Chapter 3

Performance Analysis of Applying EDWA to a Dense Wavelength Division Multiplexer Network

In this chapter, we integrated multi-channel multi-wavelength light source into our Nx1 MUX, EDWA, and 1xN DEMUX systems. Section 3-1 we introduce the basis of arrayed waveguide grating (AWG). Section 3-2 introduces of EDWA and AWG DEMUX. Section 3-3 is introduces the noise figure. Section 3-4 is describes the performance of the simulation result of the opti-system that integrated the function of WDM element and optical amplifier. All such items are summarized in section 3-5 .

3-1 Introduction of the Basics of Arrayed Waveguide Grating

Recently, the device developments of the WDM components and systems for optical communications are rapidly increased [61]. The WDM technique provides benefits for increasing capacity and network design flexibility in the telecommunication networks. The arrayed waveguide grating (AWG) technologies have attracted lots of attentions recently [62-63]. AWG multiplexes / demultiplexes [64-65] with low insertion loss and high stability are the most promising devices for application consideration in WDM backplane interconnection systems. Especially, AWGs are important building blocks in the development of multiple channel integrated devices for routing and channel add-drop in dense wavelength division multiplexing (DWDM) interconnection systems [66-68]. The demand of bandwidth in optical interconnections is rapidly increasing. Therefore, WDM components are becoming more important for solving capacity and flexibility problems in the optical interconnection network. The wavelength multiplexers and demultiplexers are key components of WDM systems. As well as performing basic multiplexing and demultiplexing functions, they can be combined with other components to create add/drop multiplexers. These devices can be passive, where the signal routing is fixed according to wavelength, or active, where optical switches are utilised to dynamically route the signals. Both circuits shown are transparent to the data format, can allow bidirectional transfer of information, and function entirely in the optical domain. Many principles have been proposed and reported. Before research on (de)multiplexers have been increasing focus on AWG, they were known under different names: Dragone-Smit router, Phased Arrays (PHASARs) [69-73], Waveguide Grating Router (WGRs) and AWGs. The AWG plays a crucial role in the realization of modern optical networks. The AWG will be presented about introducing the principles of operation of the AWG, and then examines the design process in the following sections. Multi-port by multi-port AWG may look like a conventional one port by multi-port AWG-based (de)multiplexers where the input and output ports has been increased. The N by N AWG is capable of processing multi-port by multi-port optical interconnection in a strictly nonblocking way due to the cyclic rotation property of the output wavelength. The development of optical and optoelectronic devices in silicon-on-insulator (SOI) [74-77] offers a path toward low-cost, monolithic multi-wavelength optical receiver system including the wavelength demultiplexer, photodetectors, and electronic circuits. As shown in Fig. 3-1, we can see the schematic diagram of Wavelength Division Multiplexer (WDM) system.

3-2 Introduction of Integrated EDWA and AWG DEMUX

Wavelength-division-multiplexed (WDM) passive optical networks (PON's) offer the potential of large capacity, network security, and upgradability [78]. The simplest application of EDWA technology is a single amplifier including passive functions such as input and output tap couplers, pump/signal multiplexer, and pump kill filter on a single chip. Both single channel and DWDM amplifiers for metro and pre-amplifier applications have been demonstrated [79, 80]. However, pushed by the price pressure from low cost EDFAs, this mainly has niche applications, such as integrated pre-amplifiers in receivers, in which the reduced form factor is a decisive competitive factor. The next step will be the integration of EDWAs with other passive components. Fig. 3-2 show the combination of a DWDM EDWA preamplifier with a N-channel AWG demultiplexer. The EDWA and AWG devices were realized on separate chips, but with fully compatible (Er-doped respectively undoped) manufacturing processes, allowing for monolithic integration. The EDWA/DEMUX represents a very cost-effective way of enhancing DWDM receiver sensitivity, since the monolithic addition of an EDWA to the AWG DEMUX implies virtually no extra pigtailing and packaging cost (apart from the cost of a discrete pump laser and an isolator). For this type of integration, PECVD processed silica-on-silicon PLCs have the advantage of allowing the very high process uniformity required to make state-of-the-art AWGs. As integrated optics evolves from single-functionality chips (splitter, AWGs etc.) towards multifunctional subsystems-on-a-chip (Variable Multiplexer (VMUX), Reconfigurable Optical Add-Drop Multiplexer (ROADM) etc.), the EDWA will become a key building block for amplifying and controlling signal power levels. Control may be obtained by adjusting the pump power to the EDWA to achieve the desired output signal power. Compared to the classical scheme of adjusting signal powers by Variable Optical Attenuators (VOA), the “Variable Optical Amplifier” has the advantage of an improved power budget and improved system signal to-noise ratio, because channel powers are equalized by being raised to a common high level instead of being decreased to a common low level. An example of such an application is the monolithically integrated 4- or 8-port EDWA array demonstrated by several commercial companies. The purpose of this device is to provide individual amplifier control in applications with a single-channel or a band of channels passing through each amplifier. Applications include preamplifier arrays and dynamic gain equalization at wavelength switching nodes such as ROADMs. The desire to standardize such a compact amplifier array module has led to the formulation of a Multi Source Agreement (MSA) for EDWA Arrays [81]. An interesting combination of individual channel gain control and multiplexing is the integration of colorless AWGs (typically 4-8 channels) with equivalent port count EDWA arrays for individual channel power control and a high combined output power. With 10 dBm output power from each amplifier and approximately 3 dB MUX and output pigtailing loss, an aggregate output line power of 16 dBm will be obtainable for an 8-channel colorless EDWA/MUX. This is comparable to in-line EDFAs, but with the full channel control of a Dynamic Gain Equalizer (DGE).

3-3 Noise From Optical Amplification

Because of optical amplification accompanies spontaneous emission, noise is increased when a light signal passes through an amplifier. As mentioned in Equation (2-31), this noise is called the amplified spontaneous emission (ASE) noise because it is also amplified. So this section shows the power spectral density of the ASE noise and quantifies its effect on SNR reduction using the noise figure. When the light signal is transformed to photocurrent from photodetection, there are noise terms due to ASE noise and its interaction with the signal. This section explains the various noise terms and use the noise figure (NF) to quantify their total effect. From the expression of Equation (2-31), G is the amplifier gain, hf is the photon energy, and from Equation (2-32), the population inversion factor is a parameter describing how complete the external pumping is that depletes the ground population. When a large population inversion is achieved, such as semiconductor amplifiers, n_{sp} is close 1. On the other hand, it is a parameter higher than 1 [82].

