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Compact broadband polarizer based on shallowly-etched silicon-on-insulator ridge optical waveguides

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Abstract: A new way to make broadband polarizers on silicon-on-insulator (SOI) waveguides is proposed, analyzed and characterized. The characteristics of the eigenmodes in a shallowly-etched SOI ridge optical waveguide are analyzed by using a full-vectorial finite-different method (FV-FDM) mode solver. The theoretical calculation shows that the loss of TE fundamental mode could be made very low while at the same time the TM fundamental mode has very large leakage loss, which is strongly dependent on the trench width. The leakage loss of the TM fundamental mode changes quasi-periodically as the trench width w_{tr} varies. The formula of the period Δw_{tr} is given. By utilizing the huge polarization dependent loss of this kind of waveguide, a compact and simple optical polarizer based on a straight waveguide was demonstrated. The polarizer is fabricated on a 700nm-thick SOI wafer and then characterized by using a free-space optical system. The measured extinction ratio is as high as 25dB over a 100nm wavelength range for a 1mm-long polarizer.

OCIS codes: (230.7390) Waveguides, planar; (230.5440) Polarization-sensitive devices.

References and links

1. Y. Kokubun, and S. Asakawa, "ARROW-type polarizer utilizing form birefringence in multilayer first cladding," IEEE Photon. Technol. Lett. **5**(12), 1418–1420 (1993).
2. L. Pierantoni, A. Massaro, and T. Rozzi, "Accurate modeling of TE/TM propagation and losses of integrated optical polarizer," IEEE Trans. Microw. Theory Tech. **53**(6), 1856–1862 (2005).
3. M. A. Duguay, Y. Kokubun, T. L. Koch, and L. Pfeiffer, "Antiresonant reflecting optical waveguides in $Si0_2$-Si multilayer structures," Appl. Phys. Lett. **49**(1), 13–15 (1986).
4. T. Yamazaki, J. Yamauchi, and H. Nakano, "A branch-type TE/TM wave splitter using a light-guiding metal line," J. Lightwave Technol. **25**(3), 922–928 (2007).
5. L. Z. Sun, and G. L. Yip, "Analysis of metal-clad optical waveguide polarizers by the vector beam propagation method," Appl. Opt. **33**(6), 1047–1050 (1994).
6. G. Y. Li, and A. S. Xu, "Analysis of the TE-pass or TM-pass metal-clad polarizer with a resonant buffer layer," J. Lightwave Technol. **26**(10), 1234–1241 (2008).
7. R. Wan, F. Liu, X. Tang, Y. Huang, and J. Peng, "Vertical coupling between short range surface plasmon polariton mode and dielectric waveguide mode," Appl. Phys. Lett. **94**(14), 141104 (2009).
8. R.-C. Twu, C.-C. Huang, and W.-S. Wang, "TE-pass Zn-diffused $liNbO_3$ waveguide polarizer," Microw. Opt. Technol. Lett. **48**(11), 2312–2314 (2006).
9. Y. Cui, Q. Wu, E. Schonbrun, M. Tinker, J.-B. Lee, and W. Park, "Silicon-based 2-D slab photonic crystal tm polarizer at telecommunication wavelength," IEEE Photon. Technol. Lett. **20**(8), 641–643 (2008).
10. A. d'Alessandro, B. Bellini, D. Donisi, R. Beccherelli, and R. Asquini, "Nematic Liquid Crystal Optical Channel Waveguides on Silicon," IEEE J. Quantum Electron. **42**(10), 1084–1090 (2006).
11. D. Liang, and J. E. Bowers, "Recent progress in lasers on silicon," Nat. Photonics **4**(8), 511–517 (2010).
12. Q. Wang, and S. T. Ho, "Ultracompact TM-pass silicon nanophotonic waveguide polarizer and design," IEEE J. Photon. **2**(1), 49–56 (2010).
13. A. A. Oliner, S. T. Peng, T. I. Hsu, and A. Sanchez, "Guidance and leakage properties of a class of open dielectric waveguides: Part II-New physical effects," IEEE Trans. Microw. Theory Tech. **29**(9), 855–869 (1981).
14. K. Ogusu, "Optical strip waveguide: a detailed analysis including leaky modes," J. Opt. Soc. Am. **73**(3), 353–357 (1983).
15. M. A. Webster, R. M. Pafchek, A. Mitchell, and T. L. Koch, "Width dependence of inherent tm-mode lateral leakage loss in silicon-on-insulator ridge waveguides," IEEE Photon. Technol. Lett. **19**(6), 429–431 (2007).

