New Geometrical Shaped EO Deflectors

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Abstract- We present new EO deflectors based on half-horn and parabolic geometries. Experimentally measured deflection angles of 3.1˚ and 3.0˚, respectively are reported. Non-blocking 2x2 optical switch concepts based on these EO deflectors are presented.

1. Introduction

Electro-optic (EO) beam deflectors are electrically-controlled devices which can bend light beams within an active EO medium [1, 2]. They are widely used for applications in optical displays, photographic recording, printing, data storage, laser control, as well as scanning and switching. For example, high-speed, low-loss optical switches for future agile all-photonic networks can be built from EO deflectors. Previously, packaged ultra-fast 1x2 and 1x4 optical switches based on EO deflectors have been demonstrated [3] and two new nonrectangular geometry designs, which are capable of further enhancing the deflection performance of EO beam scanners, are proposed [4]. In this article we propose two new EO deflectors with the half-horn and parabolic configurations, which demonstrate 3.1˚ and 3.0˚ deflection angles, respectively. The concept of design of non-blocking 2x2 optical switches based on these new deflector shapes is also presented.

2. Theories

These EO deflectors are created by EO crystals made in prism forms. The concatenated crystal prisms are obtained by domain inversions using electric-field poling. Applying an external uniform electrical field across the crystal induces an index change of opposite magnitude on the adjacent domain regions (e.g. the dark region within Fig. 1). According to the theory of EO effect, the amount of the index change of $\pm\Delta n = \frac{1}{2} n_0^3 r_{33} \frac{V}{D}$ is achievable. Here, n_0 is the original index; r_{33} is the electro-optic coefficient of the substrate along the z-axis, V is the externally applied electric field along the direction of the dielectric polarization, and D is the thickness of the substrate.

Each prism's vertex follows an optimally designed geometry. Here, two novel geometries, the half-horn shape and the parabola shape, are proposed as shown in Fig. 1. The left sub-figure shows the half-horn shaped envelope and the right one is parabola shaped envelope. After the application of a constant outer field, the trajectory of the light beam incident from Input *A* is diverted, as it travels through the prism shaped regions. Refractive beam deflection occurs at the boundaries of the prisms and the outgoing beam is detected by the receiving collimator *C*. When there is no voltage applied, the incoming light beam from collimator *A* travels along a straight line and is collected by collimator *D*. The deflection angles for the half-horn shaped and parabola shaped devices are given by (based on the non-rectangular geometries' design in [3]):

$$\theta_{half-horn} = 2\sqrt{\frac{2\Delta n}{n_0}\ln\left(\frac{W_{L/2}}{W_0}\right)} \qquad \text{and} \qquad \theta_{parabola} = \frac{\Delta n L}{n_0 W}$$

Here L is the length of the device. W is the height of each prism of the parabola shaped device. $W_{L/2}$ of the half-horn shaped device is the height of the largest prism, while W_0 is the height of the smallest prism.

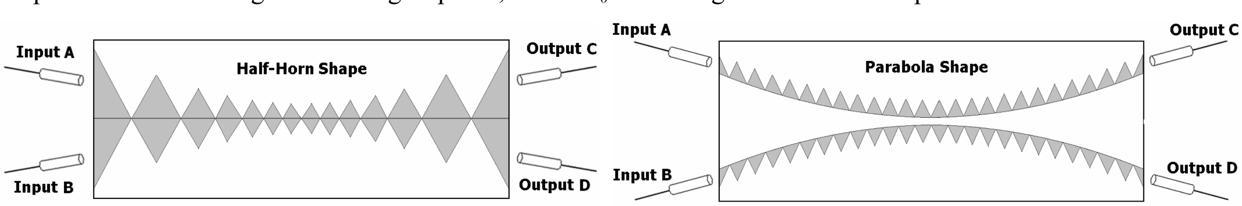

Fig. 1. The schematic of the deflectors: Right: half-horn shaped deflector; Left: parabola shaped deflector.

Non-blocking 2x2 optical switches can be constructed based upon these deflectors. A second incident collimator *B* is introduced into the deflectors (Fig. 1). The light beam from B travels along a straight line and is detected by collimator *C*, when there is no outside voltage. If a stable voltage is put on, the light beam incoming from *B* will travel alongside the pre-defined half-horn (or parabola) trajectory and is collected by collimator *D* at the output. The bar and cross status of the switches can be obtained, as shown in Fig. 2.

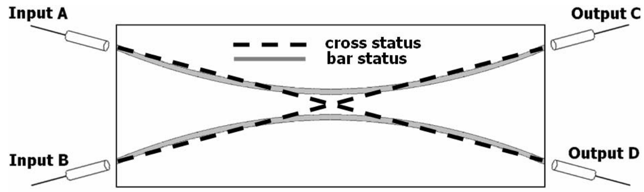

Fig. 2. The cross and bar status of the non-blocking optical switch based on the EO deflectors

3. Experimental Results

The devices are built using a 500μm z-cut $LiTaO_3$ single crystal wafer, and the prism geometries were fabricated using the domain inversion method. A 1310nm, linearly polarized, fiber coupled laser source, PM collimators, and IR cameral are used to test the device. The input collimators are strictly aligned tangent to the trajectory curve at the point of the incidence and are thus positioned at fixed angles with respect to the input facet of the crystal. Suppose that the light is captured as output spot *C*, when a 1kV voltage is applied; and that the light is captured as the output spot *D*, when there is no external filed. Two output spots, *C* and *D*, from incident beam *B* of the half-horn shaped device are shown in Fig. 3. The deflection angles are calculated from the distance measurements of these two output spots when the light beam is launched from *A* or *B*. Table I gives the deflection angles for the two EO deflectors. The deflection angles are very large compared to those produced by usual rectangular devices [4]. The experimentally measured angles are the largest angles of deflector ever reported for a bulk EO deflector.

Fig. 3. Two output spots from the incoming B in the half-horn shaped deflector

Table 1. The theoretical deflection angles and the test results of the EO deflectors

EO deflectors		Theoretical Value	Test result
The half-horn shape	The tilted angle of incident collimators	1.72º	1.6º
	The deflection angle of incoming beam A	3.44º	3.2º
	The deflection angle of incoming beam B	3.44º	3.0º
The parabola shape	The tilted angle of incident collimators	2 º	1.4º
	The deflection angle of incoming beam A	4º	3.1º
	The deflection angle of incoming beam B	4º	2.9º

5. Conclusions

We present new EO deflectors based on half-horn and parabolic geometries. Experimentally measured deflection angles of 3.1˚ and 3.0˚, respectively, are demonstrated, which exceed all other reported angles for a bulk EO deflector. Non-blocking 2x2 optical switch concepts based on these EO deflectors are also presented.

References:

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