For clarity, first consider the case that the light signal is directly by a photodiode. If the incident power to the amplifier is P_{in} and the amplifier has a gain G, the output power is

$$P_{out} = P_{in} G \tag{3-1}$$

Therefore, the photocurrent is

$$I_{ph} = RP_{out} = RP_{in}G \tag{3-2}$$

Besides shot noise from photodetection, it was first shown by Olsson [83] that there are noise terms due to ASE noise. Specifically, the total noise power at the photodiode output is

$$\sigma_n^2 = \sigma_{th}^2 + \sigma_{shot}^2 + \sigma_{sig=ASE}^2 + \sigma_{ASE=ASE}^2 \tag{3-3}$$

σ_{th}^2 is the thermal noise power, σ_{shot}^2 is the shot noise power, $\sigma_{sig=ASE}^2$ is the signal-ASE beat noise power due to signal and ASE noise interaction, and $\sigma_{ASE=ASE}^2$ is the noise power due to ASE alone. They can be expressed by

$$\sigma_{shot}^2 = 2qR(P_{in}G + S_{ASE}B_{opt})B \tag{3-4}$$

$$\sigma_{sig=ASE}^2 = 4(RGP_{in})(RS_{ASE}B) \tag{3-5}$$

$$\sigma_{ASE=ASE}^2 = R^2 S_{ASE}^2 (2B_{opt} - B)B \tag{3-6}$$

In the above equation, R is the photodiode responsivity, B is the front-end amplifier bandwidth, and B_{opt} is the optical bandwidth of the optical amplifier. Among the above noise sources, the beat noise $\sigma^2_{sig=ASE}$ in general is the most important term. This can be understood as follows. First, thermal noise can be generally neglected when the amplifier gain is large enough. Also, because GP_{in} is, in general, much larger than the ASE noise power, $S_{ASE}B_{OPT}$, $\sigma^2_{ASE=ASE}$ can be dropped when it is compared to the beat noise, $\sigma^2_{sig=ASE}$. Finally, because $R=(\eta q)/(hf)$, where η is the quantum efficiency of the photodiode,

$$RS_{ASE} = \eta q n_{sp} \chi (G-1) >> q \quad \text{when G is large} \tag{3-7}$$

Therefore, the first term of shot noise given by Equation (3-4) is much smaller than the beat noise given by Equation (3-5). From the above discussion, the signal-to-noise ratio at the photodetector output is nearly

$$SNR \approx \frac{I^2_{ph}}{\sigma^2_{sig=ASE}} = \frac{P_{in}}{4hfn_{sp}\chi B} = \frac{N_b}{4n_{sp}\chi} \tag{3-8}$$

where

$$N_b = \frac{P_{in}}{hfB} \tag{3-9}$$

is the number of photons per bit. Equation (3-8) gives the attainable upper limit of the SNR. Therefore, in order to get a good SNR at the photodetection output, the light signal must be amplified before P_{in} becomes too weak. For a given SNR required, from Equation (3-8), the incident light power is required to be

$$P_{in} > 4hfBn_{sp}\chi SBR \quad \text{or} \quad N_b > 4n_{sp}\chi SNR \tag{3-10}$$

From Equation (3-8), the noise figure as the ratio of SNR_{ref} to SNR can be computed, where SNR_{ref} is the SNR when only shot noise is considered. That is,

$$SNR_{ref} = \frac{RP_{in}}{2qB} \tag{3-11}$$

Therefore, the noise figure (NF) is

$$NF = \frac{SNR_{ref}}{SNR} = 2\eta n_{sp}\chi \tag{3-12}$$

Only when G>>1 or when other noise components such as σ_{th}^2 can be ignored, is the NF given above a true value. If this is not the case, the NF will be much higher.

When $\eta n_{sp}\chi$ =1, equation (3-12) shows that the NF of an optical amplifier is 3dB. When $\eta n_{sp}\chi$ >1 because of incomplete pumping or nonuniform carrier density distribution, the NF is worse. To reduce the NF, a higher pumping power can be used to reduce the value of $\eta n_{sp} \chi$.

3-4 Performance Analysis of the Nx1 MUX, EDWA, and 1xN DEMUX applying on DWDM optical network

In this section, we integrated the multi-channel multi-wavelength light source into our Nx1 MUX, Erbium-Doped Waveguide Amplifier, and 1xN DEMUX systems. In our system, we combined the 64 CW laser array, Nx1 MUX, EDWA, 1XN DEMUX, and Optical Spectrum Analyzer (OSA) is shown in Fig. 3-2. Fig. 3-3 shows the Schematic view of integrated EDWA and AWG DEMUX. we used the opti-system software to simulate the net gain and noise figure of 8, 16, 32, and 64 port DWDM systems. Launching 8, 16, 32, and 64 wavelengths light source as carries into 8, 16, 32, and 64 input port of Nx1 MUX, the pump power of 980nm pump laser with 100mW, 200mW, 300mW, and 400mW, respectively. The light source maximum average power is set at –30dBm. We use EDWA to amplify the optical communication light source. In section 3-4-1, we will consider the net gain and noise figure of 1x8, 8x1 MUX DEMUX and Er^{3+} waveguide amplifier for 100mW, 200mW, 300mW, and 400mW pump power, respectively. In section 3-4-2, we will also consider the net gain and noise figure of 1x16, 16x1 MUX DEMUX and Er^{3+} waveguide amplifier for 100mW, 200mW, 300mW, and 400mW pump power, respectively. In section 3-4-3, we will also consider the net gain and noise figure of 1x32, 32x1 MUX DEMUX and Er^{3+} waveguide amplifier for 100mW, 200mW, 300mW, and 400mW pump power, respectively. In section 3-4-4, we will also consider the net gain and noise figure of 1x64, 64x1 MUX DEMUX and Er^{3+} waveguide amplifier for 100mW, 200mW, 300mW, and 400mW pump power, respectively. The dose of Er^{3+} is assumed to be $3x10^{14}$ Er/cm^2.

3-4-1 Analysis of 8x1 MUX/1x8 DEMUX and EDWA

Fig. 3-2 shows the configuration of a 8x1 MUX, 1x8 DEMUX and Er^{3+} waveguide amplifier based on SOI waveguide. We would consider the performance of net gain and the noise figure with the wavelength from 1548nm to 1554nm.

