makes this research was undertaken, in order to calculate the performance of AWG in NG-PON2 with various bitrates.

The contribution of this research is making AWG adjustable wavelength by utilising changes in temperature and material properties of Silicon. And the value of bandwidth wider 0.1 nm/°C ,our wavelengths can be transmitted with a temperature 65 °C. The temperature of 40°C and 55°C are two and three wavelengths, and one wavelength using a room temperature of 25°C. Base Transmit Power value by 3 dBm, this system can not reach the standard Q-factor. Thus, with appropriate power optimisation changes that have been planned range, the stability of the Q-factor starts when all Line Card valued 9 dBm.

This paper is divided into five main sections. Section I discusses the background of the problems of NG-PON2, and explain the sections of paper simply and convey the contributions resulted from this research. Section II discusses research about standard NG-PON2 in ITU-T G.989. Section III describes the parameters and forms networking designed. Section IV relates the calculation and simulation in the scope and scalability. Finally, conclusion summaries this research.

II. NG-PON Stage 2

A. G.989 Standards

ITU-T in G.989 standard has completed developing a set of points which can explain the NG-PON2 system in the access network to mobile backhaul, residential, business and different applications. The NG-PON2 comprehensively has been completed by 2015 with the division of the standard as below.

1) Recommendation G.989.1 discusses general terms, to address and propel the physical media dependent and transmission convergence. It is contains a configuration to development, migration scenarios from the old PON systems and the requirements that are needed. Additionally, comprising service and operational requirements to develop an ease of access networks in order to support the entire application access.
2) Recommendation G.989.2 discusses more specifically the physical layer specification of the NG-PON2, Layer Physical Media Dependent (PMD).
3) Recommendation G.989.3 describes a layer of transmission convergence, more familiarly called the Transmission Convergence (TC) Layer.
4) The control and management of the ONU interface, describe the continuation of the discussion on recommendation ITU-T G.989 for NG-PON2 [6].

This paper analyzes deeply in the recommendation G989.1 and G989.2 which aims to find minimal necessary of reference, so it can be simulated to figure out the performance of the design model.

B. NG-PON2 architecture

Power splitter based on FTTx ODN operates to developed system that will make infrastructure live longer. Additionally, non-selective wavelengths, relics ODN is preferred by some operators to acquire distribution network transparently without barriers against wavelength flexible upgrade and further use of fibre spectrum. Filter within ODN determine the wavelengths allocation which limits adaptability and can expand many side quality of system arranging. In any case, the benefit of low part loss is likewise perceived and straightforwardness ought to be weighed against the potential lessening in spending needs and physical security in the wavelength specific ODNs [7]. Interest points of reach extender is not examined in this research [8] , but rather suitable elements of an usage choices can be obtained in standard ITU-T G.984.6.

Multiplexing/demultiplexing components of coexistence (CEx) is utilised for give network between PON, PON framework for a few eras (concurrence components and specialised necessities existed in ITU-T Rec G.984.5 [9] and [10]). The insertion loss is device characteriseded for an assortment from 1-1.3 dB relying upon the implementation. The other essential attributes, for example, separation channel will be point to point in the standard.

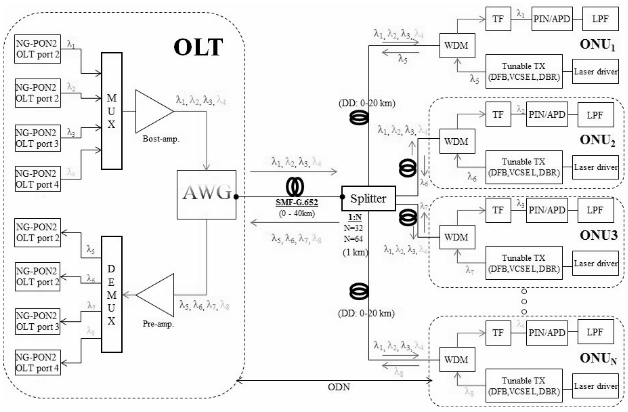

Fig. 1. Modified architecture coexistence of architecture for NG-PON2 with legacy PONs.

Fig. 1 illustrates a new scenario and points of reference NG-PON system to provide enhancement on access network. Optical Distribution Network consist power divider and the new element Mux, in this research is used AWG as a muliplexer.

