Polymer Arrayed Waveguide Grating with Box-Like Spectral Response

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Abstract: An efficient technique is used to flatten the spectral response of an arrayed waveguide grating (AWG) multiplexer. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained. A $17 \times 17$ polymer AWG multiplexer with box-like spectral response has been made using FPE polymer materials. Measured result for the AWG shows that the box-like spectral response has a 3dB bandwidth of 0.476nm, the crosstalk is about or less than $-21$dB for every output channel, and the insertion loss is $13\sim15$dB.

Key words: arrayed waveguide grating; box-like spectral response; 3dB bandwidth; crosstalk

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1 Introduction

The spectral response of the arrayed waveguide grating (AWG) multiplexer plays an important role in optical networks⁴⁻⁵⁻⁶. Ideally, the AWG should have a so-called box-like spectral response to reduce the need for accurate wavelength control. Some research groups proposed various techniques to flatten the spectral response of the AWG device⁴⁻⁵⁻⁶⁻⁷⁻⁸⁻⁹.

Manufacturing tolerances are hard to avoid in the fabrication of the arrayed waveguide grating (AWG) multiplexer, which will result in the shift of the transmission spectrum of the AWG device. However, the conventional AWG device usually possesses a Gaussian spectral response, which imposes a strong wavelength control in the communication network. Therefore, the flat spectral response of the AWG device is required.

In this paper, an efficient technique is used to flatten the spectral response of an AWG multiplexer. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained⁴⁻⁵⁻⁶. A $17 \times 17$ polymer AWG multiplexer with box-like spectral response has been made by using FPE polymer materials.

2 Optimization design of device

The FPE-51 is chosen as core material, and the styrene (St) is used to regulate the mol percent of FPE-51 and FPE-49 to form the cladding material. The cladding refractive index can be easily controlled from 1.49 to 1.51 through regulating the mol percent of FPE-49 and FPE-51. In this paper, we select the refractive index of the polymer guide core to be $n_1 = 1.51$, and that of the polymer cladding surrounding the guide core to be $n_2 = 1.4979$. So the refractive index difference between the core and the cladding is about $\Delta = (n_1 - n_2)/n_1 = 0.8\%$. Based on these polymer materials, a $17 \times 17$ conventional AWG multiplexer with 0.8 nm channel spacing is designed¹⁰, and the optimized values of the parameters are listed in Table 1.

Table 1. Optimum values of parameters of a polymer AWG with flat spectral response

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central wavelength</td>
<td>$\lambda_s = 1550.918$ nm</td>
</tr>
<tr>
<td>Wavelength spacing</td>
<td>$\Delta = 0.8$ nm</td>
</tr>
<tr>
<td>Width of guide core</td>
<td>$a = 6$ μm</td>
</tr>
<tr>
<td>Thickness of guide core</td>
<td>$b = 4$ μm</td>
</tr>
<tr>
<td>Pitch of adjacent waveguides</td>
<td>$d = 15$ μm</td>
</tr>
<tr>
<td>Refractive index of polymer guide core</td>
<td>$n_1 = 1.51$</td>
</tr>
<tr>
<td>Refractive index of polymer cladding</td>
<td>$n_2 = 1.4979$</td>
</tr>
<tr>
<td>Diffraction order</td>
<td>$m = 56$</td>
</tr>
<tr>
<td>Length difference of adjacent arrayed waveguides</td>
<td>$\Delta L = 57.786$ μm</td>
</tr>
<tr>
<td>Focal length of slab waveguide</td>
<td>$f = 7519.539$ μm</td>
</tr>
<tr>
<td>Free spectral range</td>
<td>FSR $= 13.77$ nm</td>
</tr>
<tr>
<td>Number of I/O channels</td>
<td>$2N + 1 = 17$</td>
</tr>
<tr>
<td>Number of arrayed waveguides</td>
<td>$2N + 1 = 151$</td>
</tr>
</tbody>
</table>