The net gain of 1x8, 8x1 MUX, DEMUX and Er^{3+} waveguide amplifier based under various pump power is simulated by opti-system software. As shown in Fig. 3-3, the diagrams represent the relationship between gain and wavelength when the insertion loss of the waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. We can find in these four figures the maximum net gain are 0.89 dB(1554.13nm), 2.32 dB(1548.51nm), 3.1dB (1548.51nm), 3.59dB (1548.51nm), respectively. The minimum net gain are 0.81 dB(1548.51nm), 2.2472782 dB(1554.13nm), 2.9493686(1554.13nm) and 3.3888134 dB (1554.13nm), respectively. As shown in Fig. 3-4, the diagram portrays the relationship between noise figure and wavelength when the insertion loss of Erbium-doped waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. The maximum noise figure are 4.5104 dB(1548.51nm), 4.14748 dB(1548.51nm), 3.97813 dB(1548.51nm), 3.87749 dB (1548.51nm), respectively. The minimum noise figure are 4.30586 dB(1554.13nm), 4.01619 dB(1554.13nm), 3.8794 dB(1554.13nm) and 3.79751 dB(1554.13nm), respectively. Although the results of simulating by Opti-system software has largest net gain as pump power at 400mW. But when we consider the flatness of gain and noise figure, we find that the maximum gain flatness is 0.20 (dB) when pump power at 400mW, the minimum gain flatness is 0.07 (dB) when pump power at 200mW, the maximum noise figure flatness is 0.20 (dB) when pump power at 100mW, and the minimum noise flatness is 0.07 (dB) when pump power at 400mW.

3-4-2 Analysis of 16x1 MUX/1x16 DEMUX and EDWA

Fig. 3-2 shows the configuration of a 16x1 MUX, 16x1 DEMUX and Er^{3+} waveguide amplifier based on SOI waveguide. We would consider the performance of net gain and the noise figure with the wavelength within 1547nm to 1553nm.

The net gain of 1x16, 16x1 MUX DEMUX and Er^{3+} waveguide amplifier based under various pump power is simulated by opti-system software. As shown in Fig. 3-5, the diagrams represent the relationship between gain and wavelength when the insertion loss of the waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. We can find in these four figures the maximum net gains are 0.5565207 dB(1553.33nm), 1.8944544 dB (1548.91nm), 2.6956883 dB (1547.32nm), and 3.2220974 dB (1547.32nm), respectively. The minimum net gain are 0.41971314 (1547.32nm), 1.8611999 dB(1553.33nm) , 2.581452 dB (1553.33nm) and 3.0498697 dB(1553.33nm), respectively. As shown in Fig. 3-6, the diagrams are represented the relationship between noise figure and wavelength when the insertion loss of Erbium-doped waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. the maximum noise figure are 4.66124 dB (1547.32nm), 4.2829 dB (1547.32nm), 4.10174 dB (1547.72nm), and 3.99057 dB (1547.72nm), respectively. The minimum noise figure are 4.42546 dB(1553.33nm), 4.12534 dB (1552.93nm), 3.97434 dB (1552.93nm) and 3.88072 dB (1552.93nm), respectively. Although the results of simulating by Opti-system software yields the largest net gain with pump power at 400mW. But when we consider the flatness of gain and noise figure, we can find the maximum gain flatness is 0.17 (dB) when pump power at 400mW, the minimum gain flatness is 0.03 (dB) when pump power at 200mW, the maximum noise figure flatness is 0.235 (dB) when pump power at 100mW, and the minimum noise flatness is 0.109 (dB) when pump power at 400mW

3-4-3 Analysis of 32x1 MUX/1x32 DEMUX and EDWA

As shown in Fig. 3-2, the configuration of a 32x1 MUX, 1x32 DEMUX and Er^{3+} waveguide amplifier based on SOI waveguide. We would consider the performance of net gain and the noise figure with the wavelength from 1538nm to 1563nm.

The net gain of 1x32, 32x1 MUX DEMUX and Er^{3+} waveguide amplifier based under various pump power is simulated by opti-system software. As shown in Fig. 3-7, the diagrams represent the relationship between gain and wavelength when the insertion loss of the waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. We can find in these four figures, the maximum net gain are 0.24700275 dB (1558.98 nm), 1.3490968 dB (1554.94nm), 2.1059989 dB (1546.92 nm), and 2.6542471 dB (1546.92 nm), respectively. The minimum net gain are -0.50559763 dB (1538.19nm), 1.0417356 dB (1563.05nm), 1.5781108 dB (1563.05nm), and 1.9442417 dB (1563.05nm), respectively. As shown in Fig. 3-8, the diagrams are represented the relationship between noise figure and wavelength when the insertion loss of Erbium-doped waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. The maximum noise figures are 5.32849 dB (1538.19nm), 4.83152 dB (1538.19nm), 4.57299 dB (1538.19nm), and 4.40917 dB (1538.19nm), respectively. The minimum noise figures are 4.14895 dB(1562.23nm), 3.99473 dB (1562.23nm), 3.86315 dB (1563.05nm) and 3.81343 dB (1563.05nm), respectively. Although the results of simulating by Opti-system software has the largest net gain as pump power at 400mW. But when we consider the flatness of gain and noise figure, we can find the maximum gain flatness is 0.752 (dB) when pump power at 100mW, the minimum gain flatness is 0.307 (dB) when pump power at 200mW, the maximum noise figure flatness is 1.179 (dB) when pump power at 100mW, and the minimum noise flatness is 0.595 (dB) when pump power at 400mW

3-4-4 Analysis of 64x1 MUX/1x64 DEMUX and EDWA

As shown in Fig. 3-9, we can see the schematic diagram of the integrated 64×1 MUX, EDWA, and 1X64 DEMUX. We would consider the performance of net gain and the noise figure with the wavelength from 1537nm to 1563nm.

