Strictly Non-blocking NxN Thermo-Capillarity Optical Matrix Switch using Silica-based Waveguide

Mitsuhiro Makihara, Fusao Shimokawa, and Kazumasa Kaneko
NTT Telecommunication Energy Laboratories, 3-9-11, Midori-Cho, Musashino-Shi, Tokyo 180-8585 Japan
telephone:+81-422-59-2664, fax:+81-422-59-4622, email address:makihara@ilab.ntt.co.jp

We propose a silica-based strictly non-blocking NxN thermo-capillarity optical matrix switch. The feasibility of 2-dimensional batch oil injection and multi-layered wiring were confirmed by fabricating a prototype 16x16 optical matrix switch.

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We propose a strictly non-blocking NxN thermo-capillarity optical matrix switch using a silica-based waveguide. A prototype 16x16 optical matrix switch was fabricated using 2-dimensional batch oil injection and multi-layered wiring, thus confirming the feasibility of these important development techniques.

1. Introduction

In the rapidly developing field of high-speed and high-density network systems using mainly optical wavelength division multiplexing technologies, space-division optical switches are indispensable for future fiber-optic communication systems such as optical path cross-connect nodes, photonic inter-module connectors, and protection switches. We have been studying thermo-capillarity optical switches for such applications [1]. These switches have many advantages such as low insertion loss, polarization- and wavelength-insensitive operation, low consumption power by self-latching of the optical path, long-term stability, and suitability for large-scale integration. We propose a strictly non-blocking thermo-capillarity optical matrix switch, and report two key techniques in its fabrication and their feasibility.

2. Structure of optical matrix switch

Figure 1 shows the basic structure of the thermo-capillarity optical switch element. This switch element consists of an upper substrate and an intersecting waveguide substrate that has a slit at each crossing point with refractive index matching oil in it and a pair of microheaters that produce a thermal gradient along the slit. The basic concept of the optical switching is that the matching oil within the slit is driven by a decrease in interfacial tension of the air-oil interface caused by heating (thermo-capillarity). This switch element also has bi-stable self-latching achieved by capillary pressure that depends on the slit width. These basic characteristics have already been confirmed in practice [2].

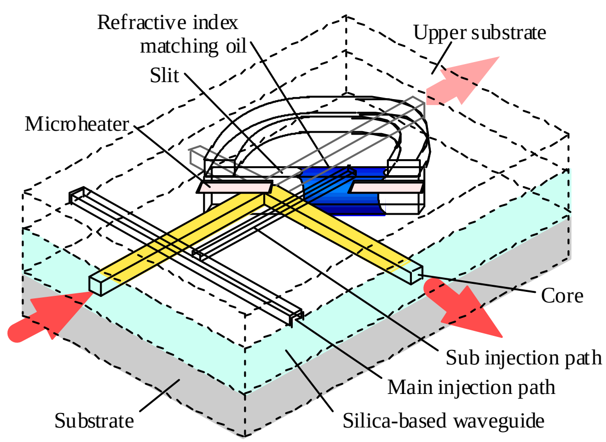


Fig. 1 Basic structure of thermo-capillarity optical switch element.

The NxN optical matrix switch consists of switch elements that are configured like a grid (Fig. 2). To inject the oil into all the slits, one main injection path is fabricated on the upper substrate for all the slits in a row, and these connect with the main injection path through sub injection paths fabricated on the upper substrate (Fig. 2). This structure allows the desired amount of the oil to be injected into all the slits simultaneously by using a conventional pressure control method [3]. After the oil in the main injection path has been removed, the main injection path is filled with a sealing agent and the sub injection paths are sealed. As a result, all of the oil in the slits is independently sealed.

