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Highly Reliable Photosensitive Phase Trimming Technique for Narrow Channel Spaced Arrayed-Waveguide Grating Multi/Demultiplexer

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1. Introduction

Arrayed waveguide grating (AWG) multi/demultiplexers are key components for constructing photonic networks based on wavelength division multiplexing (WDM) technologies, which can provide large optical transmission capacities and flexible optical networking [1,2]. The recent explosive growth of the Internet has led to a huge demand for information transmission. To meet this demand requires WDM transmission systems with large port counts and a narrow channel spacing. This in turn means that AWG multi/demultiplexers must also have large port counts and a narrow channel spacing.

AWGs are fabricated by using silica-based planar lightwave circuit (PLC) technologies. Fabrication errors, namely differences from designed values, cause phase errors in AWGs. These errors have a negative effect on the optical transmission characteristics of AWGs, including neighboring channel crosstalk, loss and transmission bandwidth. Therefore phase error compensation techniques have become important in terms of realizing narrow channel spaced AWGs with excellent characteristics.

We have already demonstrated a photosensitive phase trimming technique that can compensate for the phase errors that occur during AWG fabrication by using the UV induced refractive index change Δn in silica-based waveguides [3]. For practical applications, long-term thermal stability is also important.

In this paper, we describe a photosensitive phase trimmed AWG with improved thermal stability that we achieved by using an additional annealing process. We also show its long-term thermal stability.

2. Experimental procedure

We fabricated 12.5 GHz-spaced 64 channel silica-based AWGs by using PLC technologies including flame hydrolysis deposition, reactive ion etching and photolithographic techniques [1]. The AWGs were composed of GeO_2-doped silica-based waveguides. The GeO_2 concentration was about 7 mol %, and the index of the 7μm x 7μm core was about 0.7% higher than that of the silica-based cladding glass .

To compensate for the phase error in the AWG, we performed an optical transmission diagnosis of the AWGs using the optical low-coherence interferometry and Fourier spectroscopy (OLCI-FS) technique [4]. We designed metal mask plates based on the results of our phase error estimation by OLCI-FS. We irradiated the arrayed waveguide part of the AWG from above with 193-nm wavelength ArF excimer UV laser light through metal plates that were designed and fixed so that only part of length L_i in the i-th arrayed waveguide of the AWG was exposed. L_i corresponds to the phase error $\Delta\varphi_i$ in i-th arrayed waveguide, according to the formula $\Delta\varphi_i = (2\pi/\lambda)\Delta n L_i$ where λ is the operating wavelength and Δn is the effective induced refractive index change. Figure 1 shows a schematic view of our compensation method.

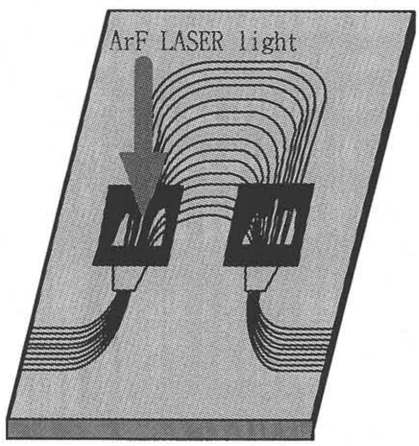

Fig. 1 Schematic view of ArF laser light irradiation at AWG

The transmission characteristics were measured with an optical spectrum analyzer. The amplified spontaneous emission (ASE) light from Er-doped fiber amplifier was introduced into the AWG through a polarization maintaining fiber with a polarizer.

In order to stabilize the photoinduced refractive index change, the phase compensated AWG was annealed for an hour at a temperature of 300°C in an electric furnace.

After that, we confirmed the long-term thermal stability. We kept the phase trimmed AWG in dry air at

85°C and confirmed its thermal stability by using the crosstalk at a neighboring channel wavelength and a 20 dB-bandwidth. We performed the above in the TE mode. It is possible to achieve polarization insensitivity by using a polyimide half-wave plate.