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1. Introduction

Polarization multiplexing and demultiplexing are important in photonic integrated circuits (PICs) for fiber optic communication, optical sensing, and optical signal processing. The devices used for polarization handling include polarization beam splitters, polarization rotators, and polarizers. Conventional bulk polarizers are usually based on a birefringent bulk crystal, however, an integrated waveguide polarizer is needed for PICs and, various waveguide polarizers have been developed. The basic principle of the polarizer is to make one polarization more lossy than the other one. In order to have such polarization dependent loss (leakage losses or absorption losses), a waveguide with birefringent materials or structures is used. In Ref [1-3], an antiresonant reflecting optical waveguide (ARROW) structure is used for realizing a polarizer. In the ARROW structure, the radiation loss of TM polarization is over 50dB/cm higher than TE polarization. However, this type of polarizer is usually long (~1cm) and the fabrication is relatively complex because an additional thin high-index cladding is needed. Metal is also often used to realize a polarizer because the strong polarization dependence of the plasmonic modes in a metal-dielectric waveguide [4–6]. In ref [7], a TE-pass polarizer is presented by utilizing the vertical coupling between short range surface plasmon polariton mode and dielectric waveguide mode. The theoretical calculation shows that it possible to realize a high extinction ratio of 30dB and a low loss of 0.1dB by using a rather short length of 50μm. However, this type of polarizer is sensitive to the dimensional variations and the wavelength shift. In ref [8], a TE-pass waveguide polarizer is realized by utilizing the process-dependence characteristics of Zn-diffused waveguides on a y-cut, x-propagation $LiNbO_3$ substrate at 1.55-μm wavelength. The best polarization extinction ratio of 32dB/cm and the corresponding propagation loss of 0.9dB/cm were obtained. In ref [9], a photonic-crystal type polarizer is demonstrated for the 1550nm wavelength. The transmission loss of the TE light was found to be 45 dB, while that of the TM polarized light is as large as 4.5 dB. Liquid crystals (LC) are also often used to realize a polarizer due to the dependence of the transmission loss on the orientation of the LC molecules [10]. By using E7 nematic liquid crystal (LC) in SiO_2-Si V-grooves [10], a polarizer with an extinction ratio about 25 dB was demonstrated. However, the fabrication and the package become complicated when LC is introduced and the temperature range is limited.

A low-cost and CMOS-compatible polarizer that is compatible with silicon sources and detectors [11] is needed. In ref [12], an ultracompact TM-pass silicon nanophotonic waveguide polarizer was designed. In this paper, we propose and demonstrate a pure silicon TE-passed polarizer based on a shallowly-etched straight optical waveguide. Our polarizer has a very broad wavelength range, which is important for many applications. By optimally designing the shallowly-etched straight optical waveguide, the polarization dependent loss is maximized and consequently a compact polarizer with high extinction ratio is achieved.

2. Characteristic analysis for the shallowly-etched SOI ridge waveguide

Figure 1 shows the cross section of optical waveguide used for the proposed polarizer. Here we use a silicon-on-insulator (SOI) wafer, a key element in most platforms for silicon photonics. For the present case, the optical waveguide is defined with two trenches and the etching depth, h_r, is shallow, e.g., $h_r = 0.15H$~$0.25H$, where H is the total height of the Si layer and we choose $H = 700$nm for our case for compatibility with low loss waveguides and hybrid silicon lasers and modulators. The refractive indices of silicon and SiO_2 are $n_{Si} = 3.455$, $n_{SiO2} = 1.445$, respectively. We use a full-vectorial finite-difference method (FV-FDM) mode solver with the perfect-matched layer (PML) boundary condition. With the FV-FDM mode solver, we can obtain the mode field profile and the propagation constant for all eigenmodes. The leakage loss is calculated with the formula $L_p = 20\log_{10}[\exp(-n_{im}k_0l_0)]$, where n_{im} is the imaginary part of the effective index for the fundamental mode, k_0 is the wave number in vacuum ($k_0 = 2\pi/\lambda_0$), and l_0 is the device length (here $l_0 = 1$mm).