Specifications number of channel AWG standard wavelengths are 4 and 8 be an option to be stacked into an aggregate 40 Gbps OLT utilising Wavelength Multiplexer (WM). Every transmitter and receiver have to be planned with 10 Gbps and 2.5Gbps. On the receiver side every ONU must be outfitted with a adjustable wavelength that can adjust with one upstream wavelength adjustable receivers apportioned and ready to upgrade every wavelength channel distributed downstream acknowledged. FEC evening out systems and methodologies ought to be utilised to make up for declining the distinctive transmission to accomplish the normal results. At long last it is likewise critical note that design could be stretched out to bolster numerous OLT (of various administrators) when all said in done ODN to give the improvement a pay-as-you-grow adaptability and spectral.

NG-PON2 system needs to be upgraded properly to solve bandwidth problem. Since a lot of services in this world grow significantly, data center with OLT have to use Wavelength Division Multiplexing (WDM) technology to bring huge data. Thus, latest technology WDM should be used in this part of NG-PON2.

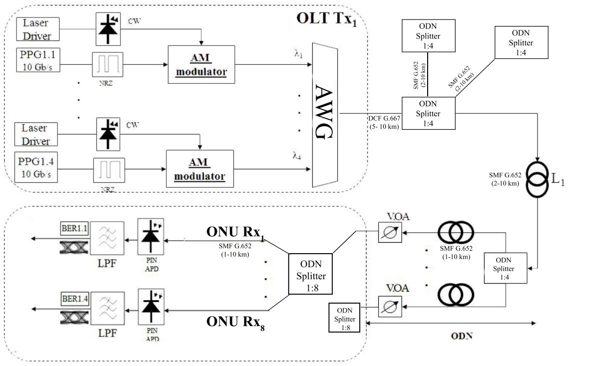

Fig. 2. Detailed architecture of a WDM-PON

Fig. 2 demonstrates the fundamental design of the NG-PON2 in a solitary OLT situations by utilising technology WDM. In the downstream, the transmitter with four fixed wavelengths 10 Gbps, one port NG-PON2 at OLT, utilised with a space channel 100 Ghz in L-Band range. This wavelength is multiplied and can be intensified as already multiplied. Arrayed Wave Guide as a Multiplexer, multiply and demultiplex optical sign in the uplink and downlink transmission successively. Thought and determinations of AWG has been portrayed in the standard ITUT G989.2 [11]. ODN comprises of fibre up to a separation of 40 km of Single Mode Fibre (SMF) (ITU-T G.652) with details and attributes of weakening and scattering particularly depicted in section 3. The ODN of NG-PON2 contains two-way transmission utilising one fibre WDM wavelengths as a part of two channels distinctive (up/down). A power divider required to communicate a sign, transmitted to each ONU through the drop fibre.

Optical Network Unit (ONU) can be kept at a maximum distance with the assortment range up to 40km, and configured in the reach of 20 km - 40 km. Access network of NG-PON2 must support users up to 256 customers, using 1:64 ratio power divider. Then, on the ONU side, other WDM filter to isolate signal upstream and downstream as well as adjustable filters should be used to select specific wavelengths to detected with a PIN or APD bitrate 10 Gbps. After the location of optical sign, Low Pass Filter (LPF) is utilised to decrease the nuisance produced by the trans impedance amplifier.

In the uplink side, ONU transmitter (Tx) requires adjustable devices to send various wavelengths. This will be accomplished by utilising diverse strategies and innovations as portrayed in first section. The signal transmitted WDM filter to receiver side which signal will be in the multiplex with splitter and after a distance of 40 km, and filtered by AWG, then will meet methods of pre-amplified and demultiplexed in the OLT. It is important to understand every element tools configuration of the transmitter and receiver side.

The evolution multiplexing technology that used in optical system is WDM, but in the new combiner PON on ONU side will be used Time Division Multiplexing (TDM) for transmit upstream. Upstream system in NG-PON2 will not used multiplexing of wavelength, because is to much for it. Thus, TDM system is sustainable for upstream. A lot of signal upstream are delayed in the same wavelength. In this case, the upstream system used power utilisation and optical delay to maintain the upstream signal form each ONU.

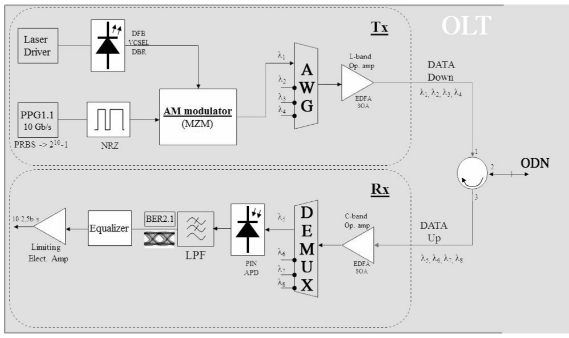

Fig. 3. OLT Transceiver for NG-PON2.

