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# Crosstalk Reduction using Cascading Configuration in Multiplexer/Demultiplexer Based Array Waveguide Grating in Dense Wavelength Division Multiplexing

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**Abstract**– This article propose a cascaded connection of AWGs filters in multiplexers/demultiplexers by using the WDM\_Phasar simulation that results in total channel accumulated crosstalk reduction which allows for reasonable channel carrying capacity and hall communication in DWDM system. Obtaining the performance of AWGs filters before cascading and after cascading connections of different AWGs (8channels, 16 channels, 32channels, and 64channels) simulation designs. Selected different channels in different simulation design, obtained a comparison of crosstalk before and after cascading configuration.

**Index Terms**– Accumulated Crosstalk, Dens Wavelength Division Multiplexer, WDM\_Phasar, Array Waveguide Grating

## I. INTRODUCTION

RECENTLY, with rapid increase in demand for large optical transmission capacity, dense wavelength division multiplexing (DWDM) systems became an attractive for high-speed data transmission systems [1]. AWG is used as multiplexer/demultiplexer and its advantages are small size, high reliability, low cost, and high ports count [2].

AWGs can support a transmission capacity of 4Tbit/s at a bit rate of 10Gbit/s in single configuration with on-chip losses ranging from 3.8 to 6.4 dB and with far-end crosstalk reduced to -30dB [3]. The commercial interest in wavelength Division Multiplexing based on phased array is rapidly increasing, and so is the scientific research and interest in Array Waveguide Gratings (AWG).

The DWDM device design involves a large number of geometric and material parameters that can be manipulated in the design process as they are found to affect device performance. A phasar arrays (PHASAR) WDM simulation package is used to speed up the design process, and reduce the fabrication runs and device costs.

WDM-phasar is powerful advanced software for design and modeling Phased Array Grating devices. It provides a number of calculation tools to estimate the device performance before running advanced simulations and fabrication. It also automates index simulations, estimates quickly the bend loss

and crosstalk level, and performs an advanced simulation of the whole device using the beam propagation method (BPM).

Additionally WDM\_phasar monitors easily and effectively crosstalk level, bend losses, phasar order, dispersion, free spectral range, channel nonuniformity, channel spacing, output channel bandwidth, and diffraction loss. But it also performs other huge variety of important tasks like effective index calculation, design of a WDM device using the Wizard tool, editing of the WDM device geometry, fast evaluation of the WDM device performance, performing a parameter scan, and run advanced calculations [4].

## II. INDEX CALCULATION

The simulator takes care of calculating the effective index of the multilayer ridge waveguide which are necessary for creating a DWDM device. For the index calculation to be performed the following parameters about the ridge waveguide should be provided:

- 1: number of layers (typically 5)
- 2: for each layer in turn the following should be entered:
  - a: layer thickness in  $\mu\text{m}$
  - b: layer real and imaginary refractive index.
  - c: waveguide real and imaginary refractive index.

Table 1: Ridge parameters inserted values

Layer from bottom	Layer thickness $\mu\text{m}$	Layer refractive index	Waveguide refractive index
First	0.2	3.171	1.5
Second	0.55	3.393	3.393
Third	0.05	1	3.393
Fourth	0.3	1	3.171
Fifth	0.1	1	1.5

With these parameters entered the multilayer ridge waveguide will look like the following Fig. 1.



Fig. 1: The multilayer ridge waveguide

Calculating the effective index for the ridge waveguide still requires knowing the waveguide width, the wavelength, the number of points in mesh and the system polarization mode TE (transverse Electrical) or TM (transverse Magnetic) which play an extremely important part in determining the design capabilities of optic communications system [5]. The waveguide taken is as  $1.5\mu\text{m}$  for waveguide width,  $1.55\mu\text{m}$  for wavelength, 501 for number of points in mesh, and TM for polarization mode, resulted in Fig. 2.