3. Results and Discussion

Figure 2 shows the crosstalk improvement at the neighboring channel wavelength against UV irradiation time. The index change increased almost linearly with the UV irradiation time [5]. This means we can trim the AWG phase easily by controlling the irradiation time. Another merit of this method is that we can trim all the arrayed waveguides simultaneously. Before UV irradiation, the longer-wavelength side crosstalk was -16.5 dB. UV light irradiation for 140 minutes with a power of about 100 mJ/cm^2 adjusted the phase error to around zero, and the crosstalk was reduced to the lowest possible level of around -30 dB as determined by the power distribution of the launched light in the arrayed waveguides. We continued UV irradiation for an extra 80 minutes to take account of the relaxation of the index change in the annealing process for stabilization.

After annealing, the neighboring crosstalk on both sides improved to about –30 dB, and the 20 dB-bandwidth was approximately 0.13 nm. Moreover, the loss value was improved by 1.8 dB. The transmission spectra at the center channel of the AWG before and after phase trimming are shown in Fig. 3.

Figure 4 shows the thermal stability of the photosensitive phase trimmed AWG in a long-term reliability test undertaken in dry air at 85°C. After 2000 hours, both the crosstalk and bandwidth retained the values they had just after trimming. These results show the fairly good thermal stability of our photosensitive phase trimmed AWG.

4. Conclusion

We described a photosensitive phase trimming procedure with an additional annealing process designed to improve thermal stability. This technique is very useful for realizing narrow channel spaced AWGs with high levels of performance.

Acknowledgments

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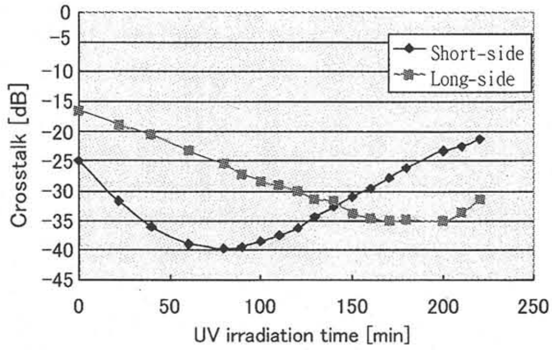

Fig. 2 Crosstalk improvement against UV irradiation time

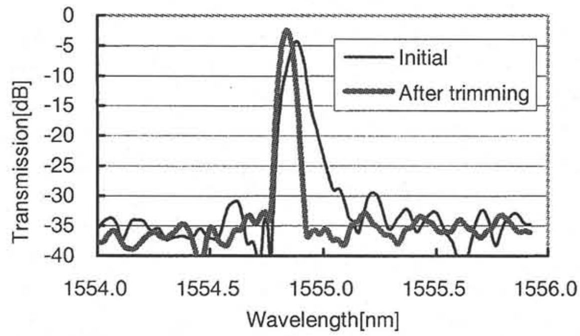

Fig. 3 AWG transmission characteristics before and after phase trimming

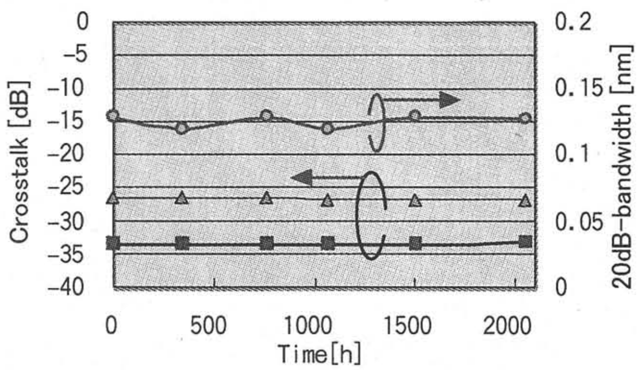

Fig. 4 Long-term thermal stability of phase trimmed AWG transmission characteristics. The circles indicate 20 dB bandwidths, the triangles and squares shows crosstalk at neighboring wavelengths on the long- and short-side, respectively.