The OLT site portrayed in Fig. 3 that the transceiver equipped with 10Gbps transmitter, the 10 until 2.5 Gbps receiver and AWG channel isolates the data up and data down transmission. Mach Zehnder Modulator functioned as External Modulated Laser (EML) for transmitter design. Within a transceiver consisting 4 EML laser that multiplexed (can select an option corroborated) before arriving to the WDM filter device, can use a wavelength filter or optical circulator.

The receivers consists of a pre-amplifier as reinforcement choice, demultiplexer, APD or PIN photodetector and Low Pass Filter. Besides, regenerator complementary used to reduce the impact of unwanted transmission and limit the power amplifiers to boost the signal receiver [12].

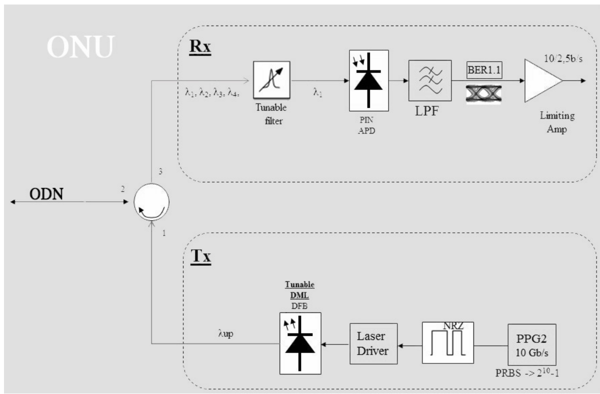

Fig. 4. ONU Transceiver for NG-PON2.

Fig. 4 describes ONU transceiver plan for this research. It is necessary to ensure that both the ONU and OLT could be adjustable, keep the end goal to meet the requirement of NG-PON2.

C. AWG Structure

AWG is a planar structure of waveguides that comprises of an array of waveguide called phased array and free propagation region contains two couplers. Optical signal of multiple wavelengths $\lambda_1 - \lambda_n$ flows from one of the input waveguides into the input coupler which appropriates the light signal amongst an array of waveguides of different lengths.

Then the light signal propagates through the array of waveguides to the output coupler. The lengths of waveguide of the array are designed so that the way contrast dL between adjoining waveguides equals a whole number numerous of the central wavelength λ_c of the demultiplexer.

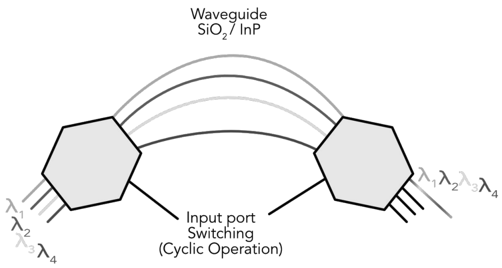

Fig. 5. AWG Structure.

Fig. 5 describes system of AWG and the way length contrast between adjoining array arms dL is given by

$$dL = \frac{m\lambda c}{n_{eff}} \ , \tag{1}$$

where n is the quantity of waveguides, m alludes to diffraction request of the demultiplexer, n_{eff} is the variable refractive record of the exhibited waveguides and λ_c is the inside wavelength of the phaser.

Expanding lengths of a cluster waveguide straightly causes impedance and diffraction when wavelength blends in a yield coupler. Subsequently, every wavelength is engaged into one and only of the N yield waveguides called yield channels.

AWG can be isolated into low-file and high file AWG. Low-list AWG with the refractive list differentiation of 0.75% this write is perfect with optical strands and has low coupling misfortunes between yield waveguides and optical filaments. It has size hindrances when number of channels increments. High record AWGs have the upsides of little size and higher coupling losses.

AWG devices can be as add drop multiplexers, demultiplexers, and filters devices in optical WDM applications.

III. Model System of NG-PON2

Design models and reference architectures based on standard components as well as cost effective design has been configured and simulated in software Optisystem. Every device displayed and the diverse subsystems (OLT, ONU) will explained and elaborated.

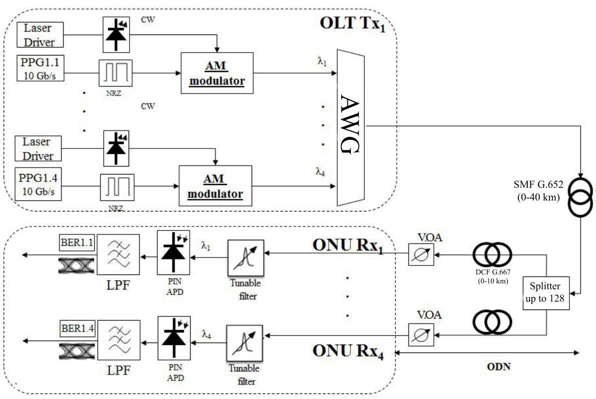

Fig. 6. General system architecture that is simulated.