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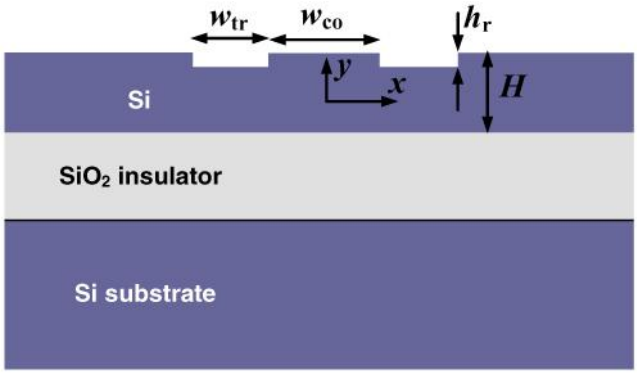

Fig. 1. The cross section of a shallowly-etched SOI ridge waveguide defined by two trenches.

First we consider the case of h_r = 140nm and w_{co} = 0.8μm as an example to show the mode properties of the shallowly-etch SOI ridge waveguide. Figure 2(a)-2(b) show the calculated effective index and the leakage loss for the three eigenmodes with lowest losses as the trench width w_{tr} ranges from 2μm to 7μm. In such a shallow SOI ridge waveguide, the TE fundamental mode (TE_0) has a dominant electric component E_x, which can be seen from the field distribution given in Fig. 3 below. This makes it easy to distinguish the TE_0 mode from the other eigenmodes. However, the situation becomes very different when considering the TM fundamental mode (TM_0) because of mode hybridization. For such hybridized modes, the two transverse components (E_x and E_y) of the electric field are comparable, which makes the TM_0 mode very similar to a higher order TE mode. In order to distinguish the TM_0 mode and the higher order TE modes conveniently, we defined the TM_0 mode as that mode which has larger E_y-component (i.e., $P = \int |E_y|^2 dxdy$, where the integration region is the ridge region).

From Fig. 2(a), the TE fundamental mode behaves like that of a regular optical waveguide. It can be seen that the effective index of the TE_0 mode does not change much as the trench width w_{tr} varies. This is because the TE_0 mode is confined well in the rib region. On the other hand, the leakage loss increases slightly as the trench width decreases, which is easy to understand by making the ridge waveguide equivalent into a multi-layer slab waveguide, which includes two low-index claddings (corresponding to the trench regions), a core layer (corresponding to the ridge regions), and two outermost layers with the same index as the core. When the low-index cladding is not thick enough, the waveguide becomes leaky. This leakage loss decreases exponentially as the low-index claddings become thick.

For the TM fundamental modes, however, the mode property becomes very different, as shown in Fig. 2(a)-2(b). As the trench width varies, the conversion between the TM fundamental mode and the higher order TE mode happens at some specific range of the trench width as denoted by the green circles in Fig. 2(a). In these ranges, the effective indices as well as the loss for these two modes (i.e., the TM fundamental mode and the higher order TE mode) become very similar. This phenomena looks like quasi-degeneracy of modes. From the leakage losses shown in Fig. 2(b), one sees that there are several peaks for the TM fundamental mode and correspondingly there are several dips at the same position for the higher order TE mode. The trench widths for peaks (or dips) are the same as those for the mode conversion denoted by the circles in Fig. 2(b).

