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Numerical Demonstration of InP 1xN Planar Optical Switch Based on Beam Deflection

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1. Introduction

Optical packet switching (OPS) network is expected to be one of the most important systems recovering future internet traffic which exceeds 1 Pb/s [1]. NxN optical matrix switch which consists of 1xN and Nx1 optical switches is a key element of the OPS systems. [2]. A lot of optical switching methods have been proposed and various types of optical switches have been demonstrated so far [1]. Among them, an electro-optical switch has a capacity of high-speed switching and low power consumption, which is suitable for the OPS systems. In addition, it is important that these optical switches have a simple and scalable structure and are operated with an easy control, which makes the OPS systems much efficient.

In this paper, we propose an InP 1xN planar optical switch which consists of aspheric lenses and carrier-injected tunable prisms integrated in a slab waveguide and demonstrate its 1x3 static switching operation numerically. An input light is switched only by a deflection of the tunable prism, which does not require complex control. The scalability, easy fabrication, operation, and low power consumption of the device are useful for the future OPS systems.

2. Switch Structure and Design

The schematic and the layer structures of the proposed 1x3 switch are shown in Fig. 1. As shown in Fig. 1(b), the device is consisted of 350 nm-thick n-doped InP substrate, 300 nm-thick n-doped InP bottom cladding layer, 500 nm-thick undoped InGaAsP core layer, 50 nm-thick undoped InP, 8 nm-thick InGaAsP etch stopped layer, 250 nm-thick undoped InP, and 900 nm thick doped InP upper layer. Lenses are formed by etching the upper InP cladding layer of a slab waveguide, which decreases the effective index [3]. The first lens focuses the input light, and the second lens collimates the light. The third lenses which locate near the output ports focus the propagated light to the outputs. The prisms are created by Ti/Au electrode for carrier injection. In addition, a deep-etched region is newly introduced on both sides of the second lens in order to remove the residual input lights as shown in Fig. 1(a) and improve extinction ratio.

A switching mechanism is described using Fig. 1(a). First, the input light enters the slab region and is dispersed spatially. It is focused by the first lens and collimated by the second lens. Although there is some residual light diffracted at the outer bailey of lenses [4], it is separated by the deep-etched region and does not propagate toward the outputs. In order to improve the cross-talk, we use two lenses for collimator which make the beam width of collimated light narrow and suppress the light diffraction. The collimated light is deflected at tunable triangular prisms, where the effective refractive index is modulated by the carrier-plasma effect.

Figure 2 shows the design of an elliptic shape lens and triangular prisms. Long axis of the left side of the first input lens and the left side of the second lens (i, iii) is 201.54 μm. The right side of the first input lens (ii) is 400 μm. The

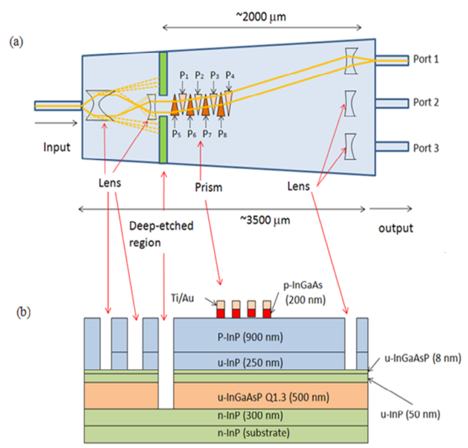

Fig. 1. Schematics of 1xN InP beam-deflecting optical switch: (a) Top-view structure. (b) Layer structure of slab, lens, prism, and deep-etched region.

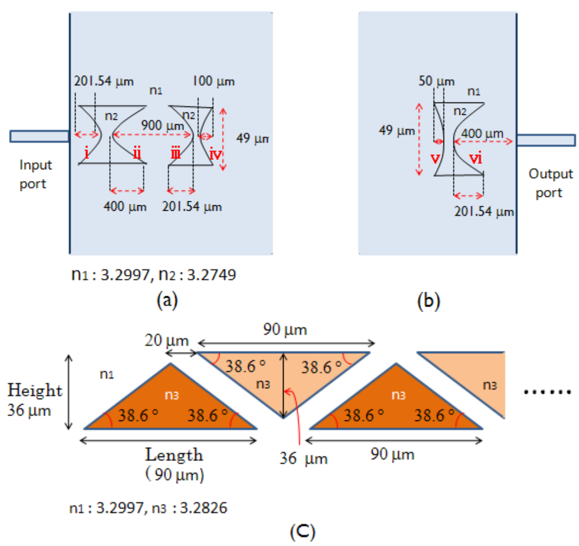

Fig 2. Detail specification of the lenses: (a) Input lenses. (b) An output lens. (c) Triangular prisms.

right side of the second input lens (iv) is 100 µm. The left side of the output lens is 50 µm, and the left side of the output lens is 201.54 µm. Short axes of all lenses are the same, 24.5 µm. The lens is fabricated by etching InP the cladding 1150 um, then the calculated effective refractive index decreases to 3.27 from 3.30.