The net gain of 1x64, 64x1 MUX DEMUX and Er^{3+} waveguide amplifier based under various pump power is simulated by opti-system software. As shown in Fig. 3-10, the diagrams represent the relationship between gain and wavelength when the insertion loss of the waveguide is set at 3dB for 100mW, 200mW, 300mW, and 400mW of pump power, respectively. We can find in these four figures that the respective maximum net gain are -0.15969588 dB (1560.61nm), 0.73560414 dB (1556.96nm), 1.3525746 dB (1554.54nm), and 1.8382285 dB (1546.92nm). The minimum net gains are -1.1411501 dB (1537.79nm), 0.19390254 dB (1537.79nm), 1.038398 dB (1539.37nm)and 1.3997096 dB (1563.05nm), respectively. As shown in Fig. 3-11, the diagrams represent the relationship between noise figure and wavelength when the insertion loss of erbium doped waveguide is set 3dB for 100mW, 200mW, 300mW, and 400mW pump power, respectively. The maximum noise figures are 5.5847 dB (1537.79nm), 5.10555(1537.79nm), 4.85821 dB (1538.58nm), and 4.6941 dB (1538.58nm), respectively. The minimum noise figures are 4.15223 dB (1563.05nm), 4.02009 dB (1563.05nm), 3.94421 dB (1563.05nm) and 3.89285 dB (1563.05nm), respectively. Although the results of simulating by Opti-system software has largest net gain as pump power at 400mW.

But when we consider the flatness of gain and noise figure, we can find the maximum gain flatness is 0.981 (dB) when pump power at 100mW, the minimum gain flatness is 0.314 (dB) when pump power at 300mW, the maximum noise figure flatness is 1.432 (dB) when pump power at 100mW, and the minimum noise flatness is 0.801 (dB) when pump power at 400mW

3-5 Summary

In this chapter, we report that EDWA for applying the Dense Wavelength Division Multiplexed (DWDM) optical transport systems. The communication system includes a multi-port tunable laser array, EDWA, 1xN AWG demux and Optical Spectrum Analyzer (OSA). We use the Opti-system software and matlab software to simulate and calculate the DWDM system, respectively. We analyze the net gain and noise figure for four kinds of MUX EDWA/AWG DEMUX systems. We compare the performance of these four Erbium-doped optical WDM elements based on Silicon On Insulator (SOI) wafer. Although the net gain of 64 port DWDM system is smaller than 8 port optical network systems but the wavelength range of sixty-four is more than eight. If we consider the flatness of gain and noise figure, we can choose the best case from Section 3-4. They are 300mW at 3-4-1, 300mW at 3-4-2, 200mW at 3-4-3, and 300mW at 3-4-4, respectively. Table II and Table III compare these four systems.

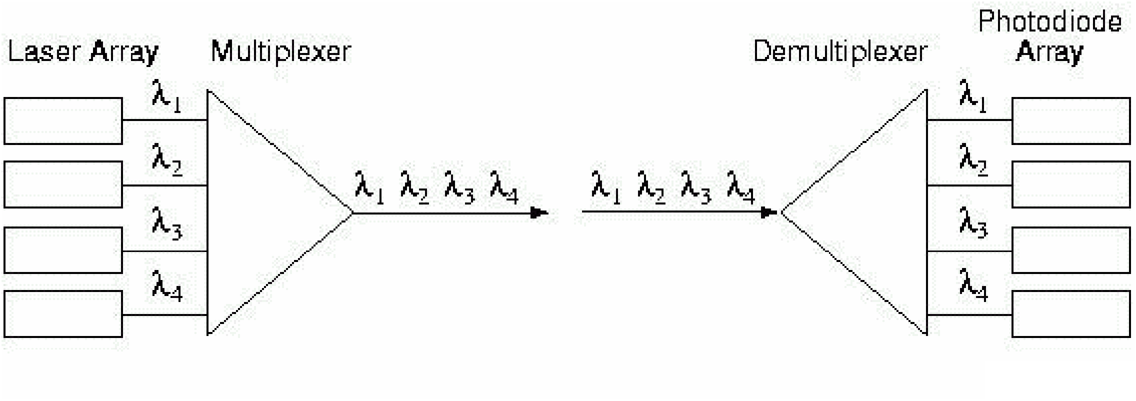

Fig. 3-1 Schematic diagram of Wavelength Division Multiplexer (WDM)