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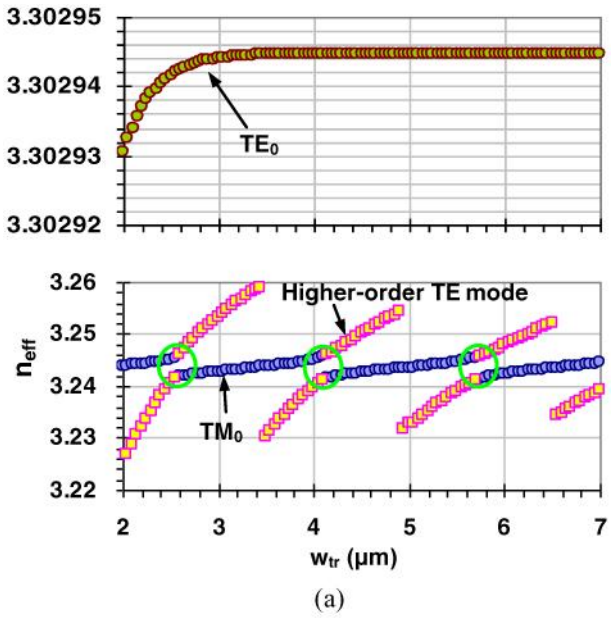
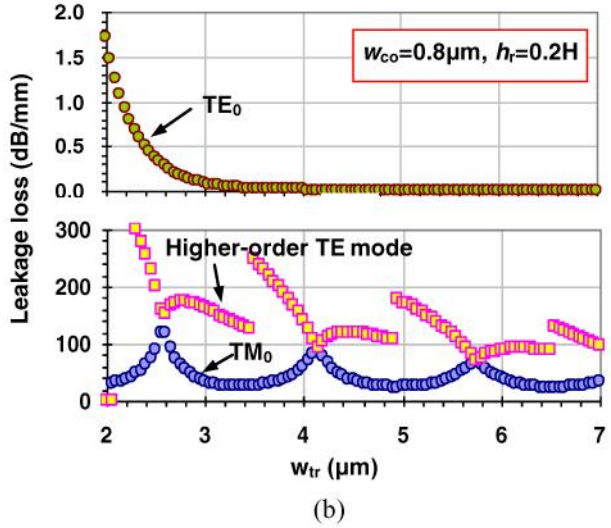


(a)



(b)

Fig. 2. The effective refractive index of the three eigenmodes (a), and the leakage loss for of the lowest three order eigenmodes (b), as a function of trench width.

In order to see the mode evolution in the shallowly-etched SOI ridge waveguide more clearly, we show the electric field profiles of both components (E_x and E_y) for three modes (including the TE_0, TM_0 modes, and the higher order TE mode) in Fig. 3(a)-(c) and Fig. 4(a)-(c). Here we choose two specific trench widths (i.e., w_{tr} = 3.2, and 4.15μm) because the TM fundamental modes for the cases of w_{tr} = 3.2 and 4.15μm have local minimal and maximal leakage losses, respectively (as shown in Fig. 2(b)). From Fig. 3(a) and Fig. 4(a), one sees that the TE_0 mode for w_{tr} = 3.2 or 4.15μm is similar to the regular one, which has a dominant *x*-component (E_x) and a minor *y*-component (E_y). However, for the TM fundamental mode (TM_0) and the higher order TE mode, the mode profiles become very different as discussed above. From the mode profiles shown in Fig. 3(b) and 3(c), one sees that TM_0 and the higher order TE mode are very similar when the trench width is chosen to be around the peaks of the

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leakage loss (e.g., w_{tr} = 4.15μm here). This is the phenomenon of mode quasi-degeneracy. In this case, both the TM_0 mode and the higher order TE mode have significant *x*-component as well as *y*-component. When the trench width is chosen to be deviated from the peaks (e.g., w_{tr} = 3.2μm), one could see the difference between the TM_0 mode and the higher order TE mode more easily. For the TM_0 mode the *y*-component becomes dominant while the *y*-component for the higher order TE mode is minor. One should note that the minor components for the TM_0 mode and the higher order TE mode are still significant. Such mode hybridization is due to the TE-TM coupling at the strip boundaries. According to the analysis given in [13–15], the TE-TM coupling will result in significant leakage loss in a rib waveguide. Recently it has also been demonstrated that the TM polarization mode in an ultra-thin SOI ridge waveguide (~200nm thick) shows width-dependent leakage loss [15]. For the SOI ridge waveguide considered in this paper, a similar phenomenon is also observed, i.e., the TM polarization has significant leakage loss as shown in Fig. 2(b).