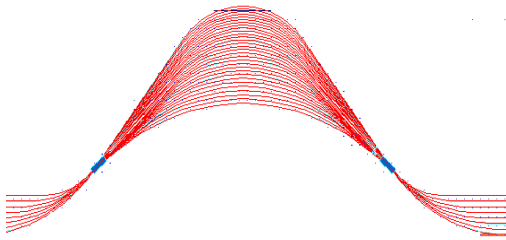


Fig. 2: WDM device design

### III. WDM DEVICE DESIGN AND SIMULATION

Using the multilayer ridge waveguide for design a WDM device it could be performed using the WDM-phasar design wizard. However to proceed with the design, the user has to provide the wizard tool with the following data for the mentioned parameters below:

1. Wafer propagation length ( $\mu\text{m}$ )	: 15000
2. Wafer width ( $\mu\text{m}$ )	: 10000
3. Wafer effective refraction index	: 3.270561
4. Wave length ( $\mu\text{m}$ )	: 1.55
5. Number of points per micron	: 20
6. Waveguide start width ( $\mu\text{m}$ )	: 1.5
7. Waveguide effective refractive index	: 3.3075939
8. Polarization	: TM
9. Maximum crosstalk level (dB)	: -35
10. Output channel mode ID	: single mode
11. Modal index	: 3.2936945

12. Input/output waveguide separation ( $\mu\text{m}$ )	: 4.2
13. Phased array waveguide separation ( $\mu\text{m}$ )	: 4.2
14. Nonuniformity (dB)	: 0.5
15. Output channel	: 8
16. Free propagation region effective index	: 3.3075939
17. Dispersion [ $\mu\text{m} / \text{Hz}$ ]	: 5.0
18. Array maximum transmission (dB)	: -0.2

The WDM geometrics and modal parameters that require for waveguide and wafer properties calculated are, crosstalk level, polarization, number of output channels and nonuniformity, array transmission and device dispersion.

Output waveguide modal index	: 3.2936945
Array waveguides modal index	: 3.2936945
Free propagation region minimum length ( $\mu\text{m}$ )	: 450.89131
Array waveguide length difference ( $\mu\text{m}$ )	: 89.883867
array waveguides number	: 30
Angular half width	: 0.13665928

### IV. WDM DEVICE AS A MUX/ DEMUX

The WDM device developed for more editing to make a MUX/DEMUX the editing adds an input section, an input coupler and its free propagation region, phase array input coupler, the phased array itself, and the output ports:

Input coupler radius ( $\mu\text{m}$ )	: 225.4465
Number of waveguide	: 8
Port separation ( $\mu\text{m}$ )	: 125
Waveguide effective index	: 3.3075939
Minimum waveguide separation ( $\mu\text{m}$ )	: 4.2
Waveguide length ( $\mu\text{m}$ )	: 250
Waveguide width ( $\mu\text{m}$ )	: 1.5

For the input coupler free propagation region the wizard tool needs:

Coupler length ( $\mu\text{m}$ )	: 450.89
Orientation angle (degree)	: 45
Angular width (degree)	: 17.67003

For the phase array input coupler the following is included:

Radius ( $\mu\text{m}$ )	: 450.89131
No. of waveguides	: 30

For the phase- array itself the following data is specified:

Waveguide effective index	: 3.3075939
No. Of waveguides	: 30
Waveguide width ( $\mu\text{m}$ )	: 1.5
Length increment ( $\mu\text{m}$ )	: 89.883867
Initial length increment ( $\mu\text{m}$ )	: 500

Lastly and for the output ports the following should be provided:

Waveguide effective index	: 3.3075939
Port separation ( $\mu\text{m}$ )	: 125

With all values of parameters entered the design of the device will be performed and an evaluation of the performance of device phased array section, its input array and its output array are respectively shown in Table 2, Table 3, and Table 4.

Table 2: Phased array section statistics

Path	Bend loss	Crosstalk (dB)
From path 1 to 30	0	-35.613698

Table 3: Input array section statistics

Path	Bend loss	Crosstalk (dB)
From path 1 to 7	0	-35.613698
Path No. 8	0	N.A

Table 4: Output array section statistics

Path	Bend loss	Crosstalk (dB)
From path 1 to 7	0	-35.613698
Path No. 8	0	N.A

### V. WAVELENGTH PARAMETER SCANNING

The WDM-Phasar provides through simulation a facility for calculating and displaying the device response in tabular and graphical form as a function of wavelength. In the simulation the wavelength is scanned (varied) in fixed steps through the critical range specified by the user the Table 5 shows that, and according to paraxial BPM. For that purpose the wizard tool is supplied with the following data assuming eight input and eight output ports:

- Parameter to be scanned : WL (wavelength)
- Parameter scanning range ( $\mu\text{m}$ ) : 1.547-1.553
- No. Of iterations (steps) : 121
- Polarization mode : TM
- Total No. Of input ports : 8
- BPM solver : Paraxial
- No. Of points per micron : 20
- Boundary condition : Simple TBC (transparent boundary condition).

