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Low Crosstalk and Low Loss Polymeric 1x8 Digital Optical Switch

N. Ooba, S. Toyoda and T. Kurihara

NTT Photonics Laboratories, Nippon Telegraph and Telephone Corp.
Tokai-mura, Naka-gun, Ibaraki, 319-1193, Japan
Phone: +81-29-287-7481 Fax: +81-29-287-7870 e-mail: ooba@iba.iecl.ntt.co.jp

1. Introduction

Space division optical switches are essential to the construction of optical cross-connect nodes for future optical communication networks. A prototype optical cross-connect system has already been successfully demonstrated using 1 x 8 silica-based waveguide thermo-optic (TO) switches with a crosstalk of less than -40 dB [1]. Digital TO switches using polymers have attracted much attention because they require only a small driving electric power as a result of the large TO coefficient of polymers. Another beneficial feature is that digital switches are more tolerant to driving power changes and process errors than interferometric optical switches. The following digital TO switches using polymers have been developed; 1 x 2, 2 x 2 [2], 1 x 8 [3 - 5], 4 x 4[6] and 8 x 8 [7]. For 1 x 8 switches, however, a crosstalk value of less than -40 dB has not yet been achieved.

In this paper, we report a 1 x 8 digital TO switch formed using a silicone resin. We designed the switch to have short Y-branching switches and this resulted in improved loss and crosstalk values.

2. Switch Design

Our 1 x 8 TO switch consisted of seven component Y-branching switches in a tree configuration as shown in Fig. 1. We designed the component switch using a short Y-branch waveguide with a large branching angle to reduce the length of the 1 x 8 switch chip. The use of a short switch chip is an effective way to reduce propagation loss.

A branching angle of about 0.1 degrees is commonly chosen to keep the crosstalk low [2 - 4]. We found that our digital TO switch with a large branching angle of about 0.5 degrees exhibited a low crosstalk if we used a thin film heater to provide the branching region with a suitable temperature distribution. We optimized the thin film heater pattern by using thermal diffusion and beam-propagation-method simulations.

3. Fabrication

We fabricated the 1 x 8 branching waveguide using a thermosetting silicone resin with low birefringence, a low propagation loss and good environmental stability [8]. The waveguide structure was formed by spincoating, thermal curing, photolithography and dry etching. The core size was 8 x 8 μm^2 and the refractive index difference between the core and cladding was set at 0.24 %. The thin film heaters were formed by the sputtering deposition of Au alloy followed by a dry etching patterning process. Input and output fibers were fixed to the polished waveguide endfaces with a UV adhesive after the fibers had been actively aligned precisely with the waveguide cores.

4. Switch Characteristics

We measured the transmission of the 1 x 8 TO switch using a 1550 nm laser diode by changing the electric power supplied to three heaters located on a selected path. The three heaters were driven by the same electric power. Figure 2 shows the fiber-to-fiber transmission of the selected (ON) and other (OFF) ports as a function of total supplied power. At 390 to 450 mW, the insertion loss was less than 2.9 dB and the crosstalk was less than -41 dB. Since the waveguide propagation loss was 2.0 dB and the fiber coupling loss was about 0.1 dB, the excess loss for each element switch was estimated to be 0.3 dB. We tested all the switched states of the 1 x 8 switch chip at a driving power of 450 mW. The results are summarized in Table 1. These values are the best yet reported for polymeric 1 x 8 optical switches.

Table 1 Transmission characteristics of the 1 x 8 digital TO switch at a 450 mW driving power.

	ON port	OFF ports
Transmission	> -3.0 dB	< -43 dB
PDL *	< 0.1 dB	about 3 dB

* Polarization Dependent Loss

5. Reliability

To evaluate stability of the digital TO switch operation, we measured the transmission changes during temperature cycling and switch repetition. Figure 3 shows the results of 50 temperature cycles from 75 to -40 °C when the driving power was 390 mW. Transmission changes for the ON port were within 0.3 dB. The crosstalk increased to -36 dB at -40 °C. In the -10 to 75 °C temperature range, the ON port transmission and the crosstalk were less than 3.0 and -40 dB, respectively. We observed no noticeable changes in the ON and OFF state transmission during 1 x 10^7 switch repetitions (20 times/s, 140 h).