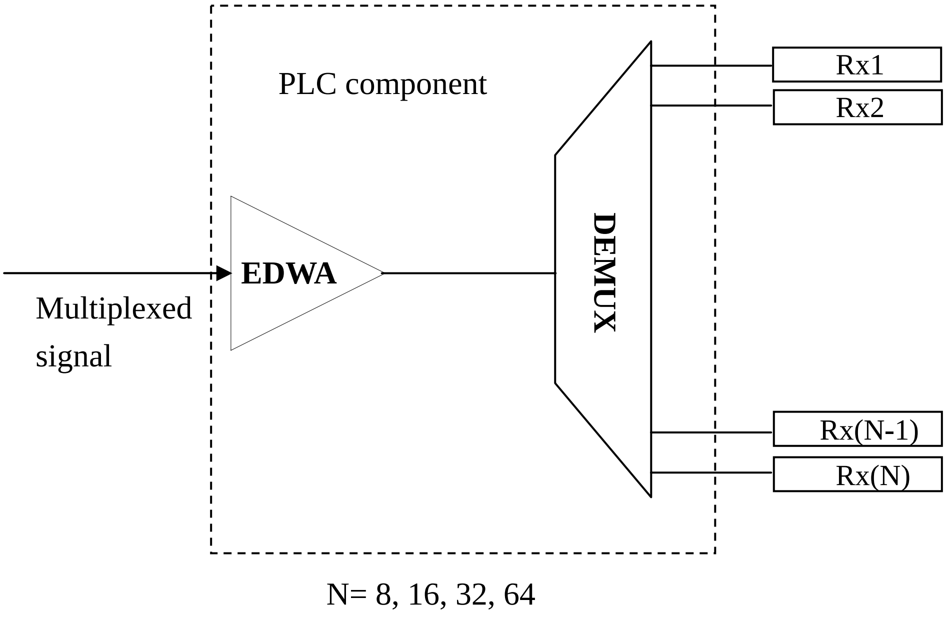

Fig. 3-2 Schematic view of integrated EDWA and AWG DEMUX

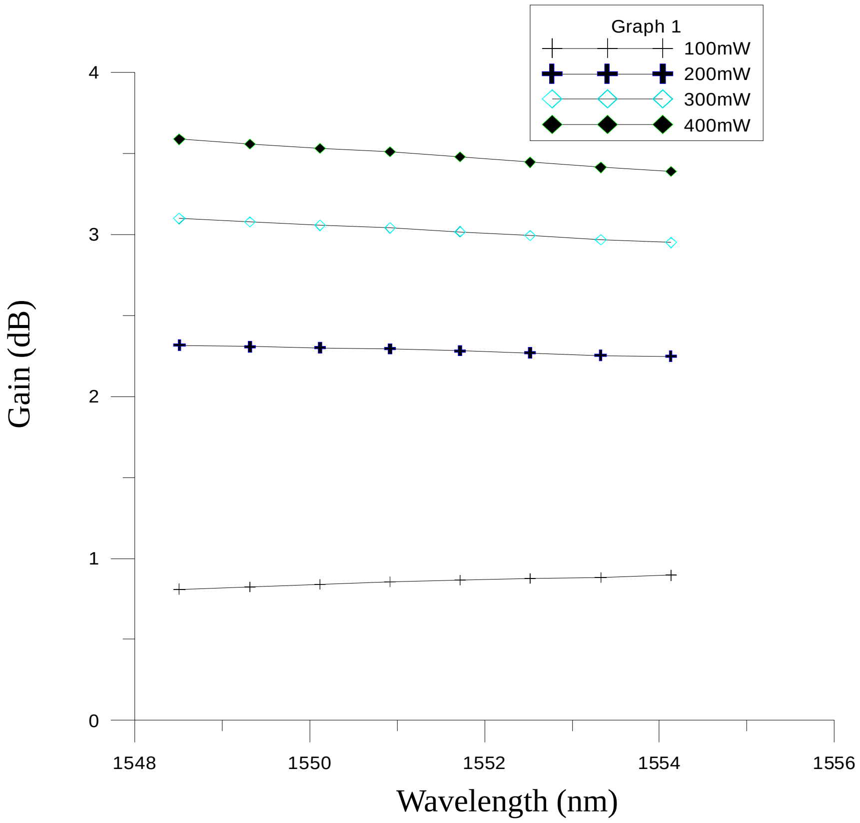

Fig. 3-3 Simulation result of Gain and Wavelength of 8x1 MUX, EDWA, 1x8 DEMUX

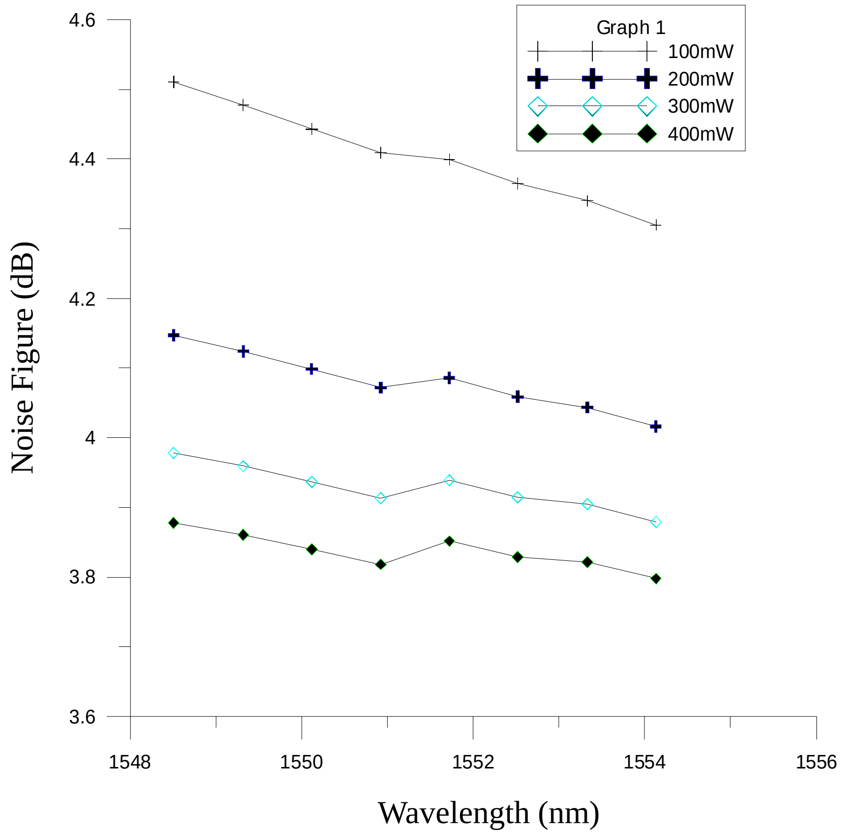

Fig. 3-4 Simulation result of Noise figure and Wavelength of 8x1 MUX, EDWA, 1x8 DEMUX