Table 5: Parameter scanning range

No. of iterations (steps)	Wavelength (WL) in scanning range in ( $\mu\text{m}$ )
1	1.547
115	1.5527
116	1.55275
117	1.5528
118	1.55285
119	1.5529
120	1.55295
121	1.553

### VI. RUNNING ADVANCED SIMULATIONS

The device which is designed has eight input ports and the same number of output ports. This step is used to analyze the device working in a demultiplexing regime, by changing the number of input ports to 1.

At the end of this step, a device with one input port and eight output ports is obtained as shown at Fig. 3.

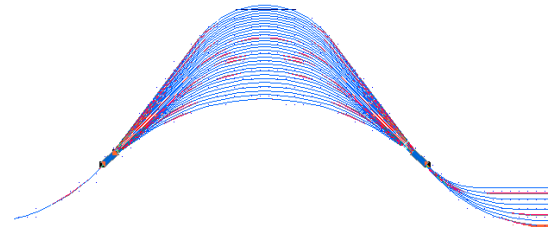


Fig. 3: AWG device with one input port and eight output ports

At the end of an eight channels simulation, the output power vs. the Scan Parameter is displayed graphically, Fig. 4 shows that.

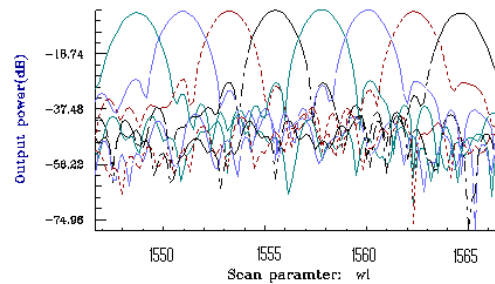


Fig. 4: The Scan Parameter vs. output power

The simulator also provides a list in Table 6 form for the device performance and statistics as shown below where individual channel amplitude, width and crosstalk are displayed [4].

Table 6: Device performance

channel	Amplitude	Channel spacing	Crosstalk in dB
1	-4.973324	0.000700	-29.216834
2	-4.417054	0.000700	-28.921708
3	-3.956224	0.000650	-29.114058
4	-3.731089	0.000700	-29.391477
5	-3.946152	0.000700	-29.673149
6	-4.162486	0.000650	-29.538424
7	-4.366012	0.000700	-28.502909
8	-4.874898	-	-28.024551

VII. WDM\_PHASAR SIMULATOR-BASED AWG UNITS DESIGN

Now that WDM\_Phasar simulator is used for designing an 8-channels, 16-channels, 32-channels, and 64-channels as WDM multiplexers/Demultiplexers. The simulation is run for each unit to obtain the crosstalk of each channel, before cascading. Then the simulation is run in cascading manner by activating the cascading tool for each unit, and after taking about twenty four hours the simulator provides the resulting crosstalk after cascading. Then channel crosstalk before and after cascading connection of the AWGs are compared. The comparison shows that cascading connection of AWGs, reduces the accumulated crosstalk of large scale AWG in Table 7 and Fig. 4 [6].

Table (7-A): Crosstalk before and after cascade of selected channel of eight AWG channels system

System channels	Selected Channels	Crosstalk before cascading (dB)	Crosstalk after cascading (dB)
8	3	-33.7	-48.9
8	4	-33.1	-44.4

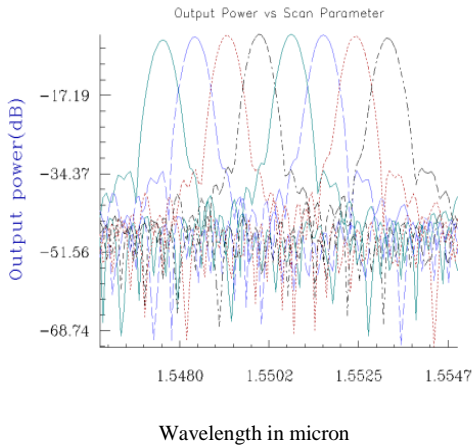


Fig. (4-A): Output power vs wavelength in micron (scan parameter), of eight channels

Table (7-B): Crosstalk before and after cascade of selected channel of 16-AWG channels system