In the prism region, its effective refractive index is changed by band filling effect and free carrier plasma effect with a sufficient DC current injection [5]. We set the operating point of each tunable prism to 15 mA and the effective refractive index of operating prism is 3.28. We determine the prism design as shown in Fig. 2(c). Reflection angle becomes larger when the length of triangle lengthen or the height of triangle shorten. Because horizontally long prisms take much space of slab region, we considered an adequate prism length, height and angles based on ref.[4]. Reflection angle obtained by one side four prisms is about 4.3 degree.

3. Simulation result

Figure 3 shows the simulation result of the 1x3 static switching operations using 3D-BPM, RSOFT Design Group. When the upper prisms (P5, P6, P7, P8) are activated, the collimated input light deflects and propagate toward the upper port (Fig. 1(a)). Similarly, when the lower prisms (P1, P2, P3, P4) are activated, the input light deflects and coupled to the lower port. When any prisms are not activated, the input light propagates straightforward and coupled to the center port. The static 1x3 switching operation is obtained with a simple DC current control. The optical power at the end of the device for each switching condition is shown in Fig. 4. We obtain the -5dB insertion loss and more than 13 dB extinction ratio. In addition, we expect high-speed switching with several nano-seconds switching time because the modulation principle is based on carrier-plasma effect.

4. Conclusions

We design 1xN planar optical switch based on beam deflection, which consist of aspheric lenses and tunable triangular prisms and demonstrated 1x3 static switching operation numerically. By introducing the deep-etched region, we have efficiently improved the cross-talk from 11 dB to 13 dB with maintaining the insertion loss lower than -5dB. A quite simple switching control of this device is useful for integrated InP optical switch.

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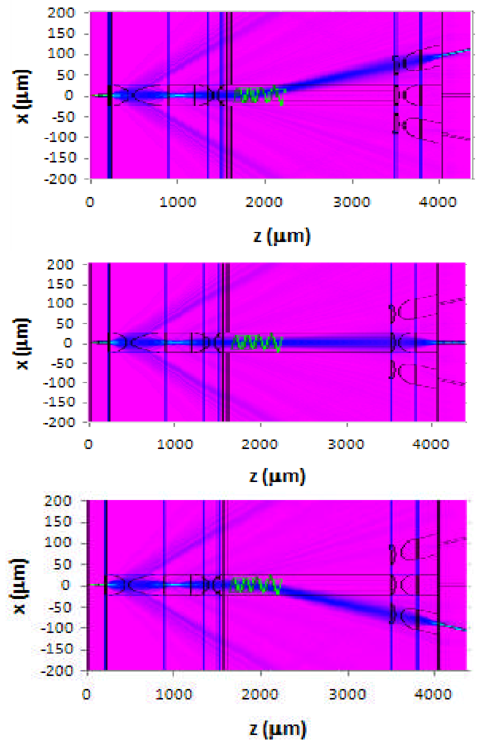

Fig. 3. Beam propagations while (a) P5, P6, P7, P8, are activated, (b) any prisms are not activated, (c) P1, P2, P3, P4 are activated.

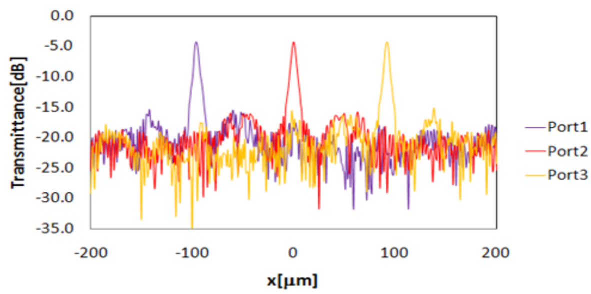

Fig .4. Optical power at the end of the device for each switching conditions.