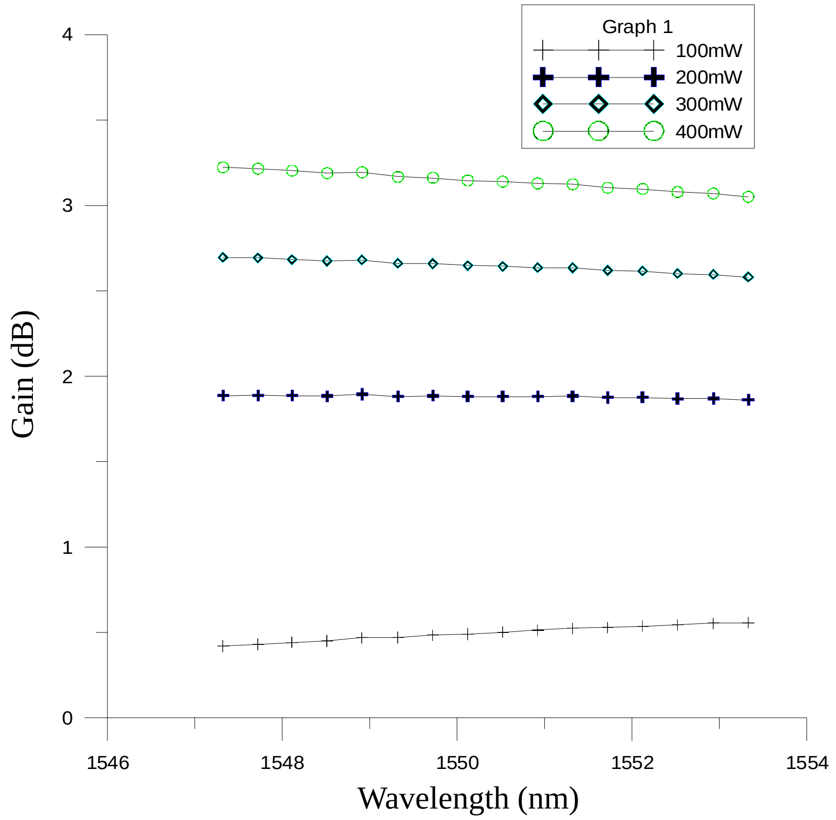

Fig. 3-5 Simulation result of Gain and Wavelength of 16x1 MUX, EDWA, 1x16 DEMUX

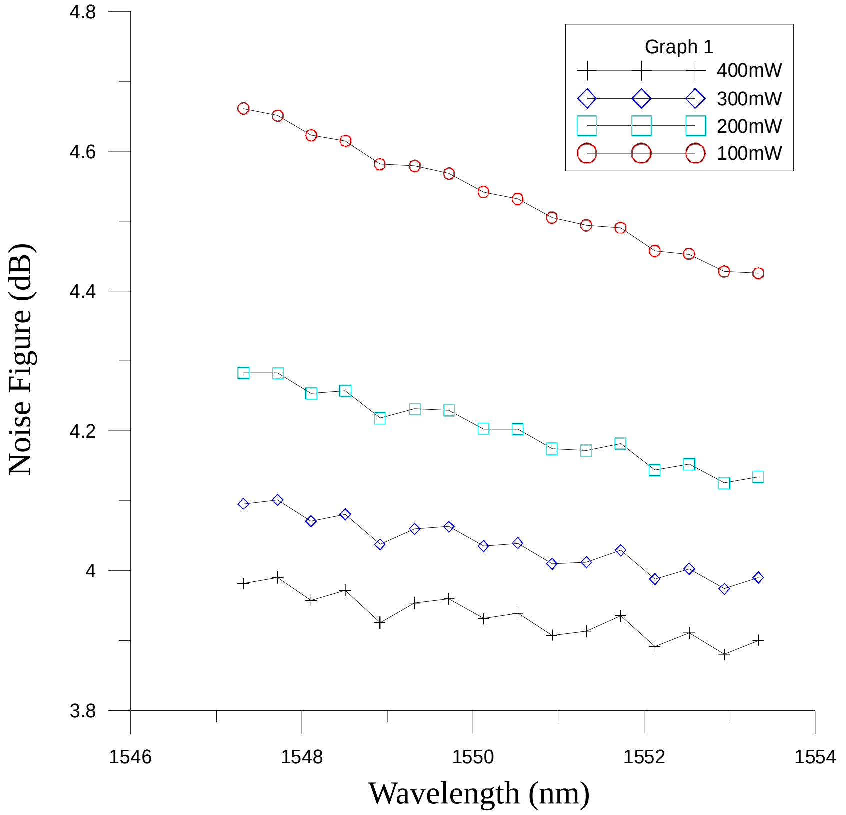

Fig. 3-6 Simulation result of Noise figure and Wavelength of 16x1 MUX, EDWA, 1x16 DEMUX