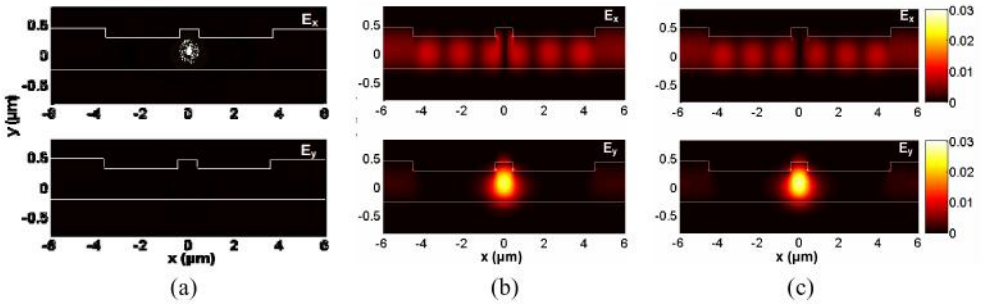

Fig. 3. The mode profiles when w_{tr} = 4.15μm, h_r = 140nm and w_{co} = 0.8μm; (a) TE_0; (b) TM_0; (c) the higher order TE mode.

In the examples shown above, the ridge height is chosen as h_r = 140nm. In order to investigate the influence of the ridge height on the leakage loss, we also calculate the eigen-modes (TE_0 and TM_0) for the cases with different ridge heights (h_r = 110, and 140nm), as shown in Fig. 5(a)-5(b). For any given ridge width w_{co} and trench width w_{tr}, the TE_0 mode has a smaller leakage loss when choosing a larger ridge height h_r. One could also reduce the leakage loss for the TE_0 mode by choosing a wider trench width or ridge width. This is because larger height or width of the ridge introduces stronger optical confinement.

For the TM_0 mode, one sees very different results shown in Fig. 5(a)-(b). For a given core width, the leakage loss changes quasi-periodically as the trench width varies and there are several specific trench widths w_{trj} to have a local maximal leakage loss. For the waveguide with a larger core width w_{co} or a larger etch depth h_r, the quasi-period becomes larger. For the case that the etching depth is very shallow (e.g., h_r~110nm, or 140nm), the maximal leakage loss is close to 120dB/mm when choosing the trench width and the core width appropriately. When a low leakage loss is desired for the TM fundamental mode, one should choose a larger height and width for the rib. The quasi-periodical behavior for the leakage loss shown in Fig. 5(a)-(b) can be explained as follows.

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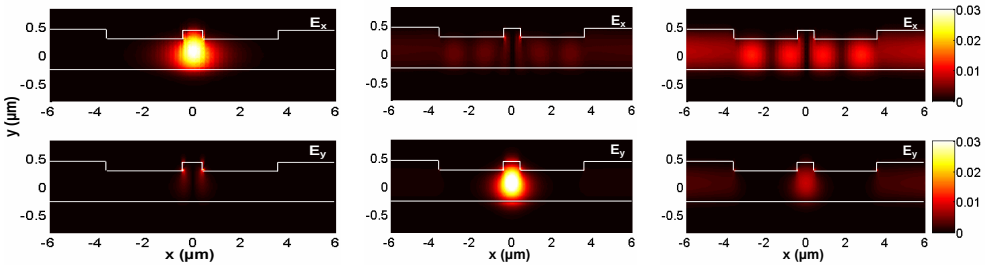

Fig. 4. The mode profiles when w_{tr} = 3.2μm, h_r = 140nm and w_{co} = 0.8μm; (a) TE_0; (b) TM_0; (c) the higher order TE mode.

