# طراحی و شبیه سازی مالتی پلکسر AWG شانزده کاناله با پاسخ طیفی تخت

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**چکیده – در این مقاله یک طراحی جدید برای گریتینگ موجبری آرایه ای (AWG) ۱×۱۶ کاناله با پاسخ خروجی صاف به منظور کاربرد در شبکه های مالتی پلکس تقسیم طول موج (WDM) ارائه شده است. مالتی پلکسری ۱۶ کاناله با طول موج مرکزی ۱۵۵۰ نانومتر و فاصله کانالی ۱/۶ نانومتر مبتنی بر سیلیکن طراحی شده که در آن، اتلاف الحاقی کانالهای کناری به میزان ۶ دسی بل کاهش یافته و بیشترین اختلاف میان اتلاف الحاقی کانال ها نیز از ۸ به ۲ دسی بل تقلیل پیدا کرده است و پاسخ طیفی قطعه نسبت به طراحی های پیشین صاف تر است.**

کلید واژه- اتلاف الحاقی، پاسخ طیفی تخت، گریتینگ موجبری آرایه ای، مالتی پلکس تقسیم طول موج.

# Design and Simulation of a 16-Channnel AWG Multiplexer with a Flat Frequency Response

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Abstract- In this paper a new design for a 16×1 arrayed waveguide grating (AWG) with a flat spectral response is presented which is suitable for wavelength division multiplexing (WDM) networks. We designed a 16 channel silicon-based device with center wavelength of 1550 nm and 1.6 nm channel spacing. In our new design the insertion loss for the side channels decreases drastically up to 6 dB. Also, the maximum insertion loss difference between channels decreases from 8 to 2 dB and the spectral response of the device is flattened.

Keywords: arrayed waveguide grating, flat spectral response, insertion loss, wavelength division multiplexing.

# Design and Simulation of a 16-Channnel AWG Multiplexer with a Flat Frequency Response

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***Abstract:*** *In this paper a new design for a 16×1 arrayed waveguide grating (AWG) with a flat spectral response is presented which is suitable for wavelength division multiplexing (WDM) networks. We designed a 16 channel silica-based device with center wavelength of 1550 nm and 1.6 nm channel spacing. In our new design the insertion loss for the side channels decreases drastically up to 6 dB and spectral response of the device is flattened.*

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## 1 Introduction

The huge demand for internet is requiring development of high-speed broadband optical networks, such as DWDM systems components [1]. The most important DWDM components are the wavelength multiplexers and demultiplexers. There are many publications on realization and characterization of this components until now. Commercially available components are based on fiber-optic or microoptic techniques [2].

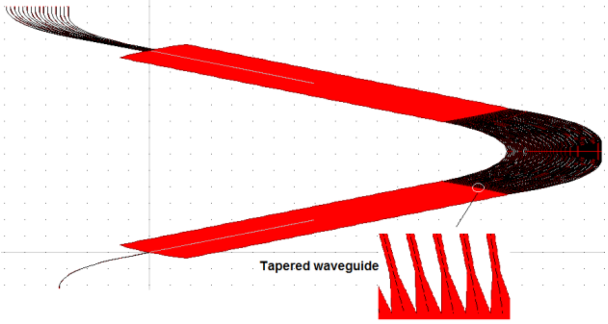



Figure 1: Schematic diagram of AWG. Waveguides connections to star couplers are tapered.

Silica-based planar lightwave circuits (PLCs) have been used in numerous types of devices as they have unique design flexibility, stability, and mass-producibility. Since multiple-interference makes it possible to form an AWG in a single device regardless of its channel count, among PLCs devices, arrayed waveguide gratings (AWGs) have more importance than other types of wavelength multi/demultiplexers, such as dielectric multilayered filters, in terms of compactness and multichanneling. Therefore AWGs with various channel number of 16 to 64 is now marketing as multi/demultiplxers in WDM networks in region like as North America and Japan [3].