The system architecture is commonly utilised all through this study are appeared in Fig. 6. Just downstream transmission is considered for reasons clarified. Characteristics such as fibre length, the ratio of the power divider and tolerance to disturbance linear and non-linear tested. This study provides some power in the splitter. It can be seen that the image above includes 3 point splitter, the splitter with 1:4, is stored after passing the DCF fibre, and from splitter is divided into 1:4 again. Scalability increased by breaking down the average power becomes 1:8 with an estimated farthest distance of 10 km. In addition, description of the research advances toward a network that can be implemented.

OLT is located in the data center consisted four DFB laser on OLT are boarded externally by the amplitude modulator (AM) or Mach Zehnder Modulator (MZM) at several wavelengths:

$$\lambda_1 = 1596.34 \text{ nm} \ , \lambda_2 = 1597.19 \text{ nm} \ ,$$
$$\lambda_3 = 1598.04 \text{ nm} \ , \lambda_4 = 1598.89 \text{ nm}$$

and devices, Arrayed Waveguide Grating (AWG), to join wavelengths through to the optical cable. The Optical Distribution comprises of single modes fibre feeders and device hub where the sign is circulated to the heap by means of the N fibre drop, for shorter than fibre feeder. This device is the power splitter that imitated into variable optical attenuator (VOA) designed with lost 21 dB part per 1:128 power splitter. Every receiver consist adjustable channel which filter wavelength distinctively and straight to location plan outlined with a photo receiver took after by an electric channel that minimises noise. Other VOA utilised before to control the ONU power extent gotten and post losses because of fibre attenuation and other transmission devices and the fact.

A. *Definition of Devices*

The libraries segment of Optisystem stage, the majority of the building squares (CW lasers, optical cable, couplers, multiplexers, photodiodes, analytic instruments, and so forth) were accessible.

Table I shows outline the parameters utilised as a part of the requirement to every transmitter, distribution guidelines and photo receiver used as part of beneficiaries.

B. *Equations Thermal Analysis of AWG*

This paper has proposed thermal condition formula of silica-doped matters AWG on the substrate of silicon. The AWG center wavelength changes with temperature shifted is communicated as [13]

$$\frac{d\lambda_c}{dT} = \frac{\lambda_c}{n_c}\left(\frac{d\lambda_c}{dT} + n_c\alpha_{sub}\right) \ , \tag{2}$$

where λ_c is the middle wavelength of AWG in μm , n_c is the successful refractive index of the AWG, α_{sub} is the coefficient of temperature extension of the Silica substrate, and $\frac{dn_c}{dT}$ is the thermo-optic (TO) coefficient of dT the waveguide. Coordinating temperature and wavelength then (2), can be communicated as [14]

$$\lambda_c = Cn_c e^{(\alpha_{sub}T)} \ , \tag{3}$$

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TABLE I
DEVICE AND COMPONENT PARAMETERS

Tx Parameter	Value
Emission Frequencies	187.6 THz - 187.9 THz
Wavelength Channel	4
Channel Spacing	100 Ghz
Power Transmit	3 dBm - 11 dBm
Laser Line width	1 Mhz
Modulation	On-Off Keying
WDM MUX	Value
Insertion loss	2 dB - 4 dB
Fiber Parameters (SMF)	Value
Dispersion	17 ps/km.nm
Dispersion Slope	0.0561 ps/km.nm^2
Attenuation	0.35 dB/km
Nonlinear Index	2.610^{-20} m^2/W
Effective Area	80 μm^2
Length	0-40 km
Optical Filter Parameter	Value
Filter Type	Gaussian
Filter Order	2
Bandwidth	10-100 Ghz
Rx Parameter	Value
PD Type	PIN or APD
PD Responsivity	0.7 A/W
PD Thermal Noise	10^{-12} pA/Hz
PD Electrical Filter Type	Bessel

where C is a coordinating steady. Accept that $\lambda_c = \lambda_o$ and $n_c = n_{co}$ when $T = T_o$ at chamber temperature, it can decide C as the accompanying expression

$$C = \frac{\lambda_o}{n_{co}} e^{(-\alpha_{sub} T_o)} \quad , \tag{4}$$

where n_{co} is the variable refractive index at chamber temperature. Substituting of (4) through (3), we get