System channels	Selected Channels	Crosstalk before cascading (dB)	Crosstalk after cascading (dB)
16	2	-30.3	-45.6
16	3	-29.6	-47.5
16	14	-30.9	-43.3

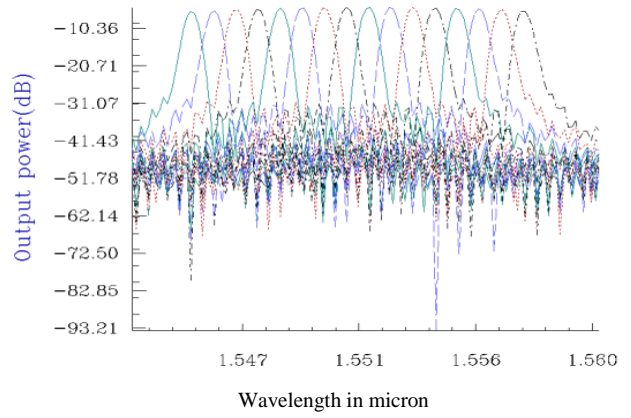


Fig. (4-B): Output power vs. wavelength (scan parameters) of 16 channels

Table (7-C): Crosstalk before and after cascade of selected channel of 32-AWG channels system

System channels	Selected Channels	Crosstalk before cascading (dB)	Crosstalk after cascading (dB)
32	20	-34.9	-54.1
32	26	-33.8	-53.5
32	27	-32.9	-47.2

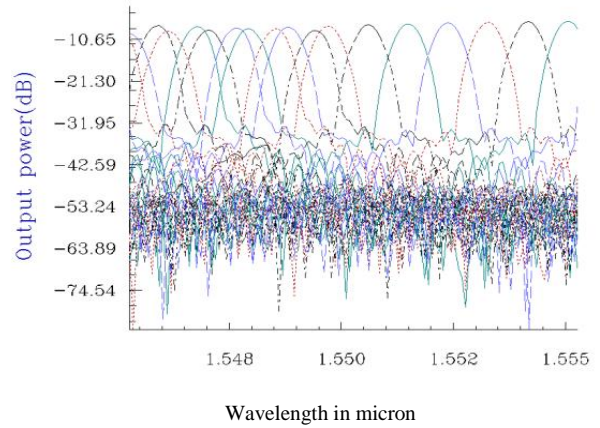


Fig. (4-C): Output power vs wavelength (scan parameter) of 32 channels

Table (7-D): Crosstalk before and after cascade of selected channel of 64-AWG channels system

System channels	Selected Channels	Crosstalk before cascading (dB)	Crosstalk after cascading (dB)
64	1	-39.6	-67.9
64	2	-37.8	-64.2
64	27	-32.5	-62.9
64	51	-32.4	-65.7
64	58	-33.5	-65.7
64	61	-34.6	-59.2

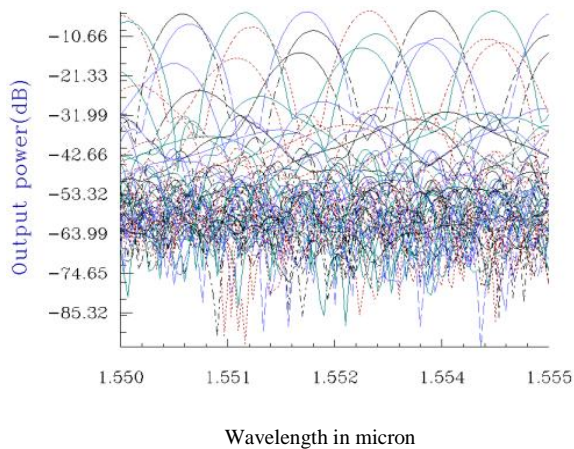


Fig. (4-D): Output power vs. wavelength (scan parameter) of 64 channels

### VIII. CONCLUSION

AWGs are most powerful devices that used in optical DWDM multiplexers/demultiplexers systems but it is affected by accumulated crosstalk. This research work used WDM\_Phasar simulator for designing different AWGs (8 channels unit, 16 channels unit, 32 channels unit, and 64 channels unit) systems. The simulation was run for each unit to obtain the crosstalk for each channel. Then, simulation was run in cascading manner. Results obtained proved that the cascade method is a reasonable technique for enhancement the crosstalk levels.

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