6. Conclusion

We have demonstrated a 1 x 8 digital TO switch that uses silicone resin waveguides. We designed this compact 40 mm long switch using short Y-branching switches. Our switch has a low insertion loss of less than 3 dB and a low crosstalk of less than -40 dB at 1550 nm. These characteristics were maintained over a wide temperature range and for long term switch repetition. These excellent results meet the requirements for optical components in advanced optical cross-connect systems.

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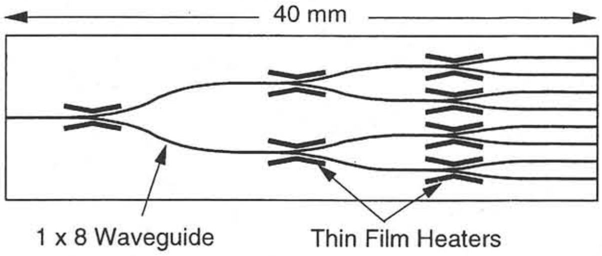

Fig. 1 Schematic configuration of the 1 x 8 digital TO switch.

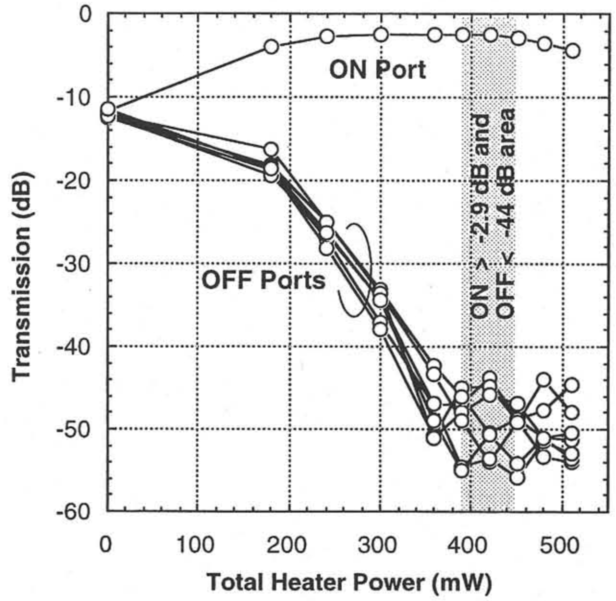

Fig. 2 Fiber-to-fiber transmission of the 1 x 8 digital TO switch at 1550 nm as a function of the total heater power.

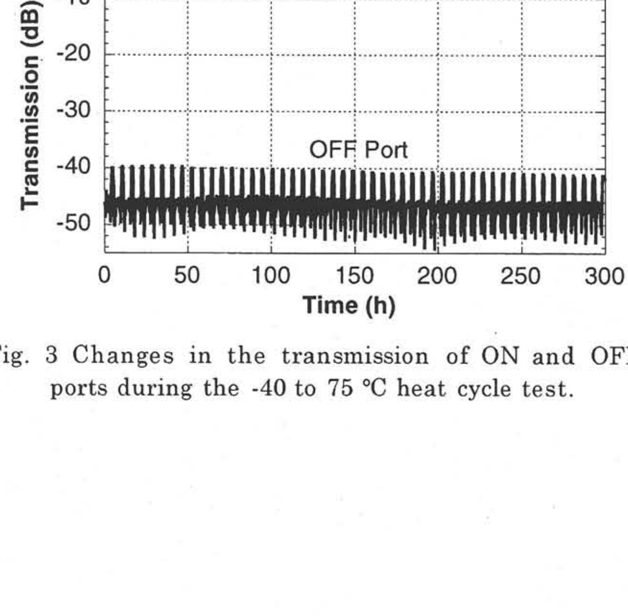

Fig. 3 Changes in the transmission of ON and OFF ports during the -40 to 75 °C heat cycle test.