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Wide-Band Thermo-Optic Wavelength Tunable Filter Using Silicone Resin with a Fast Response for WDM Systems

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1. Introduction

Wavelength tunable filters are important devices for wavelength division multiplexing (WDM) systems because they can select any WDM channel from among the WDM channels [1]. Arrayed waveguide grating (AWG)-type thermo-optic wavelength tunable filters (TOWTFs) have already been developed using polymers [2-4]. Gaussian-type filters such as AWG demultiplexers are advantageous in that their design parameters have greater tolerance as regards realizing excellent system performance than those of Lorenzian-type filters such as dielectric multilayer filters [5]. Polymer TOWTFs operate with a wide tuning range of ~ 10 nm because their polymers have large thermo-optic coefficients of the order of 10^{-4}°C^{-1}. These TOWTFs are tuned by controlling the temperature using a Peltier-type heater [2-4]. The wavelength tunability is limited (~ 10 nm) and the response is slow (minute-second order) because the response time and temperature control range of the Peltier-type heater are limited. A millisecond order response and a wide tuning range can be expected if we mount a thin film heater on the filter waveguides. In this Letter, we report a polymer TOWTF with a triangular phase shifter consisting of a thin film heater on the arrayed waveguides to provide the filter with a fast response and wide-band tunability. Our polymer TOWTF operated with a response-time of 2-60 ms and a tuning range of > 20 nm.

2. Experimental

We fabricated the AWG demultiplexer on a silicon substrate using silicone resin as the waveguide material. The propagation loss was 0.5 dB/cm at 1.55 μm [3]. The design parameters for fabricating the AWG demultiplexer are shown in Table I. We installed the straight 1.5-cm long waveguides in the heater area of arrayed waveguides (Fig. 1). Therefore, the length of the arrayed waveguides is larger than that previously reported [2]. We deposited a pair of triangular thin film heaters (type-A and type-B) with a path difference (ΔL_h) of 100 μm between adjacent waveguides on each arrayed waveguide, as shown in Fig. 1. The center wavelength λ_c of the TOWTF is expressed by

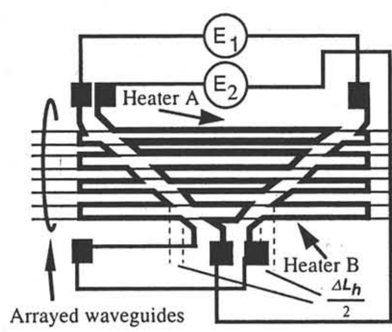

Fig. 1 Heater structure on the arrayed waveguides.

Table I Design parameters for AWG multiplexers.

Effective index of channel waveguides	1.49
Refractive index difference	0.58 %
Waveguide path difference	63.2 μm
Operating wavelength	1.55 μm
Diffraction order	60

$$\lambda_c=\lambda_0+\Delta n \times\Delta L_h/m \qquad (1)$$

where λ_0, Δn, ΔL_h, and m denote the center wavelength before heating, the effective index difference between before and after heating, the heater path difference between adjacent waveguides, and the diffraction order, respectively. We varied Δn by heating the arrayed waveguides using the thin film heaters, thus tuning λ_c. Wavelengths shorter than λ_0 are tuned by using the type-A heater because the optical path length difference (Δn x ΔL_h) decreases. Here, the optical path length means the value of the path length multiplexed by the refractive index. By contrast, wavelengths longer than λ_0 are tuned by heating the type-B heater because the optical path length difference increases. We measured the transmission spectra using a spectrum analyzer. We obtained the response time by the following procedure. A wavelength tunable laser signal was launched through the TOWTF. The laser wavelength was tuned to the filter peak wavelength of 1.55 µm before heating. We obtained the response time from the time-dependence of the output intensity using a digital oscilloscope when the heater was on or off.

3. Results and discussion

Figure 2 shows the wavelength tunability of the polymer TOWTF for the TE mode. We tuned the TOWTF in the 1539.9 to 1550.0 nm range using the type-A heater. The maximum power consumption was 3.9 W. We then tuned the TOWTF in the1550.0 to 1560.1 nm range using the type-B heater. The tuning range of the TOWTF was, therefore, totally over 20 nm, which is comparable to the free spectral range. The crosstalk was below –30 dB over the whole consumption power range. The insertion loss was 6.0 - 7.5 dB. This large loss value results from the increase in the waveguide propagation loss that was caused by the increase in the arrayed waveguide length. We believe that the bandwidth expansion, which resulted from the phase error when the consumption power was large, caused the transmission deterioration.

