Silicon Nitride Waveguide Polarization Components for Rubidium Saturated Absorption Spectroscopy On-Chip

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Abstract: A silicon nitride waveguide polarization rotator and polarization beam splitter that operate with a polarization extinction ratio close to 30 dB at the rubidium atomic transition of 780 nm wavelength are demonstrated.

1. Introduction

Quantum technologies are benefiting from the size, weight, power, and cost reduction provided by silicon technology [1]. Research has now intensified on even smaller form factors by leveraging photonic integrated circuits (PICs). For quantum systems based on atoms such as Rb, silicon nitride (Si_3N_4) waveguides can provide low loss propagation and high-Q ring resonators [2]. Figure 1 shows a schematic diagram of an envisaged PIC for saturated absorption spectroscopy for laser stabilization on-chip. By utilizing a PR and PBS this can create a counter-propagating pump and probe with the pump filtered from returning to the laser. PR and PBS waveguide devices have been extensively studied on the silicon-on-insulator platform. There has been recent Si_3N_4 PR and PBS with the smallest wavelength demonstration operating within the O-band (1260-1360 nm). In this work, we present a Si_3N_4 PR and PBS operating at the Rb atomic transition of 780 nm with a polarization extinction ratio ~ 30 dB and corresponding insertion loss ≤ 1 dB.

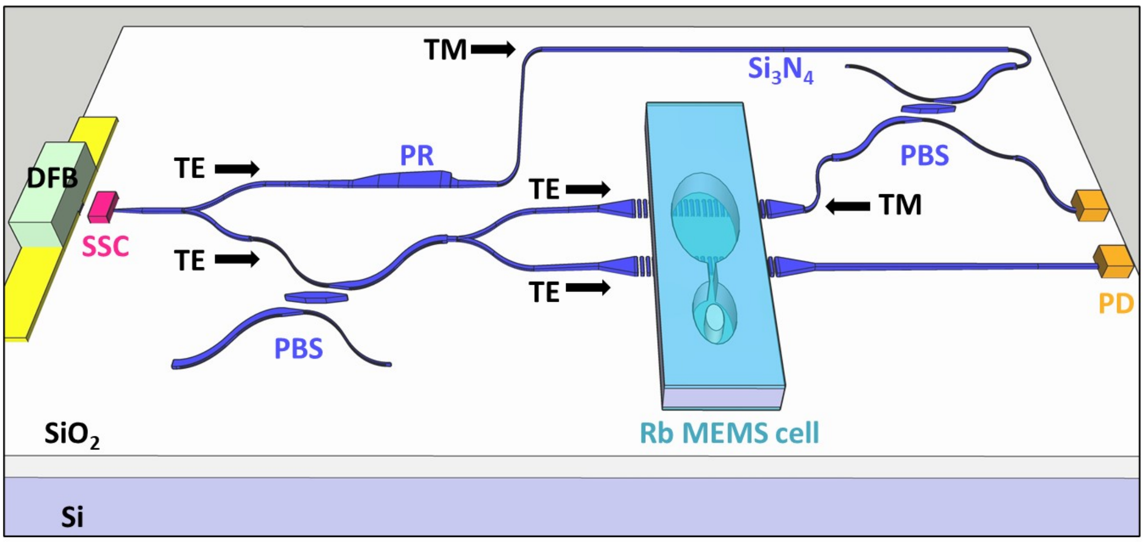

Fig. 1. A schematic diagram of a photonic integrated circuit for saturated absorption spectroscopy of rubidium atoms on-chip using Si_3N_4 waveguides. The key components include a Si_3N_4 waveguide polarization rotator (PR) and a polarization beam splitter (PBS), distributed feedback laser (DFB), Rb vapor MEMS cell, and photodetectors (PD).