$$\lambda_c = \frac{\lambda_c n_c}{n_{co}} e^{[\alpha_{sub}(T-T_o)]} . \tag{5}$$

At that point from (5), the middle wavelength shift brought several changed by temperature variety can be communicated as

$$\delta\lambda = \lambda_c - \lambda_o \left[n_c e^{(\alpha_{sub}(T-T_o))} - n_{co} \right] \quad , \tag{6}$$

taking $\delta\lambda = 0$, in (6), the thermal state of the AWG can as

$$\alpha_{sub} \left(T - T_o \right) = \ln \left(\frac{n_{co}}{n_c} \right) \quad , \tag{7}$$

separating (7) variables refractive index with temperature, a temperature state of the AWG communicated in another structure as [15]

$$\frac{dn_c}{dT} = -\alpha_{sub} n_c \, . \tag{8}$$

C. Parameter Design of AWG

Diffraction m is a very important parameter. Once diffraction is defined, some kind of configuration parameters AWG temperature affected, such as channel selection, spacing between channels, center frequency of the desired channel and the number of waveguide shown. In the testing process, we identify the relationship between the diffraction m and each of these parameters, and to conduct a review of the quality of the resulting. The way of length qualification between neighbouring indicated waveguides ΔL is

$$\Delta L = \frac{m\lambda_0}{n_c} \quad , \tag{9}$$

where m diffraction order, n_c is the refractive index of the material AWG that can be tuned, and λ_0 is lambda of the waveguide in μm. The channel length as shown in the middle of the condition [16]

$$L_f = \frac{d^2 n_c^2}{m \Delta\lambda n_g} \quad , \tag{10}$$

where d is the length of the pitch that affect the value of the input / output and shown in units of μm. ΔL is the wavelength direct dispersing in nm, and n_g is the gathering refractive index and is given as the accompanying

$$n_g = n_c - \lambda_0 \frac{dn_c}{d\lambda} \quad . \tag{11}$$

A property of AWG most important is free spectral range (FSR), or commonly called the demultiplexer periodicity. This resulted in the wavelength periodicity to be diverse and has a value of output at the interface FSR. Free spectral range indicates the wavelength and the important division between the highest and lowest channels to produce a number of channels in the AWG. The division between the wavelength and diffraction m are expressed :

$$FSR = \frac{\lambda_0 n_c}{m n_g} . \tag{12}$$

The number of input / output channels, written with the greatest of N_{max} based on the FSR. Shipping capacity data from the multiplexed channels, it is $\Delta\lambda$ have to be narrower than an FSR to keep the value of the black area or canal that is not the purpose. Thusly, N_{max} can be determined as [16]

$$N_{\max} = \text{integer} \left(\frac{FSR}{\lambda_0} \right) \quad . \tag{13}$$

The number of wavelengths shown are not the main parameters in the design of AWG which light in separated channels through channel spacing and the greatest wavelength value of a channel. The greatest value, P selected to show the number of wavelengths that is sufficient for the numerical aperture, where the frames are more visible than the number of input / output waveguides. The end of the design is the division of the wavelength channel spacing via diffraction into the free spectral range. When in the planning, the amount of output will be greater than four times the quantity of channels [16].

$$P = 4N_{\max} \, . \tag{14}$$

IV. SIMULATION AND ANALYSIS

A. Calculation and Simulation Results Of Thermal AWG

This paper analyzes the focus at the beginning of temperatures, room temperature $T_0 = 25$ °C is chosen to be λ_0 = 1.596 μm , which is one of the standard wavelengths suggested by the (ITU). AWG material made from silicon substrate has a coefficient of thermal $\alpha_{sub} = 2.63\text{x}10^{-6}$/°C. Temperature parameters used in devices ranging from 25 °C to 65 °C AWG and aims to increase the number of channels

