A LONG-TERM STABILITY MEASUREMENT ON THE CONVERSION EFFICIENCY OF ZN-INDIFFUSED LINBO$_3$ MODE CONVERTER

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Abstract: *A long-term stability measurement on the conversion efficiency of an x-cut Zn-indiffused lithium niobate mode converter has been performed at a wavelength of 0.632 μm for the first time. According to the experimental results, the bias-polarity dependence on the stability of conversion efficiency has been observed and discussed. Finally, the optimized phase-matching and mode-conversion voltages are 12 V and –5 V, respectively, the stable conversion efficiency of about 99.5% can be achieved in a period of 60 minutes.*

1. Introduction

The commercial lithium niobate (LN) waveguide devices operating in the infrared wavelengths were widely used in fiber optical communications. Since the LN waveguides easily suffer from the optical damage due to photorefractive effects in the visible wavelengths, and also the input power levels are limited even in the infrared wavelengths under high irradiated powers [1]. In the optical waveguide sensors, a He-Ne laser of 0.632-μm wavelength is often used as a light source. In order to obtain reproducible and stability during optical measurements, it is essential to use a stable waveguide device with enough throughput power for providing a sufficient signal to noise ratio to the received photo-detectors. Although a proton-exchanged (PE) waveguide has a higher resistant to the optical damage than that of the Ti-indiffused (TI) one [2], the PE waveguides support only an inherently extraordinary polarization, which can not be applied to a dual-polarization guiding device such as a polarization phase modulator or a mode converter [3]. In comparison with the conventional TI waveguides, the metallic Zn-indiffused (ZI) waveguides not only have better resistant to photorefractive effects, but also have the same dual-polarization guiding capabilities [4]. In this paper, a long-term stability measurement on the conversion efficiency of an x-cut ZI LN mode converter has been performed at a wavelength of 0.632 μm for the first time. According to the experimental results, the bias-polarity dependence on the stability of conversion efficiency has been observed and discussed.

2. Experiments

Similar to the device structure as proposed in [3], the geometry of this device consists of a channel waveguide of 4 μm-wide and 22 mm-long with three parallel electrodes, which was formed parallel to the z axis on an x-cut LN substrate. The central electrode width W_C is 8 μm; the electrode gaps G_C between the center and the two outer electrodes are also 8 μm. The length of electrodes L is 15 mm. To fabricate a single-mode waveguide for both TE and TM polarizations, a 35 nm Zn-strip with a predeposition Ni film of 6 nm is formed. After thermal diffusion of 850°C for 150 min, and substrate end faces polished, a silicon dioxide (SiO_2) buffer layer of 300 nm was deposited. Then an Al electrode of thickness 300 nm was deposited and patterned. One of the outer electrodes V_2 is grounded (V_2 = 0 V), and two independent voltages V_C and V_1 can be applied to the center and the other outer electrode, respectively.

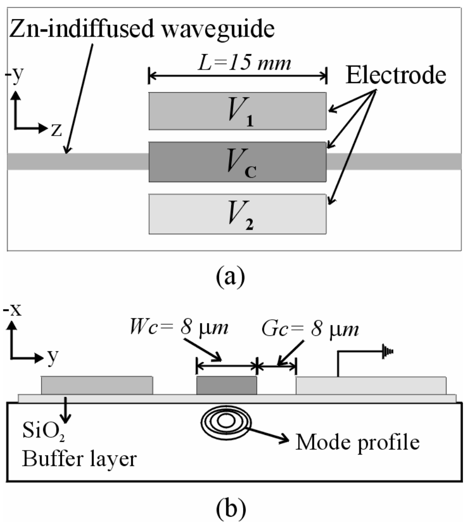

Fig. 1. Device structures for (a) top view, and (b) cross section view.

3. Results and discussions

Figure 2 shows the long-term stability measurements under a throughput power of 25 μW measuring after the output coupling lens at the wavelength of 0.632 μm. An applied phase-matching voltage of V_1 = 12 V, and a continuous saw-tooth voltage V_C with a frequency of 10 Hz were used to measure the conversion characteristics. To achieve a complete conversion from input TM polarization to output TE polarization, the maximum conversion efficiency of about 99.5% is obtained at V_C = +6 V, V_C = −5 V as shown in Fig 2(a).

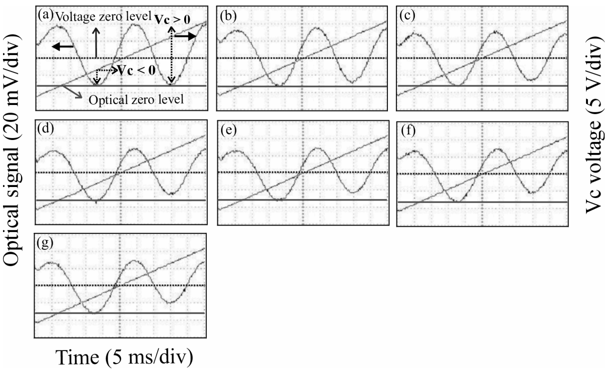

Fig. 2. Long-term stability measurements on the conversion performance at different measured times. (a) Initial, (b) 10 min, (c) 20 min, (d) 30 min, (e) 40 min, (f) 50 min, and (g) 60 min.

It is found that the maximum conversion is gradually reduced as an increase of illuminating time at the applied mode-conversion voltage of V_C = +6V. However, the maximum conversion is stable at the applied voltage of V_C = −5 V. The mechanism of a time-dependent change on the conversion efficiency can be explained according to Fig. 3. Basically, the layered structures of V_C electrode, silicon dioxide, and LN substrate are similar to that of a metal-oxide-semiconductor (MOS) device. In the case of $V_C > 0$ (V_C = +6 V), there are negatively voltage-induced charges, which accumulated under the SiO_2 layer, and near the top edge of the waveguide mode. At the same time, the negatively photo-excited carriers that generated from the Fe^{2+} sites, due to photorefractive effects, will be spatially separated under a bias difference between V_1 and V_2. The photo-excited carriers can produce a net electric field to reduce the electric field strength driven by the external applied voltage V_1. Therefore, the conversion efficiency is gradually reduced from 99.5% to 81.2% over an illuminating time of 60 min as shown in Fig 2 (b)−(g). This means that the amount of the photo-excited carriers is increased as well as the illuminating time. However, in the case of $V_C < 0$ (V_C = −5 V), the positively voltage-induced charges can possibly trap most of the photo-excited carriers. There is no induced electric field to reduce the electric field driven by the applied voltages V_1. Thus, the unchanged phase-matching conditions can maintain a stable mode conversion in the long-term operations.

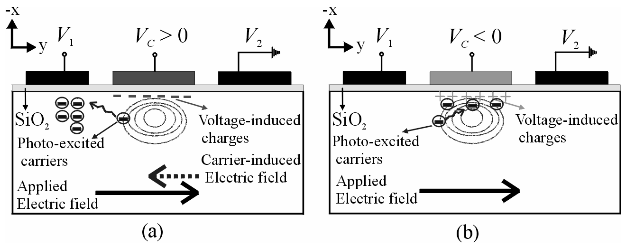

Fig. 3. A schematic explanation for the carrier-induced electric field due to the photorefractive effects: (a) $V_C > 0$ and (b) $V_C < 0$.

4. Summary

We report on the long-term stability measurements on the conversion efficiency of an x-cut Zn-indiffused LN mode converter. The stable operations can be achieved by using suitable voltage polarity for complete mode conversion. This technique is very attractive to be using in the integrated waveguide sensors with stable power handling and polarization controlling, especially in the visible wavelength region.

Acknowledgement

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