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In this section, we improve the structure of the preceding conventional AWG, and flatten the spectral response of the improved AWG. We reduce the core width of the odd arrayed waveguides from $a$ to $a - \delta a$, and increase that of the even arrayed waveguides from $a$ to $a + \delta a$, that is, the AWG is divided into two sub-gratings, the core width of one sub-grating is $a - \delta a$, and that of another is $a + \delta a$, where $\delta a$ is the core width increment. In this case, using the grating diffraction theory, Figure 1 shows the effects of the core width increment $\delta a$ on the spectral response, where $\delta a = 0$ is corresponding to the conventional AWG, and $\delta a = 0.20, 0.24, 0.28, 0.35 \mu m$ are corresponding to the improved AWG. It can be seen from Fig. 1 that when the core width increment $\delta a = 0$, the spectral response of the conventional AWG is sharper and narrower, of which the shape is convex, and the 3dB bandwidth is about 0.23nm. As the core width increment $\delta a$ increases, the spectral response of the improved AWG becomes flatter and wider. As the core width increment $\delta a$ increases to a proper value, for instance $\delta a = 0.24 \mu m$ (bold solid line), a box-like spectral response is formed, of which the 3dB bandwidth is about 0.5nm. If the core width increment $\delta a$ further increases, however, the spectral response becomes saddle-backed.

We select the core width increment to be $\delta a = 0.24 \mu m$. Figure 2 shows the calculated demultiplexing spectrum of 17 output channels of the designed AWG. It can be seen from Fig. 2 that a box-like spectral response is formed, of which the 3dB bandwidth is about 0.49nm. The AWG multiplexer is shown schematically in Fig. 3.

3 Fabrication and measured results

The guide core is buried in the cladding, and the schematic diagram of the fabrication procedures is drawn in Fig. 4, which includes (a) spin-coating the lower cladding and core layer in turn, (b) depositing metal mask, (c) photolithography, (d) reactive ion etching, and (e) spin-coating the upper cladding. Figure 5 shows the scanning electron microscope micrograph of waveguides after the reactive core etching.
The measured transmission spectrum is presented in Fig. 6, where a box-like spectral response is formed, of which the 3dB bandwidth is about 0.476nm. This proved that the method to design AWG device with box-like spectral response is feasible and that we stated theoretically, it has certain practical value. We have fabricated a $17 \times 17$ polymer AWG device, whose waveguide width is about 0.49nm, which is more than two times of that of the conventional AWG. When some factors result in the shift of the transmission spectrum of the AWG device, it relaxes a wavelength control in the communication network. For the designed AWG device, the central wavelength of the AWG is about 1550.97nm, the shift of the transmission spectrum is about 0.05nm, which is much less than the wavelength spacing of 0.8nm, so the AWG may realize normal demultiplexing. The insertion loss and the crosstalk are $13 \sim 15$dB and about $21$dB respectively. For the designed AWG device, however, the increments are 5 and 4dB, respectively, mainly because the additional insertion loss and crosstalk have been produced in the flat transmission spectrum. So how to reduce the insertion loss and the crosstalk of AWG device is a problem that needs further to be solved.

4 Conclusion

In summary, we have designed and fabricated a $17 \times 17$ AWG device with flat spectral response by using FPE polymer materials. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained. In our experiment, we select the core width increment to be $\delta a = 0.24\mu m$, the measured transmission spectrum is presented in Fig. 6, where a box-like spectral response is formed, of which the 3dB bandwidth is about 0.476nm, the center wavelength is 1550.87nm, insertion loss is $13 \sim 15$dB, and crosstalk is about $21$dB. Currently, we are devoting ourselves to further reducing the loss and crosstalk of the AWG device in order to fabricate this device with better features.

References

箱型光谱响应聚合物阵列波导光栅的研制

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摘要：通过减少奇数阵列波导的芯宽度，同时增加偶数阵列波导的芯宽度的技术，构造了箱型光谱。选用氟化聚芳醚 FPE 聚合物材料，设计并制备了 17×17 信道箱型光谱响应阵列波导光栅(AWG)波分复用器，测试结果表明，器件的中心波长为 1550.87nm，波长间隔为 0.88nm，3dB 带宽约为 0.476nm，串扰低于 -21dB，插入损耗为 13～15dB。

关键词：阵列波导光栅；箱形光谱响应；3dB 带宽；串扰

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