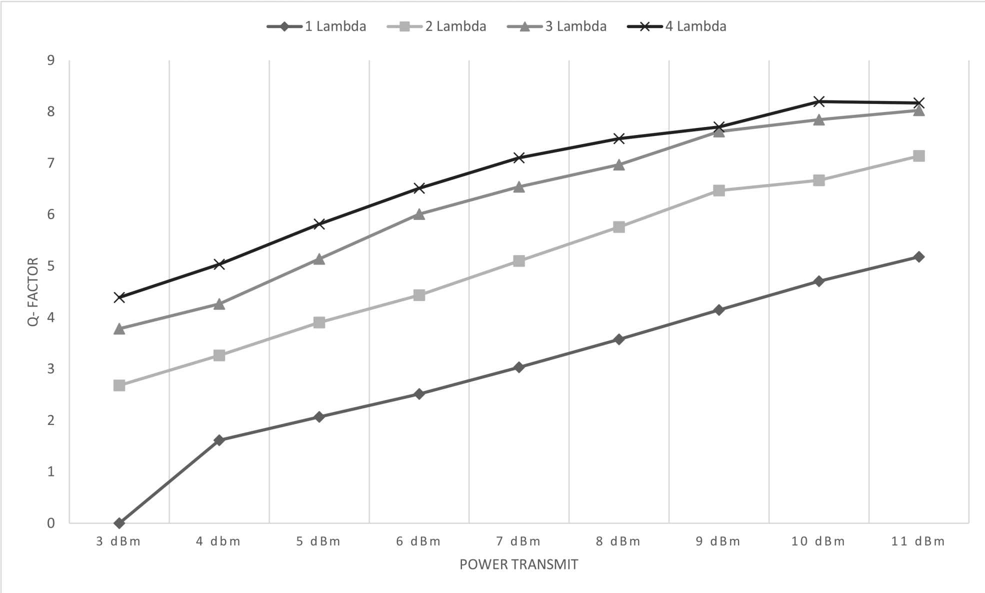


Fig. 7. The influence of temperature changes on the AWG.

that can be passed by the AWG-doped silica material. In a view of investigation to show an expected condition and arrangement from working parameters as be showed in Table II.

TABLE II
OPERATING THERMAL PARAMETERS FOR AWG

Operating Parameter	Value
Temperature Range (T)	25°C <T <65°C
Pitch Length (d)	15 μm
Operational Signal Wavelength(μm)	1.45 <λ <1.65
Room Temperature (T_0)	25 °C
Channel Spacing ($\Delta\lambda$)	0.2 <μm <1.6
Centre Wavelength at T_o	1.596 μm
Thermal expansion coeff (α_{sub})	2.63x10^{-6}/°C
Core Radius (a)	4 <μm <5
Ratio Of Germania Dopant(x)	x<0.3
Material AWG	Silica-doped

Table II shows the parameters generated from calculations, coupled with some assumption of the authors. The material used is silica-doped, because the results indicates that the doped silica has the best performance for temperature regulation in the AWG. The development of this calculation results will get the value form, temperatures used for setting λ_c at AWG.

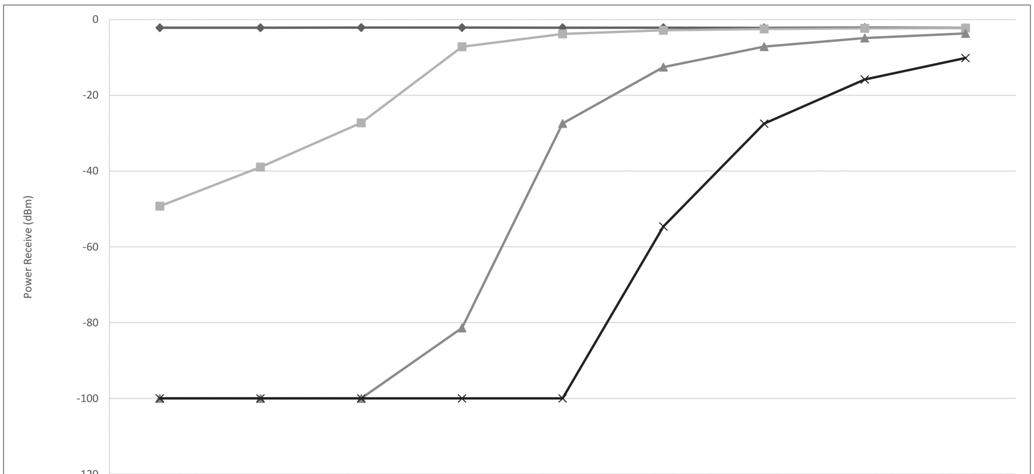
The refractive index of AWG changes with temperature. This causes the channel reaction of AWG to move the wavelength when its temperature is changed. The measure of movement only depends on the refractive index change with temperature and not the channel outline itself. Silica AWG move roughly $+0.01nm/°$C, InP and Si AWG move around $+0.1nm/°$C, and polymer AWG move roughly $-0.3nm/°$C . The movement is undesirable in DWDM frameworks. To maintain a strategic distance from this, frequently the PLC is temperature controlled, utilising either a thermoelectrical cooler or a warmer. Another methodology is to make the PLC a thermal, the theme of this segment.

