Adiabatic Polarization Rotator-Splitter based on Thin-Film Lithium Niobate Platform

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***Abstract*—We demonstrated a fully adiabatic TFLN-based PRS with large fabrication tolerance. The proposed PRS using standard i-line photolithography achieved a large PER of > 20 dB across the whole C-band.**

Keywords—polarization rotator-splitter, thin-film lithium niobate, adiabatic coupler

I. Introduction

Polarization sensitivity is an important factor restricting the development of photonic integration. Polarization rotator-splitter (PRS) is an ideal solution to this problem. Moreover, with the development of higher-order modulation, the PRS as the core element of polarization multiplexing is worthy of further study. Recently, with the successful realization of various lithium niobate (LN) electro-optic devices, thin-film lithium niobate (TFLN) has become a promising platform for future electro-optical integrated circuits [1-3].

In this paper, we demonstrated a fully adiabatic PRS based on TFLN. Two-step mode conversion is used to realize the TM_0-TE_1-TE_0 transition. The adiabatic taper was used to realize the mode conversion of TM_0 to TE_1. The adiabatic coupler was used to separate TE_1 and TE_0. The proposed device is fabricated by standard i-line photolithography, which is more competitive with lower cost and faster production than electron beam lithography (EBL). The PRS demonstrates a polarization extinction ratio (PER) of >20 dB across the whole C-band. When the width changes ±150 nm, it still has a PER of >15 dB.

II. Design and Manufacture

A. Device structure

The PRS structure is shown in Fig. 1. The blue regions represent the LN waveguide with a height of 300 nm, and the light blue regions represent the LN slab with a height of 100 nm. The ridge waveguide breaks the vertical symmetry of the waveguide, mainly to realize the mode conversion from TM_0 to TE_1. Then the TE_0 and TE_1 are separated using an adiabatic coupler. Compared with asymmetric directional coupler [4], the adiabatic coupler is less sensitive to size and wavelength. Symmetrical SiO_2 cladding is adopted to facilitate integration with other devices. The adiabatic design allows for greater bandwidth and fabrication tolerance.

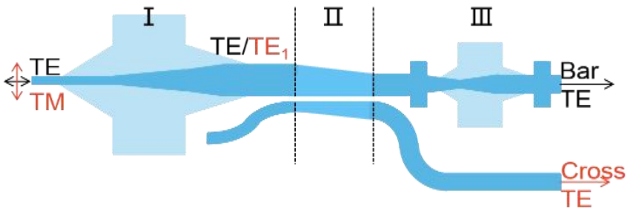

Fig. 1. Schematic structure of the PRS.

B. Polarization rotator of TM_0 to TE_1

The partially etched ridge waveguide structure was used to strengthen the degree of hybridization, which occurs near the width of 1.2 μm, as shown in Fig. 2. In the mode hybridization region, TM_0 and TE_1 cannot be distinguished. As the ridge waveguide continuously widens, the effective index difference between the second largest refractive index mode (mode 2) and the third largest refractive index mode (mode 3) allows a TM_0 input to remain in mode 2 and evolve into TE_1 finally. At the same time, the TE_0 input does not change the polarization state. A tapered slab is a transition between the fully etched and partially etched regions.

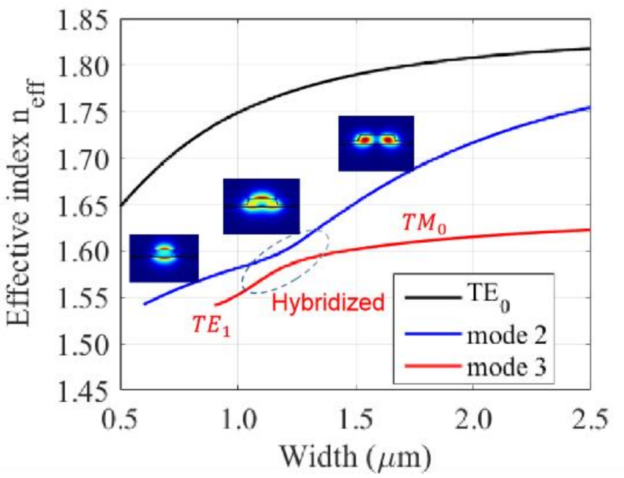

Fig. 2. The effective index of ridge waveguide as the width varies.

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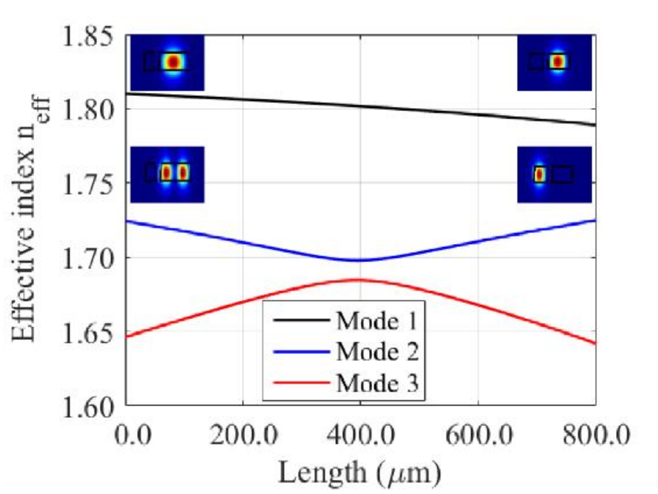

Fig. 3. The effective index of supermode in the adiabatic coupler.

