Broadband and Non-volatile Liquid Controlled Silicon Photonics Switch

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Abstract: A broadband and non-volatile liquid controlled silicon photonics switch is proposed. The measured crosstalk is less than −22dB and −12dB over 100nm wavelength range for bar and cross state, respectively. The insertion loss is less than 1dB.

OCIS codes: (130.3120) Integrated optics devices; (130.4815) Optical switching devices

1. Introduction

The rise of new internet-based services will trigger the demand for more high-speed internet connections in which FTTx will play an important role. Optical switching will be required to manage the complexity of this network infrastructure. While speed is very important for packet switching, applications for optical switching in the access network with a low power consumption and low insertion loss are also necessary. In this paper, we propose a new concept for a switch with a low static power consumption. The concept has the potential for low insertion loss (IL), broad optical bandwidth and low crosstalk (XT).

2. Concept and design

The newly proposed switch concept consists of an adiabatic coupler which is actuated by liquids. A drawing of the coupler and a cross-section is shown in Fig. 1(a) and (b). The 2×2 adiabatic coupler is actuated by two liquids with a different refractive index. The two switching states (as schematically shown in the inset of Fig. 1(a)) are realized by bringing one or the other liquid in contact with the coupler. The liquids could be brought to the coupler by e.g. electrowetting actuation [1]. The advantage of such a system is that in both switch states the liquid can remain on top of the coupler, without presence of an electric field. As a result, a non-volatile bistable optical switch could be realized with zero electrical power consumption in the two switch states.

The oxide cladding on top of the coupler is locally removed by an etching process to expose one waveguide to a changing medium. By applying liquids with a different refractive index on top of the coupler, the effective index

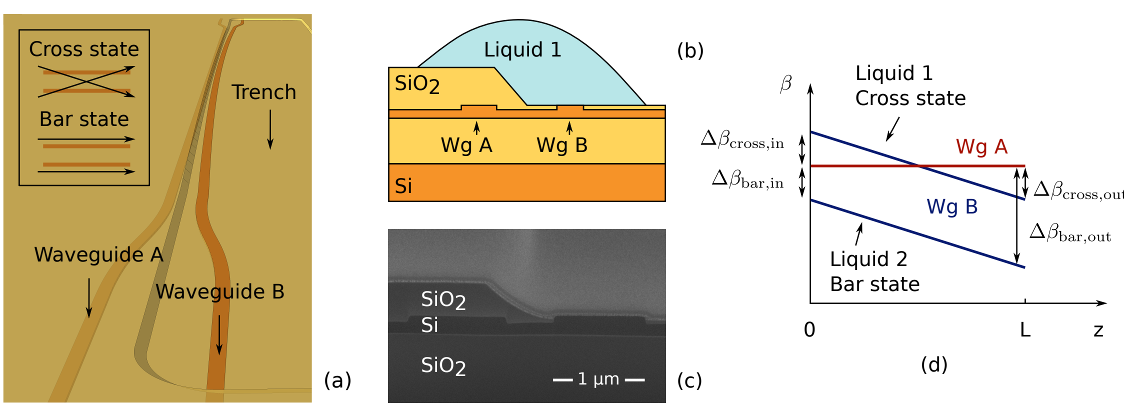

Figure 1: (a) Drawing of liquid controlled adiabatic switch element and (b) cross-section; (c) cross-section SEM picture at middle of coupler; (d) propagation coefficients of the waveguides as a function of distance along the coupler.