The temperature affect ability of the passband center wavelength (recurrence) in the silica-based AWG is about $d\lambda/dT = 1.2$ x 10^{-2}(nm/deg) [dv/dT= - 1.5(GHz/deg)], which is fundamentally dictated by the temperature reliance of silica glass itself [d_{nc}/dT= 1.1 x $10^{-5}(deg^{-1})$]. The temperature AWG multiplexer should be controlled with a warmer or a Peltier cooler to settle the channel wavelengths. This requires a steady power utilisation of Watts and critical gear for the temperature control.

This study breaks down the analysis on the number of wavelengths which are represented by the aggregate bitrate. The breakage aims for more in-depth and detailed analysis. The division is based on the bitrate of each 10 Gbps. The analysis will start with 10 Gbps, 20 Gbps, 30 Gbps and 40 Gbps. At each analysis, will be shown the spectrum of these signals, the bit period for, and performance results in the form of BER test.

In this study, the acquisition of the values which depend on AWG temperature, are obtained from literature. The study is conducted to improve the research in telecommunications field. Furthermore, the selection of literature becomes important in AWG design. This means that the AWG designing are in accordance with the proportional standards and values of parameters are. In the AWG planning, the authors use Silica-doped with temperature effects valued at $+0.1nm/°$C. This research obtains the pattern of the temperature dependence of the bandwidth AWG. The effect is seen in the picture below.

Fig. 7 shows the effect of temperature on the port AWG. In the first, there are four wavelengths are transmitted, and multiplexed by the AWG. In the temperature 25°C AWG transmits first wavelength, or in this study formed the unit of frequency is 186.7 THz and that value is λ_c from AWG design. Increasing temperature make more wide bandwidth AWG, where every degree is $+0.1nm/°$C. Wide bandwidth AWG peaks located at 65 °C, where all four waves display passed with each unit of frequency values. However, at a temperature of 65°C wavelengths to four (λ_4) has a value lower than the three wavelengths.



	25˚C	30˚C	35˚C	40˚C	45˚C	50˚C	55˚C	60˚C	65˚C
187.6 THz	-2,1497791	-2,1375	-2,1212413	-2,128053	-2,1609734	-2,145097	-2,1795179	-2,1051178	-2,1870235
187.7 THz	-49,264793	-38,9575	-27,263568	-7,1819127	-3,7775801	-2,8041127	-2,4796587	-2,3277933	-2,2519386
187.8 THz	-100	-100	-100	-81,42473	-27,439285	-12,541531	-7,1188963	-4,879056	-3,6561707
187.9 THz	-100	-100	-100	-100	-100	-54,623884	-27,463626	-15,810909	-10,140957

Fig. 8. The influence of various power transmits.

B. Increasing performance of NG-PON2 System

The research on the NG-PON2 using configurable thermal AWG as a wavelength, plus DCF cable for reducing the effects of dispersion, has been done through standard parameters. Systems are calculated and simulated yet to get optimal value, in accordance with the standard Q-factor optical fibre communication system . In this study, in section III has made the boundaries of parameter values. Some parameter values are considered to be converted are; power transmit (3-11 dBm).

From the Fig. 8, there was clearly an increase in quality results after power had been enhanced. There is a saturation value at the increased power, which is at 9 dBm. Values above 9 dBm power, released the results of the Q-factor of relatively equal and practically stagnant. Thus, based on the empirical method optimisation, it was determined that the value of power transmit is 9 dBm. However, the results of this characterised is not ideal, because the bit rate of 10 Gbps is below standard Q-factor, then the authors suggestion when ISP / internet providers will provide a bit rate of 10 Gbps, do not use the system AWG. However, the conventional system using TDM. This study is much lower in power usage about 10% , rather than planning workshop NG-PON2 ITU-T/IEEE [22]. In addition, compared to paper [17], this study has a lower 25%

Fig. 9 depicts a comparison that is achieved from each study were almost the same. Research workshop IEEE / ITU-T initiated for NG-PON2 network of 10 dBm. Reference [17], using a modulation method DML get 12 dBm value of power transmit. However, this study get value lower transmit power with EML modulation by 9 dBm. This research can be superior because of some differences in the factors of previous studies. The minimum transmit power is transmitted by the transmitter is affected by the absence of superposition in the LC representation caused by Mach Zechnder. In addition, non-linear effects on multi channels like Xross Phase Modulation helps improve after passing MUX-AWG, although one wavelength into power drops. But it can be ignored because emittance 9 dBm still get the value of the Q-factor above 6.

