Triplexers Based on SOI Flattop AWGs*

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Abstract: Triplexers are designed based on SOI flattop arrayed waveguide gratings (AWGs). Three wavelengths (1310, 1490, and 1550nm) operate at three diffraction orders of AWGs. Simulation shows that the 3dB bandwidth, crosstalk, and loss are 6nm, less than −40dB, and 5dB, respectively. The output optical fields of the device fabricated in our laboratory are clear and show a good triplexing function.

Key words: integrated optics; arrayed waveguide grating; triplexer
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1　Introduction

With the rapid increase of bandwidth requirements, the speed of access networks becomes a bottleneck to improve the user's bandwidth. Fiber-to-the-home (FTTH), which is developing rapidly, holds promise. In applying FTTH, the cost reduction of the optical network unit (ONU) is the key issue. The ONU consists of a triplexing filter for an optical wavelength division multiplexing (WDM) function, a laser diode (LD), and photodiodes (PDs).

According to the ITU-T 984 standard, the triplexing WDM of the ONU module transmits 1310nm upload data and receives 1490nm download data and 1550nm download analog signals. The most common triplexer is embedded thin film filter (TFF) based on a planar lightwave circuit (PLC) platform. However, embedded TFFs require complicated assemblage. Planar waveguide based triplexers seem more promising[1~4] and can be integrated with LDs and PDs conveniently. Silica-based arrayed waveguide gratings (AWGs), the most common planar waveguide components, are used as triplexers[5]. However, considering integrating LDs and PDs, silicon substrate should be etched 15～20μm before depositing silica undercladding[6], which requires an extra fabrication step. Silicon on insulator (SOI) PLC is an alternative choice. In this paper, we present a detailed design for triplexers based on SOI flattop AWGs and the corresponding output optical fields are tested.

2　Design of SOI flattop AWG triplexers

The waveguide we use is an SOI ridge waveguide. To ensure single mode condition, the waveguide is 4μm wide and has an inter ridge height of 5μm, and an outer ridge height of 3μm. Because of the large silicon refractive index and wide wavelength space, the three wavelengths of the triplexers do not operate at the same diffraction order of AWGs[3]. We design the three wavelengths (1310, 1490, and 1550nm) to operate at three different diffraction orders. After optimization, we choose 38.1nm as the free spectrum region of AWGs. The wavelength of 1550nm operates at m diffraction order, the wavelength of 1490nm operates at $m+1$ diffraction order, and the wavelength of 1310nm operates at $m+6$ diffraction order. At m and $m+1$ diffraction order, the output central wavelengths of AWGs are 1538.5 and 1500.4nm, respectively. The wavelengths of 1490 and 1550nm are output from different output waveguides, port a and port c, as denoted in Fig. 1, which lie up and down of the output central waveguide. The wavelength of 1310nm inputs reversely at the central output waveguide,

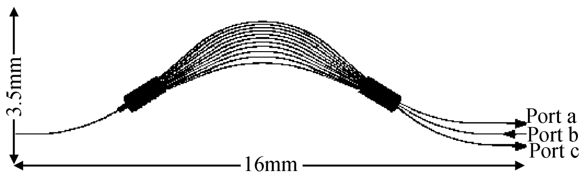

Fig.1　Schematic of a triplexer based on SOI flattop AWGs

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Table 1 Design parameters of AWGs for triplexers

Channels	3
Length difference of adjacent waveguides	17.737μm
Diffraction order m	40
Length of FPR	1100μm
Space of arrayed waveguide	8μm
Space of output waveguide	17.75μm
Number of arrayed waveguides	33

denoted as port b in Fig. 1. The central wavelengths of the three selected diffraction orders satisfy the following equations:

$$n_c(1538.5\text{nm})\Delta L = m\lambda(1538.5\text{nm}) \quad (1)$$

$$n_c(1500.4\text{nm})\Delta L = (m+1)\lambda(1500.4\text{nm}) \quad (2)$$

$$n_c(1310\text{nm})\Delta L = (m+6)\lambda(1310\text{nm}) \quad (3)$$

The other parameters are listed in Table 1. In order to obtain a flattop response and release the wavelength requirement of LD, a multimode interference (MMI) structure with 10μm width and 160μm length is used at the end of the input waveguide[7]. The chip size is 16mm×3.5mm, as shown in Fig. 1.

3 Simulation and test results

In order to reduce simulation time, a three-dimensional SOI ridge waveguide is converted to a two-dimensional (2D) planar waveguide using the effective index method. Adopting the 2D finite difference beam propagation method (FD-BPM), the input slab waveguide and output slab waveguide are computed. In combination with the arrayed waveguide phase accumulation, the output spectra are simulated. Figure 2 shows the simulated output spectra, where the dotted line, solid line, and dashed line correspond to output from ports a, b, and c, respectively. Diffraction orders of Figs. 2(a), (b), and (c) are $m+1$, m, and $m+6$, respectively. Figure 2 shows that three wavelengths of 1310, 1490, and 1550nm operate at different diffraction orders, and signals of 1490, 1310, and 1550nm are output from ports a, b, and c, respectively, which agree well with the design. By adopting an MMI structure at the end of the input waveguide, the 3dB bandwidth increases to 6nm. Of course, the insertion loss increases, up to 5dB. Using enough arrayed waveguides, the background noise is suppressed substantially. The cross talk is less than −40dB.