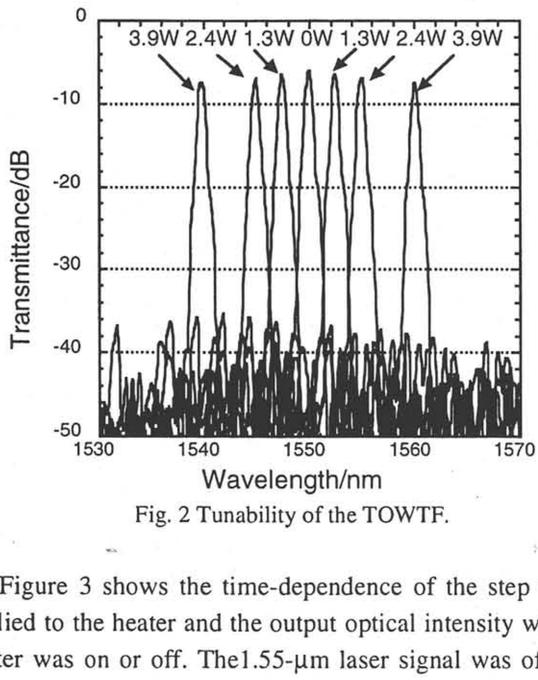

Fig. 2 Tunability of the TOWTF.

Figure 3 shows the time-dependence of the step voltage applied to the heater and the output optical intensity when the heater was on or off. The1.55-µm laser signal was off when the heater was on. Then, the laser signal was detected when the heater was off. The time-response was about 2 ms when the heater was turned on and about 60 ms when the heater was off. Here, we obtained the response-time when the intensity was 10% or 90 % of the initial one. Thus, this TOWTF using the thin film heater had a fast response

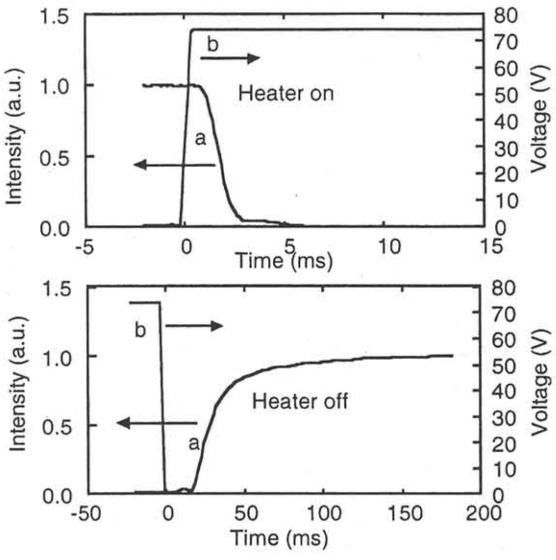

Fig. 3 Response characteristics of the TOWTF (a) and the applied voltage (b) when the heater was on and off.

whereas its response was slow (minute-second order) when using the Peltier-type heater.

4. Conclusions

We developed a polymer TOWTF with a pair of triangular phase shifters on the arrayed waveguides so that it would operate with a fast response and wide-band tunability . The TOWTF had a response-time of 2-60 ms, a tuning range of > 20 nm, a crosstalk of < -30 dB, and an insertion loss of 6.0 - 7.5 dB. These results show that polymer TOWTFs have great potential as wavelength tunable filters for WDM systems.

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References

[1] A. Hiramatsu, M. Tsukada, T. Matsunaga, and K. Yukimatsu, *ISS, 1997* (1997) IS-02.20.

[2] S. Toyoda, A. Kaneko, N. Ooba, M. Hikita, H. Yamada, T. Kurihara, K. Okamoto, and S. Imamura, IEEE Photon. Tech. Lett., **11**, 1141 (1998).

[3] T. Watanabe, N. Ooba, S. Hayashida, T. Kurihara, and S. Imamura, IEEE J. Lightwave Technol., **16**, 1049 (1998).

[4] J. Kobayashi, Y. Inoue, T. Matsuura, and T. Maruno, IEICE Trans. Electron., **E81-C**, 1237 (1998).

[5] M. Tsukada, M. Yamaguchi, M. Ogawara, S. Toyoda, and N. Ooba, *LEOS Summer Topical Meeting, 1999* (1999) p. 26.