Since design of AWG-WDM highly affect its performance, simulation method of the device play a key role in the design. In the past decade, various new method have been proposed to characterize the performance of an AWG-WDM multi/demultiplxer, such as the imaging method, the Fourier optics method, and the beam propagation method (BPM). Since the imaging method is assuming that the imaging is ideal for simulation, its accuracy is not adequate. Also in the Fourier optics method the coupling coefficient for each waveguide in the array is obtained by overlapping the far field in the free propagation region at the entrance of the waveguide array and the fundamental modal field of an arrayed waveguide [4].

The BPM is one of the most common methods for simulating the light propagation in a planar lightwave circuits. BPM is also a very efficient, flexible, and extendable method in modeling the integrated and fiber optic photonic devices [4].

Since the cross section of star coupler has a curved shape, the side channels experience less coupling efficiency and have more insertion loss than the central channels. In the WDM systems it is expected that all the laser diodes have the same power, the optical amplifiers have same gain, and also the detectors have same threshold. So a device with less insertion loss differences among channels is more applicable in WDM networks. In this work we introduce a new design having flatter spectral response.

The rest of this paper is organized as follows. In Section 2, we state a brief theory of AWG. In Section 3, our new design is presented and the results are discussed in Section 4. Finally, conclusions are presented in Section 5.

## 2 Theory

Figure 1 shows the schematic diagram of an AWG. It consists of three main parts; the two star couplers and the arrayed waveguides. Light in first star coupler diverges to the arrayed waveguides and the path difference $\Delta L$ between adjacent waveguides is so that the phase difference between delivered beams at second star coupler causes interference of them. This interference is so that each wavelength focus at certain point. $\Delta L$ must be equal to an integer multiple of the central wavelength in the waveguide:

$$\Delta L = \frac{m\,\lambda_C}{N_{guide}} \qquad (1)$$

Where $m$ is an integer called grating order, $\lambda_c$ is the central wavelength and $N_{\text{guide}}$ is the effective refractive index of the arrayed waveguide [4].

## 3 Design

In this paper we designed and compare two 16×1 AWG devices for WDM network applications. They consist of two star couplers with input/output tapered waveguides and 120 arrayed waveguides. The number of arrayed waveguides can be found approximately with Equation (2) as below.

$$N_a = 2\theta_a \frac{n_S \Delta\lambda D}{\lambda_0 d_a} N_{ch} + 1 \qquad (2)$$

$\lambda_0$ is the center wavelength, $\Delta\lambda$ is the channel spacing, $d_a$ is the waveguide spacing in the array aperture, $n_S$ is the effective index of the slab region, $D$ is the lateral spacing (on center lines) of the waveguides in the receiver aperture and $\theta_a$ is the aperture width [5].

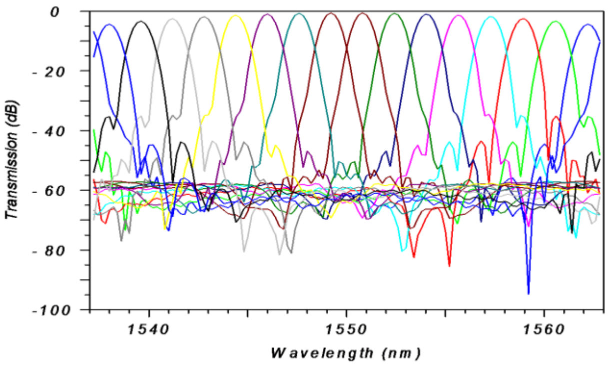
Because of the curvature of the star couplers the side channels have more insertion loss than the central channels. Therefore we designed a 32 channels device and select only the 16 midst channels as output of device. We also designed a 16 channel one with same primary design parameter in [4] for better comparison. The designed parameters of the new device are as table 1. All connection to the star couplers are tapered shape. This increases the coupling efficiency for all waveguides and hence decreasing insertion loss for all channels.

Table 1: designed parameters for 16×1 AWG device.