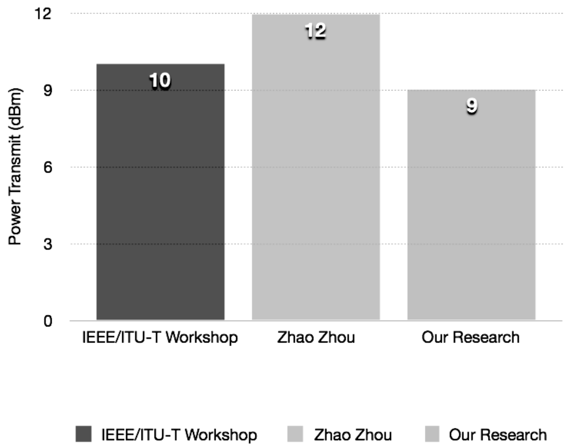


Fig. 9. Power Transmit Comparison.

Fig. 10 shows the stability of the AWG output obtained at a temperature of 100. Although some literature mentions limit of 65°C, but this study could be a picture, that the calculations are carried out up to 100°C, could make the AWG has a value of optimal power output. In addition, researchers also tried AWG output temperatures up to 200°C shown in the attachment. In the resulting data, the value of saturation in the AWG is on 140°C.

V. Conclusion

This paper has presented that the AWG structure influence NG-PON2 applied to the system could make the technology more adaptive. Four wavelengths transmitted with the Q-factor results 5.71. This system can be applied but not suitable for a single wavelength. The power transmit 9 dBm is used for this paper and has a power consumption 10% lower than the IEEE / Workshop. In addition, when compared to the DML modulation, this paper uses 25% less power. This paper consist from several methods are combined into one unified system, comprehensively. In this research, there is still a lot thing that can be developed and improved.

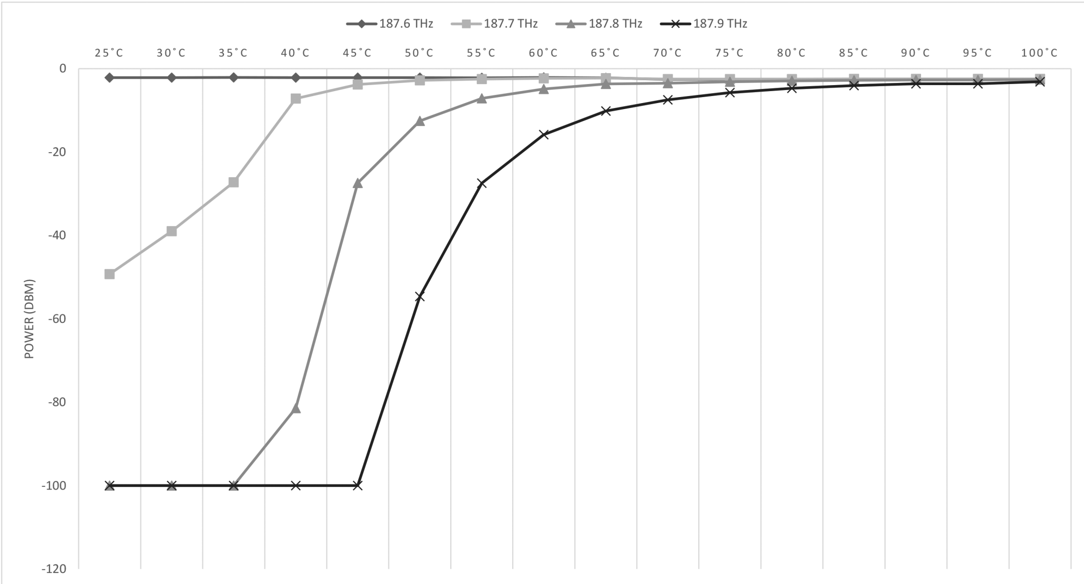


Fig. 10. The influence of various power transmits.

One of them analysed bi-directional with regard upstream parameters, both in terms of multiple access Time Division Multiple Access (TDMA) with buffer selector, as well as from the wavelength plan, and can be analysed in terms of the selection of transmitter receiver.

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Brian Pamukti received his BSc and MSc degrees in Telecommunication Engineering, from Telkom University in 2014 and 2016, respectively. His interests include Optical Communication Systems and Network Engineering.

Doan Perdana received his BSc and MSc degrees in Telecommunication Engineering, from the Institute of Technology Telkom in 2004 and 2012, respectively. He completed his PhD in Electrical Engineering Department, University of Indonesia. His interests include Telecommunication Systems and Computer Engineering.

Mukhammad Ramdlan Kirom received his BSc and MSc degrees in Physics, from Bandung Institute of Technology in 1997 and 2004, respectively. He is now a senior lecturer and head of Engineering Physics Study Program of Telkom University in Bandung, Indonesia. His current research are in area of optical filter model, expecially fibre Bragg Grating, heat flow modelling, and Biomass energy.