The designed SOI flattop AWGs were fabricated using the standard semiconductor process. A silica film with 1μm thickness was deposited after induced coupler plasma (ICP) etching silicon. The end faces of the AWGs were polished after being diced from the wafer. The optical source with wavelengths of 1490 or 1550nm was coupled into the input waveguide from a single fiber. The optical source with the wavelength of 1310nm was input to the AWGs reversely. The output optical fields were tested using an infrared camera. The corresponding output fields are shown in Fig. 3. Figures 3 (a), (b), and (c) correspond to the output fields of 1490, 1550, and 1310nm, respectively.

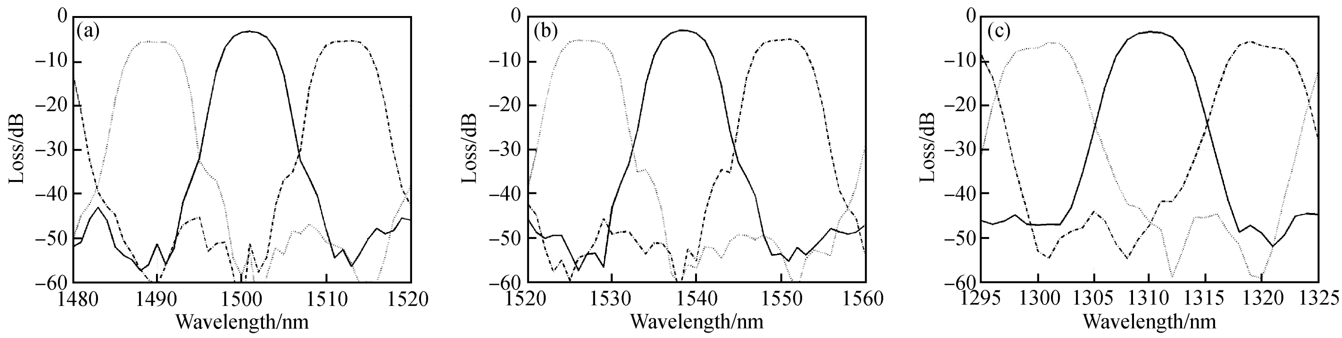

Fig. 2 Simulated spectral responses of SOI flattop AWGs (dotted line, solid line, and dashed line correspond to the output spectra from ports a, b, and c, respectively) (a) Output spectrum at $m+1$ diffraction order of AWGs; (b) Output spectrum at m diffraction order of AWGs; (c) Output spectrum at $m+6$ diffraction order of AWGs

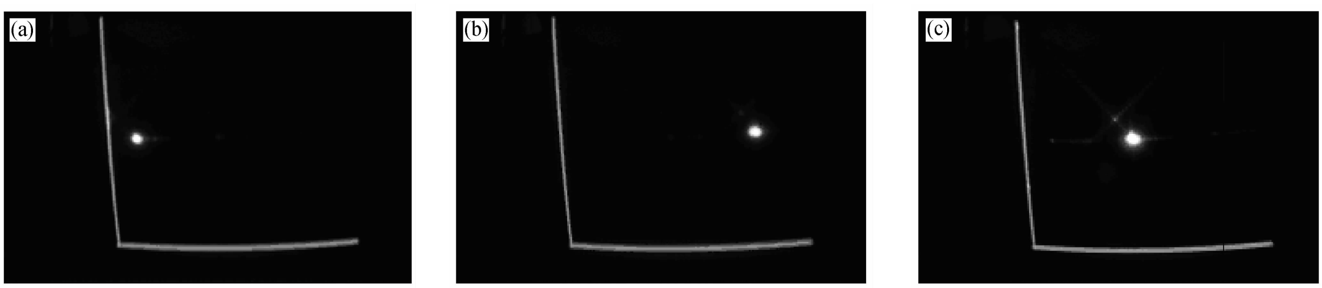

Fig. 3 Tested output optical fields of SOI flattop AWGs (a) Output field at port a with 1490nm; (b) Output field at port c with 1550nm; (c) Reverse output field at port b, corresponding to that of 1310nm

The optical fields are very clear, showing a good triplexing function, which is accordance with that of our design. The output spectra analysis of the triplexer will be discussed in detail in another paper.

4 Conclusion

Triplexers based on SOI flattop AWGs are designed and fabricated for the first time. Simulation results show that the 3dB bandwidth is about 6nm, the insertion loss is less than 5dB, and the crosstalk is less than −40dB. Furthermore, the output optical fields were tested and showed good performance.

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基于绝缘层上硅平坦化阵列波导光栅的单纤三向器*

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摘要: 设计了基于绝缘层上硅(SOI)平坦化阵列波导光栅单纤三向器.三向器三个波长(1310,1490 和 1550nm)工作在阵列波导光栅的三个不同的衍射级数, 并在阵列波导光栅的输入波导末端引入多模干涉器(MMI), 实现了平坦响应的三波长波分复用.模拟结果表明基于这一设计的三向器 3dB 带宽为 6nm, 串扰小于−40dB, 插损为 5dB. 制备的三向器经测试输出光场清晰,实现了三向器的功能.

关键词: 集成光学; 阵列波导光栅; 单纤三向器

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