C. Adiabatic Coupler

The adiabatic coupler relies on the principle of mode evolution. The phase matching widths of two waveguide ($n_{eff,TE_1,wide\ waveguide} = n_{eff,TE_0,narrow\ waveguide}$) were selected as the center widths of the adiabatic coupler. The start and end widths satisfy $n_{eff,TE_1,input} = n_{eff,TE_0,cross\ output}$ and $n_{eff,TE_1,bar\ output} = n_{eff,TE_0,cross\ input}$, which are conducive to shortening the total length while maintaining high performance. The effective index of supermode in the adiabatic coupler is shown in Fig. 3. The TE_0 outputs from the bar port, while the TE_1 transmits adiabatically to the TE_0 output from the cross waveguide.

D. MMI Filter

The polarization extinction characteristic of the bar port is mainly affected by the residual TM_0 and TE_1. After the adiabatic coupler, we add the first 1×1MMI to filter out the TE_1. Then add the mode conversion area and the second 1×1 MMI to filter the residual TM_0. The polarization extinction characteristic of the cross port is mainly affected by the crosstalk of TE_0 input. The extinction ratio of the cross port can reach 30 dB at the current width.

The proposed PRS is fabricated by standard i-line photolithography, the microscope picture is shown in Fig. 4.

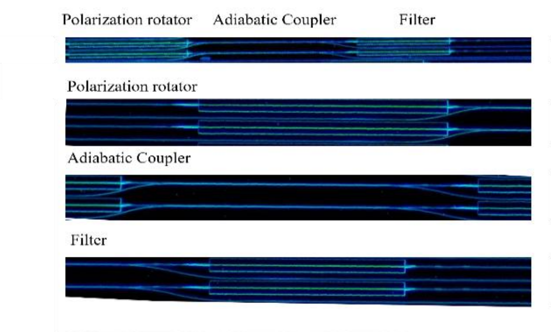

Fig. 4. Microscope picture of the PRS.

III. Measurement

The polarization extinction ratio (PER) is defined as the power ratio when TE_0 and TM_0 mode input, respectively. By adjusting the angles of the polarization controller, TE_0 mode input or TM_0 mode input can be realized. As shown in Fig. 5, the PERs of both ports are higher than 20 dB over the wavelength range of 40 nm. Due to the light source conditions, we estimate that the extinction ratio will still be high over a wider wavelength range. At the same time, we test the transmission performance at the width change of ±150 nm. As shown in Fig. 6 and Fig. 7, the PER is higher than 18 dB and 15 dB, respectively. Therefore, our device has a large fabrication tolerance.

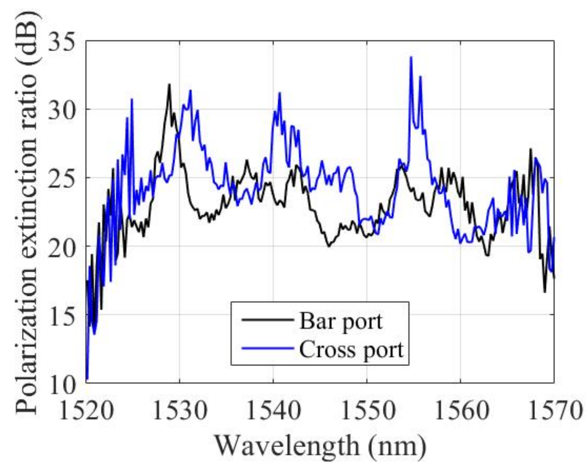

Fig. 5. Measured PERs as a function of wavelength.

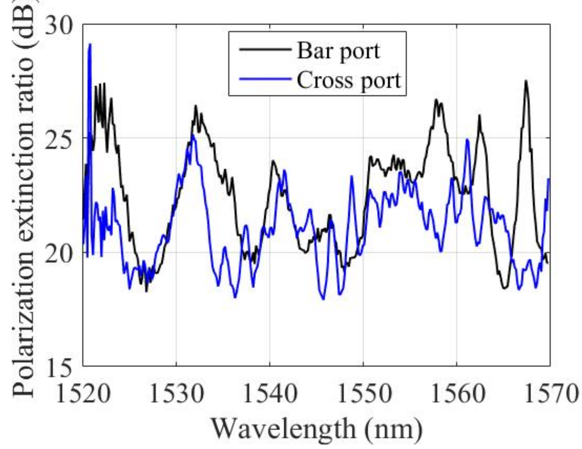

Fig. 6. Measured PERs at δ= +150 nm width change.

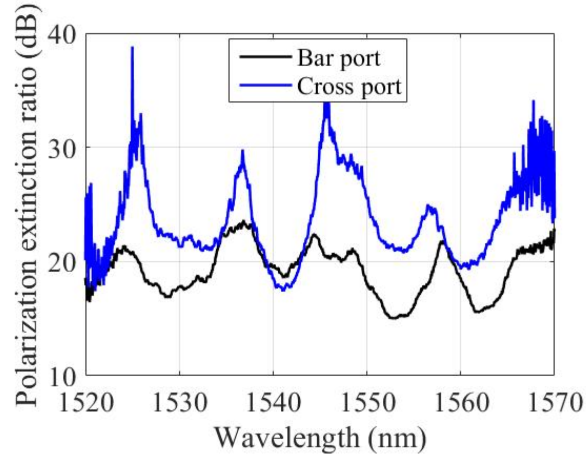

Fig. 7. Measured PERs at δ= -150 nm width change.

IV. Conclusion

In summary, we demonstrate a TFLN-based PRS. The proposed device is fabricated by standard i-line photolithography. The PERs of both ports are greater than 20 dB in the wavelength range of 40 nm, which reflects the excellent wavelength characteristics of the adiabatic device. In addition, when the width is changed by ±150 nm, the extinction ratio of the bar port and the cross port can be greater than 15 dB and 18 dB, respectively. The PRS proposed above is an attractive candidate for polarization multiplexing based on the TFLN photonic integration platform.

References

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