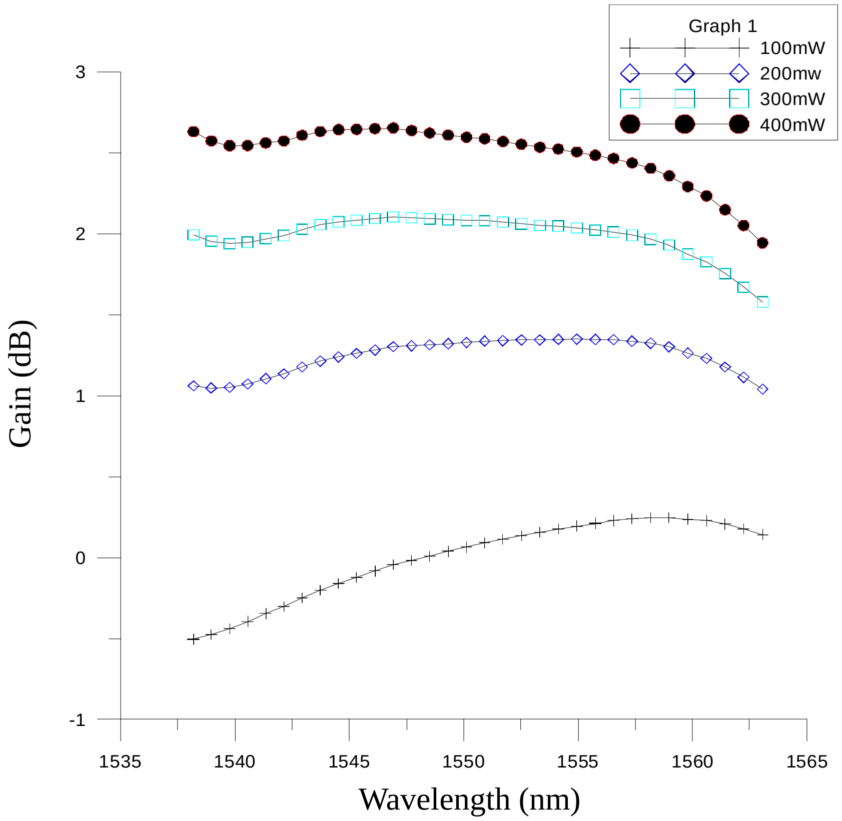

Fig. 3-7 Simulation result of Gain and Wavelength of 32x1 MUX, EDWA, 1x32 DEMUX

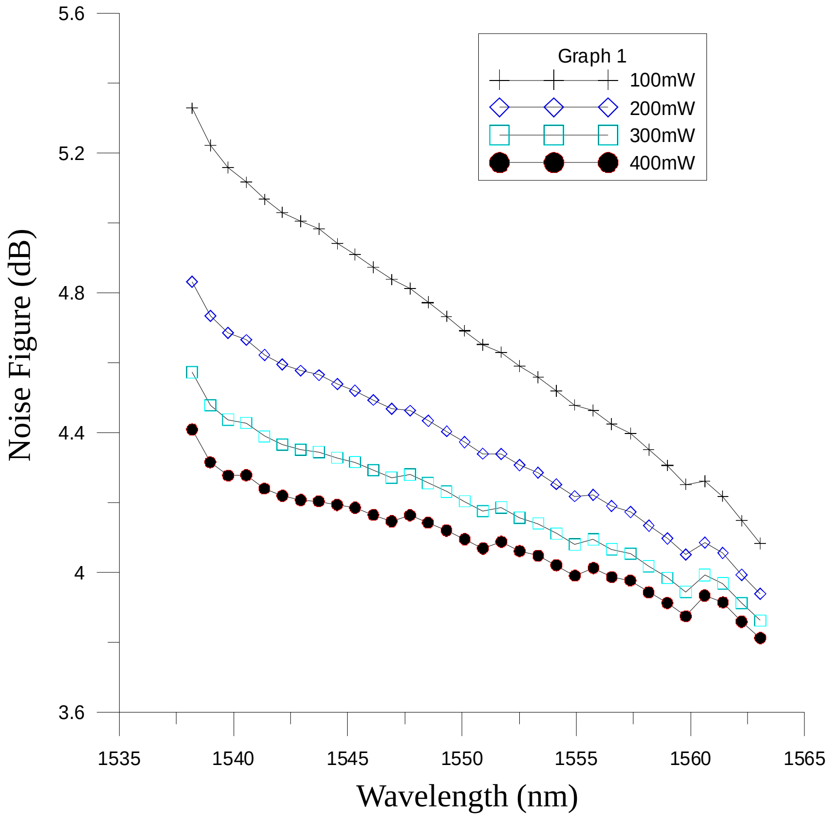

Fig. 3-8 Simulation result of Noise figure and Wavelength of 32x1 MUX, EDWA, 1x32 DEMUX