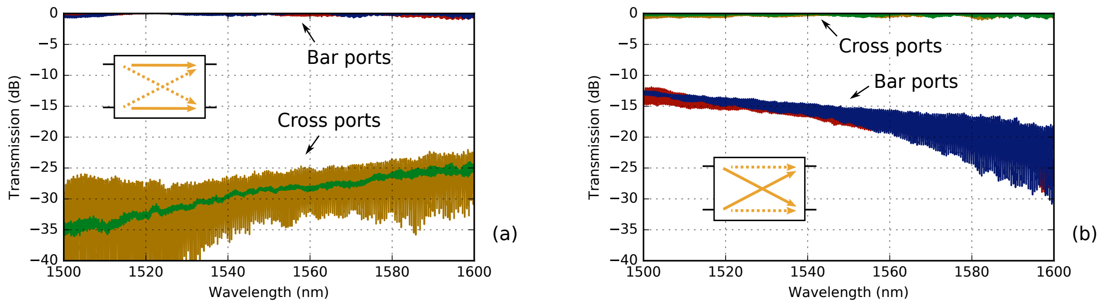

Figure 2: Measured transmission of the fabricated switch in (a) bar and (b) cross state.

of the uncovered waveguide changes. The coupler can be designed such that it is in cross/bar state when a high/low index liquid is on top. The propagation coefficients β of the waveguides are shown in Fig. 1(d). In the cross state, the propagation coefficients of the two waveguides cross each other at the middle of the coupler and light is coupled to the neighboring waveguide. In the bar state, the propagation coefficients of the two waveguides do not cross and the light remains in the same waveguide.

The couplers are designed following a self-consistent orthogonal coupled mode theory as described in [2]. The waveguide width and gap between the waveguides are controlled to achieve a lower crosstalk for the same coupler length compared to more traditional design approaches. The larger $\Delta\beta$ at the input and output position of the coupler, the lower the IL and XT can be. This can be realized by liquids with a large difference in refractive index (n_{liq}).

The coupler is designed for $n_{\text{liq}} = 1.42$ for the bar state and $n_{\text{liq}} = 1.63$ for the cross state. Refractive indices are mentioned at a wavelength of 1550 nm. In both switch states the simulated IL is lower than 5 mdB over 100 nm wavelength range (assuming no absorption and scattering losses). In cross state a XT better than −30 dB is obtained over the same wavelength range and in bar state the XT is even better than −80 dB. The latter is particularly interesting for switch networks which are designed to have most couplers in bar state. The length of the coupler is 1.4 mm.

3. Fabrication and characterization

The coupler is fabricated on SOI with 2 µm buried oxide and a 220 nm silicon top layer using 193 nm optical lithography [3]. The waveguides are defined by a 70 nm partial etch. All waveguides are covered by a SiO_2 layer which is planarized and uniformly etched to a thickness of 450 nm. A trench is then created above one of the waveguides by optical lithography and buffered oxide etching. A scanning electron microscope (SEM) picture of a cross-section at the middle of the coupler is shown in Fig. 1(c). The coupler ports are connected to fiber grating couplers.

Measurement results of the two switching states are shown in Fig. 2. Port names are indicated in the inset. The input light is TE polarized. The transmission measurements are normalized with respect to a straight waveguide to exclude the response of the fiber grating couplers. In Fig. 2(a) the switch is in bar state with a low index liquid ($n_{\text{liq}} = 1.42$) on top. The XT is lower than −22 dB from 1500 nm to 1600 nm. In Fig. 2(b) the switch is in cross state with a high index liquid ($n_{\text{liq}} = 1.67$) on top. The XT is lower than −12 dB. The IL for cross and bar state over the measured wavelength range is lower than 1 dB after the normalization. The interference pattern visible at the output port with low power transmission is due to unwanted coupling of light to the second input fiber grating coupler.

4. Conclusion

A new concept of a liquid controlled, adiabatic 2×2 switch element has been proposed and realized. The switch actuation is performed by two liquids with a different refractive index applied sequentially on top of the coupler. By exposing one waveguide of an adiabatic coupler structure to the liquids, a switch element was realized with low XT and IL over a wide bandwidth. The realized switch has a XT lower than −22 dB in bar state and −12 dB in cross state and an IL lower than 1 dB over the wavelength range 1500 nm to 1600 nm. An adiabatic coupler actuated by liquids, which potentially has zero static power consumption, could be a promising alternative to previous optical switch approaches.

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