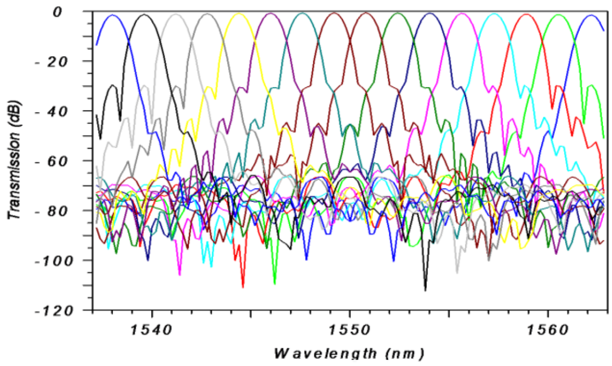
| symbol | quantity | description |
|---|---|---|
| $N_{output}$ | 16 | Number of output waveguide |
| $N_{ch}$ | 32 | Number of channel |
| $N_a$ | 120 | Number of arrayed waveguide |
| $N_{slab}$ | 1.4532 | Refractive index of free propagation region |
| $N_{guide}$ | 1.4512 | Effective index of the phase array waveguide |
| $N_b$ | 1.4482 | Background refractive index |
| m | 30 | Grating order |
| $\lambda_0$ | 1.55 $\mu m$ | Central wavelength |
| W | 6 $\mu m$ | Waveguide width |
| $\Delta L$ | 32.04 $\mu m$ | Length difference between adjacent phase array |
| $D_i$ | 25 $\mu m$ | Waveguide separation on the end of arrayed waveguide |
| $D_o$ | 18.5 $\mu m$ | Waveguide separation on the input and output of device |

## 4 Results and Discussion

In this work we used the BeamPROP software from Rsoft Company for designing of a 16×1 AWG device. Method of computation is beam propagation method. Figure 2 shows output spectra of 16 channel AWG for a) device based on primary designed parameters and b) flatten response by applying new changes to the star couplers according to the table 1. It is obvious that the insertion loss for side channel in new design decrease drastically. In this paper we proposed a new design that there is no need to change the Rowland circles radius according [4] to lowering the insertion loss. According to table 2 the decrease of insertion loss is up to 6 dB. The difference of insertion loss between side channel and the 8$^{th}$ channel in the old design is more than 8



(a)



(b)

Figure 2: output spectra of a 16 channel AWG (a) device based on primary designed parameters and b) flatten response by applying new changes to the star couplers.

dB, However in the new design this difference is about 2 dB. Therefore we see a more flatten response from a 16 channel AWG. For reduce of total insertion loss we tapered all waveguide connections to star couplers. Also for insuring these connections the waveguide overlapped with star coupler, it means the waveguide extended to star coupler.

Table 2: comparison of channel insertion loss for two design.

| channel | Insertion loss (dB) | |
|---|---|---|
| | old design | New design |
| 1 | -9.96 | -3.44 |
| 2 | -7.60 | -2.91 |
| 3 | -5.66 | -2.47 |
| 4 | -4.11 | -2.12 |
| 5 | -2.95 | -1.84 |
| 6 | -2.10 | -1.62 |
| 7 | -1.54 | -1.48 |
| 8 | -1.25 | -1.41 |
| 9 | -1.25 | -1.41 |
| 10 | -1.55 | -1.49 |
| 11 | -2.15 | -1.65 |
| 12 | -3.08 | -1.92 |
| 13 | -4.41 | -2.30 |
| 14 | -5.84 | -2.81 |
| 15 | -7.63 | -3.08 |
| 16 | -9.95 | -3.46 |

## 5 Conclusion

A 16×1 channel AWG with flattened response, cener wavelength of 1550 nm and 1.6 nm channel spacing for applications in WDM networks were presented. The new design has the advantage of decreasing the insertion loss for side channels by about 6 dB. Also, the maximum insertion loss difference between channels decreases from 8 to 2 dB.

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