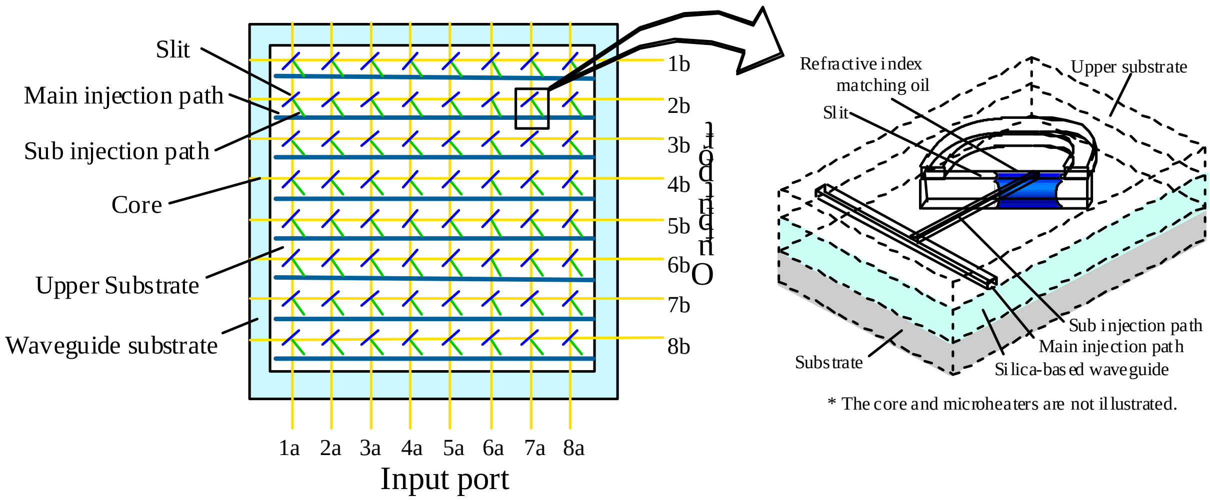


Fig. 2 Structure of 8x8 thermo-capillarity optical matrix switch.

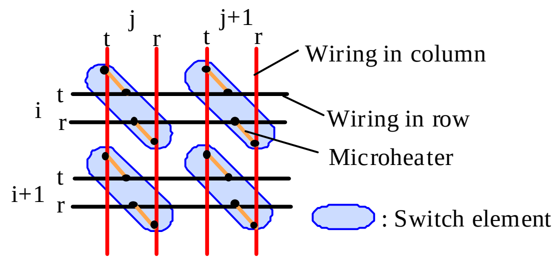
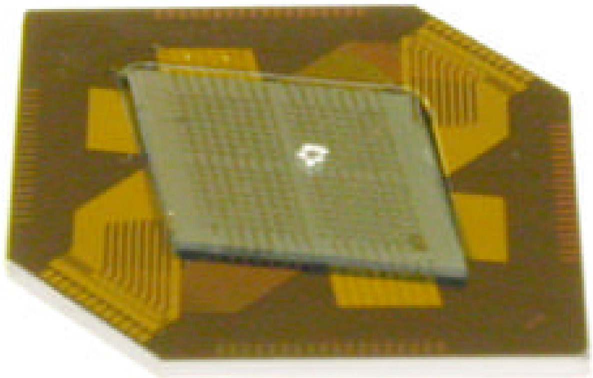


Fig. 3 Structure of multi-layered and shared wiring to microheater.

In our NxN optical matrix switch, wiring to 2 NxN microheaters is necessary in order to drive the oil in the slit. We applied multi-layered wiring in the semiconductor chip fabrication and shared wiring to fabricate flexible high-density wiring. Figure 3 shows their structures. The wiring is configured in rows and columns, and the microheaters share a wire. A microheater is heated by applying a voltage between wires at the row and column. This structure does not allow the matrix switch to switch all optical paths at the same time, but it does allow a very small large-scale optical matrix switch to be fabricated by exploiting the bi-stable self-latching feature.

3. Prototype of optical matrix switch

The NxN optical matrix switch is intended for scales of 8x8 to 16x16. Figure 4 shows a prototype 16x16 thermo-capillarity optical matrix switch fabricated using the 2-dimensional batch oil injection and the multi-layered and shared wiring. Figures 4(a) and (b) show the appearance and switch elements of the optical matrix switch, respectively. The waveguide chip size was 23 mm x 23 mm and the core pitch was 500 µm. The chip size is about one sixteenth of a thermo-optic matrix switch of the same scale [4]. The insertion losses were measured at a wavelength of 1.55 µm using an ASE (Amplified Spontaneous Emission) light source with single-mode fibers butted to input and output waveguides. The losses were 4 dB and 10 dB at the shortest and longest optical paths, respectively. These results confirm the feasibility of 2-dimensional batch oil injection and multi-layered wiring, which are important techniques in depeloping an optical matrix.



(a) Appearance of 16x16 optical matrix switch

(b) Switch elements of optical matrix switch

Fig. 4 Prototype of thermo-capillarity optical matrix switch.

4. Conclusion

We have proposed a strictly non-blocking NxN thermo-capillarity optical matrix switch using a silica-based waveguide with structures of main and sub injection paths for 2-dimensional batch oil injection and multi-layered wiring for flexible high-density wiring. The prototype 16x16 optical matrix switch with these structures was fabricated, and the result of the fabrication confirmed the feasibility of 2-dimensional batch oil injection and multi-layered wiring, which are important techniques for developing an optical matrix switch.

References

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