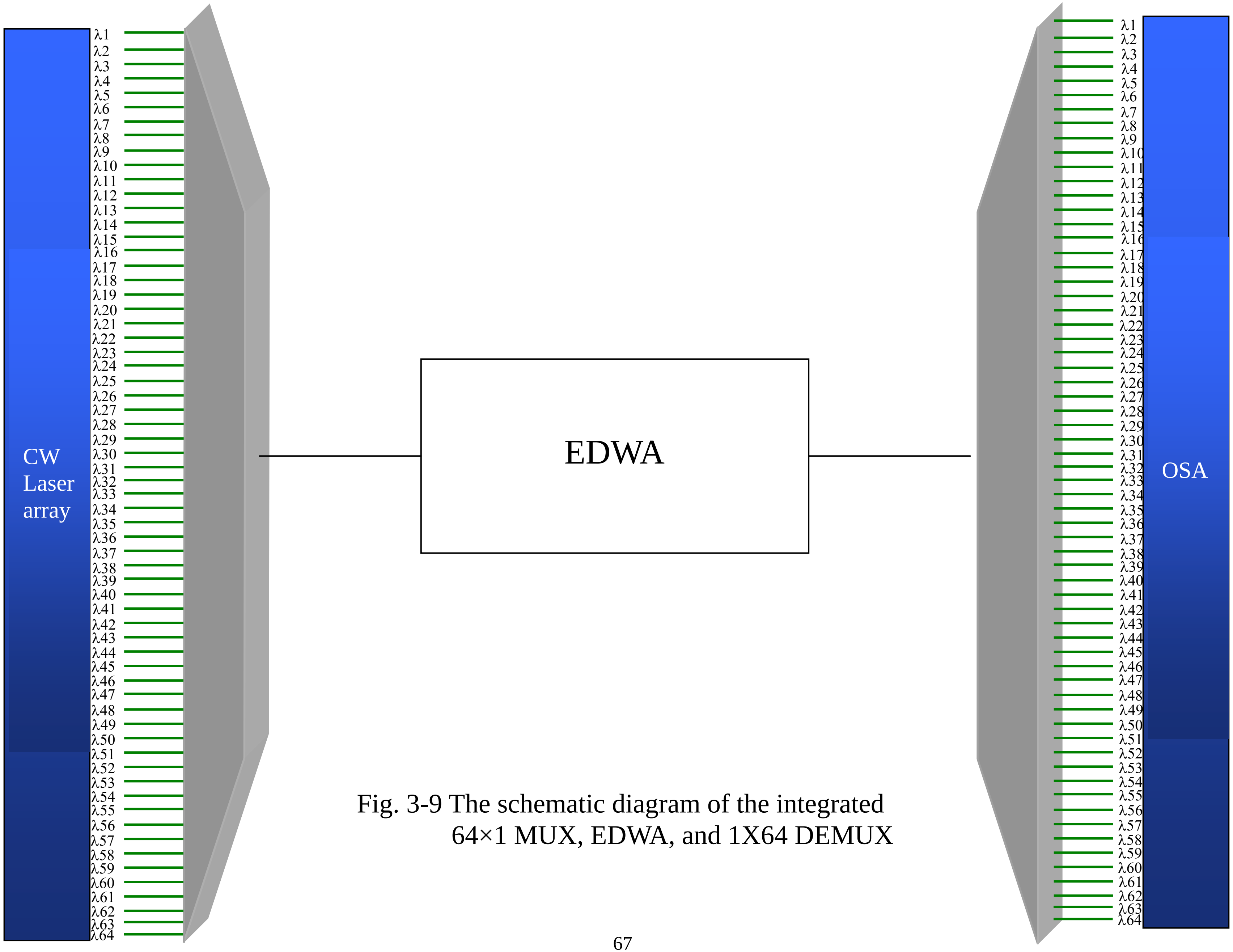

Fig. 3-9 The schematic diagram of the integrated 64×1 MUX, EDWA, and 1X64 DEMUX

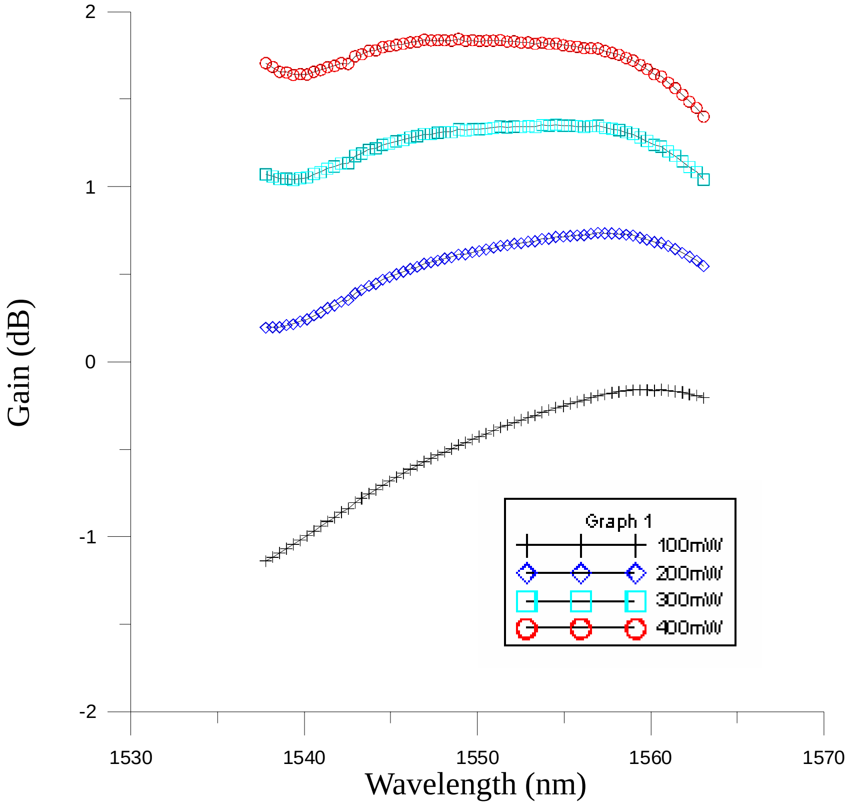

Fig. 3-10 Simulation result of Gain and Wavelength of 64x1 MUX, EDWA, 1x64 DEMUX

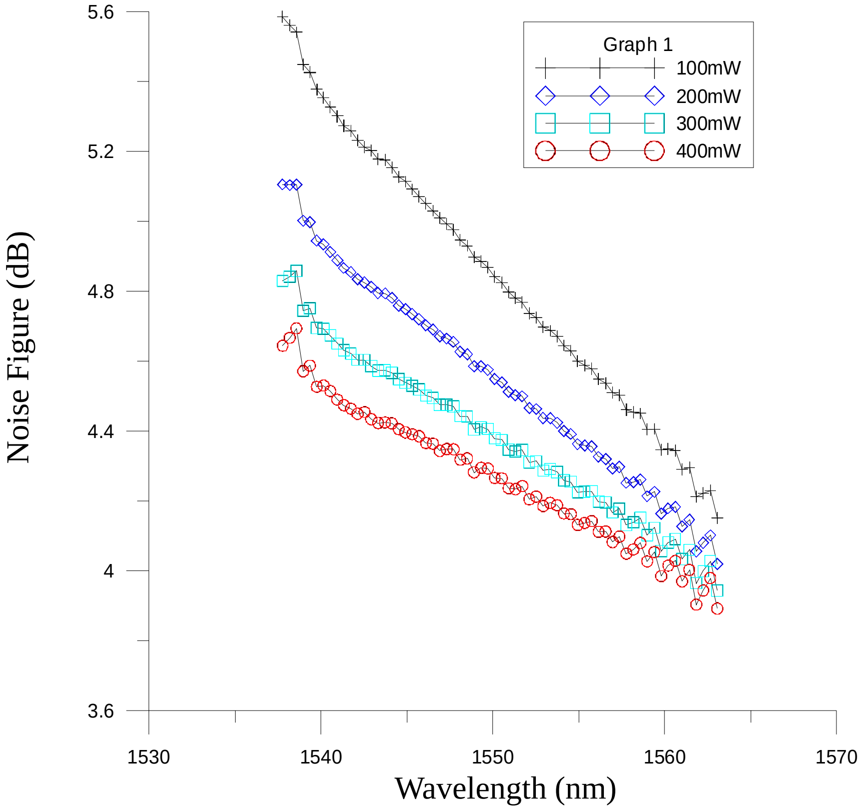

Fig. 3-11 Simulation result of Noise figure and Wavelength of 64x1 MUX, EDWA, 1x64 DEMUX

Table II Comparison of maximum gain and noise figure of four kinds of Nx1 MUX, 1xN DEMUX and Er^{3+} waveguide amplifier.

Input signal	Structure	Pump power	Maximum net gain(dB)	Maximum Noise figure(dB)
-30dBm	1x8 MUX,8x1 DEMUX	100mW	0.89572987 (dB)	4.5104 (dB)
		200mW	2.3151788 (dB)	4.14748 (dB)
		300mW	3.0968664 (dB)	3.97813 (dB)
		400mW	3.5860905 (dB)	3.87749 (dB)
-30dBm	1x16 MUX,16x1 DEMUX	100mW	0.5565207 (dB)	4.66124 (dB)
		200mW	1.8944544 (dB)	4.2829 (dB)
		300mW	2.6956883 (dB)	4.10174 (dB)
		400mW	3.2220974 (dB)	3.99057 (dB)
-30dBm	1x32 MUX,32x1 DEMUX	100mW	0.24700275 (dB)	5.32849 (dB)
		200mW	1.3490968 (dB)	4.83152 (dB)
		300mW	2.1059989 (dB)	4.57299 (dB)
		400mW	2.6542471 (dB)	4.40917 (dB)
-30dBm	1x64 MUX,64x1 DEMUX	100mW	-0.15969588 (dB)	5.5847 (dB)
		200mW	0.73560414 (dB)	5.10555 (dB)
		300mW	1.3525746 (dB)	4.85821 (dB)
		400mW	1.8382285 (dB)	4.6941 (dB)

Table III Comparison of the flatness of gain and noise figure of four kinds of Nx1 MUX, 1xN DEMUX and Er^{3+} waveguide amplifier.

Input signal	Structure	Pump power	Gain Flatness(dB)	Noise figure Flatness(dB)
-30dBm	1x8 MUX,8x1 DEMUX	100mW	0.08 (dB)	0.20454 (dB)
		200mW	0.0727222 (dB)	0.13129 (dB)
		300mW	0.1506314 (dB)	0.09873 (dB)
		400mW	0.2011866 (dB)	0.07998 (dB)
-30dBm	1x16 MUX,16x1 DEMUX	100mW	0.1368076 (dB)	0.23578 (dB)
		200mW	0.0332545 (dB)	0.15756 (dB)
		300mW	0.1142363 (dB)	0.1274 (dB)
		400mW	0.1722277 (dB)	0.10985 (dB)
-30dBm	1x32 MUX,32x1 DEMUX	100mW	0.75260038 (dB)	1.17954 (dB)
		200mW	0.3073603 (dB)	0.83679 (dB)
		300mW	0.5348909 (dB)	0.70984 (dB)
		400mW	0.7100054 (dB)	0.59574 (dB)
-30dBm	1x64 MUX,64x1 DEMUX	100mW	0.98145422 (dB)	1.43247 (dB)
		200mW	0.5417016 (dB)	1.08546 (dB)
		300mW	0.3141766 (dB)	0.914 (dB)
		400mW	0.4385189 (dB)	0.80125 (dB)