2. Design and Characterization

The PR design is based on the mode evolution approach, where adiabatic tapers can efficiently convert between a TM and TE mode (see inset of Fig. 2 (a)). This approach has recently demonstrated a PR with record bandwidth and fabrication tolerance [3]. The PBS design consists of a cascaded tapered asymmetric directional coupler (see inset of Fig. 2 (b)). A self-aligned fabrication process was utilized to allow integration of the rib and ridge waveguide structures required for the PR and PBS, respectively. Figure 2 (a) shows the measured PER and IL as a function of the wavelength for the PR. Over the wavelength range where the IL $\leq$ 1 dB (730-840 nm), the PER is $\geq$ 17.5 dB. The PER at 780 nm wavelength is $\sim$ 30 dB. Figure 2 (b) shows the PER for fabricated PBS. The cross port demonstrates a PER $\geq$ 20 dB across the full 140 nm measurement range with it peaking at 30 dB close to 780 nm wavelength. This broadband PER is expected since there is negligible cross-coupling of the TE mode. The main parameter of interest for the cross port is the IL, which is $\leq$ 1 dB between 760 to 810 nm wavelength. The PER for the through port peaks at 27.5 dB at 780 nm wavelength. The PER is $\geq$ 15 dB for a bandwidth of 18 nm.

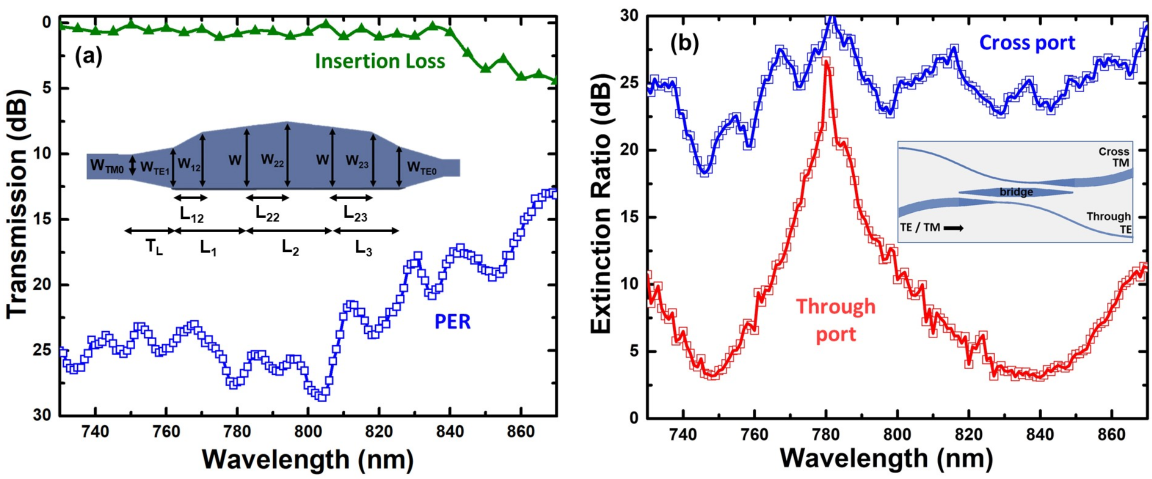

Fig. 2. (a) The experimentally measured polarization extinction ratio (PER) and insertion loss for the fabricated Si_3N_4 waveguide polarization rotator as a function of the wavelength. (b) The experimentally measured PER for the cross and through port of the fabricated Si_3N_4 waveguide polarization beam splitter as a function of the wavelength.

3. Conclusion

A Si_3N_4 waveguide polarization rotator and polarization beam splitter that operates at the Rb atomic transition of 780 nm is presented. These devices are fabricated together on the same chip using a simple self-aligned process for integration of the required rib and ridge waveguide structures. The polarization rotator based on the mode evolution approach using adiabatic tapers demonstrates a polarization extinction ratio (PER) of $\geq$ 20 dB over 100 nm bandwidth (730-830 nm wavelengths) with an insertion loss (IL) $\leq$ 1 dB. The polarization beam splitter is based on a cascaded tapered asymmetric directional coupler design with phase matching engineered between the fundamental and higher-order TM mode, whereas the TE mode is separated by the through port. This approach provides a PER $\geq$ 20 dB over 50 nm bandwidth for the cross port and a PER $\geq$ 15 over 18 nm for the through port. These polarization control waveguide devices have sufficient performance to enable photonic integrated circuits for saturated absorption spectroscopy of atomic vapors for laser stabilization on-chip and other thermal and cold atom photonics packages.

References

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