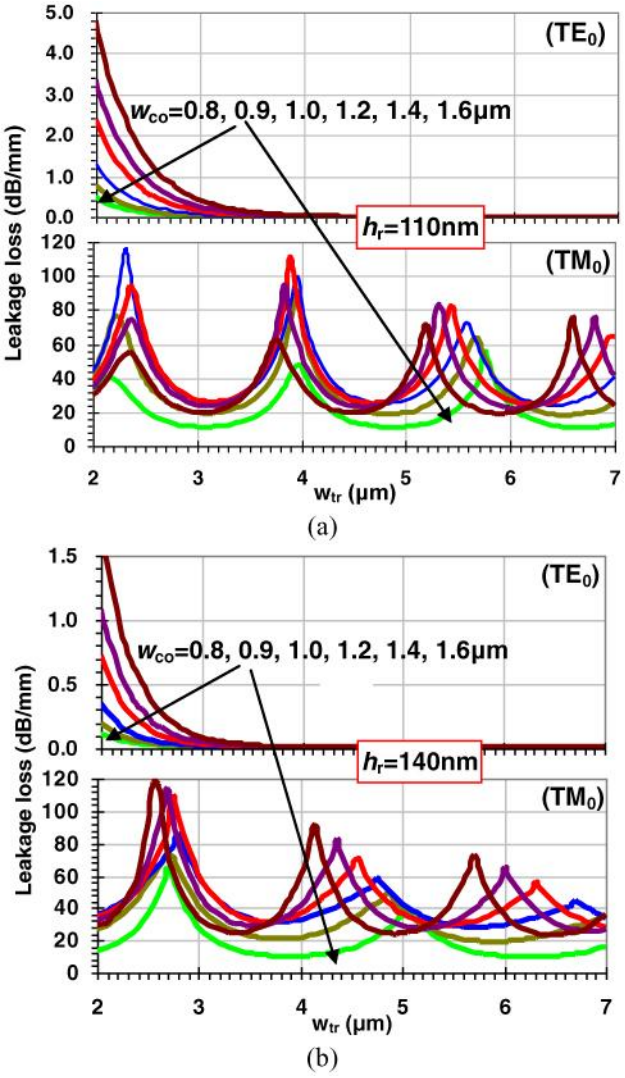

Fig. 5. The leakage losses of the TE_0 mode and the TM_0 mode for the cases of w_{co} = 0.8, 0.9, 1.0, 1.2, 1.4, and 1.6μm as the trench width w_{tr} varies. (a) h_r = 110nm; (b) h_r = 140nm.

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As mentioned above, a simple analysis is possible if the ridge waveguide is analyzed as a multi-layer slab waveguide consisting of two low-index claddings (corresponding to the trench regions), a core layer (corresponding to the ridge regions), and two outermost layers with the same index as the core, as shown in Fig. 6. In the SOI ridge waveguide, there is a TE-TM coupling at the strip boundaries [13–15]. In the equivalent five-layer slab waveguide, when the light incident to the core-cladding boundary (#1) as shown in Fig. 6, a part of the light will be reflected and the other will be converted into the TE mode and go forward. When the TE light hits boundary #2, it will be reflected again and enter the core region again. This is very similar to the behavior of the light interference in a single-layer thin film. In order to have a minimal loss, the interference should be constructive and thus the phase condition is then given by

$$2\sqrt{n_{\mathrm{cl\_neff\_TE}}^2 - N_{\mathrm{TM}}^2}\, w_{\mathrm{tr}} k_0 + \phi_2 - \phi_1 = m2\pi, \tag{1}$$

where k_0 is the wavenumber in vacuum ($k_0 = 2\pi/\lambda$), $n_{\mathrm{cl\_neff\_TE}}$ is the cladding index in the equivalent five-layer slab waveguide for TE mode, N_{TM} is the effective index of the SOI ridge waveguide for the TM fundamental mode, φ_1 and φ_2 are the phase changes when light is reflected at boundary #1 and #2. This formula is similar to those given in ref [13–15]. From Eq. (1), the period for the trench width shown in Fig. 5(a)-(b) is given by

$$\Delta w_{\mathrm{tr}} = \frac{\lambda}{2\sqrt{n_{\mathrm{cl\_neff\_TE}}^2 - N_{\mathrm{TM}}^2}}, \tag{2}$$

When the core width increases, the effective index N_{TM} becomes larger and consequently the denominator in Eq. (2) becomes smaller. Therefore, the period Δw_{tr} is larger, which is consistent with what is seen in Fig. 5(a)-(b). When the rib height become shallow (i.e., the Si height (H-h_{r}) in the trench region is larger), the effective index $n_{\mathrm{cl\_neff\_TE}}$ is larger and consequently one has a smaller period Δw_{tr} (according to Eq. (2)). This is also seen by comparing the results for h_{r} = 110nm, and 140nm shown in Fig. 5(a)-(b). For example, for the cases of h_{r} = 110nm and 140nm, the effective index N_{TM} is 3.243101 and 3.249885, respectively, and the effective index $n_{\mathrm{cl\_neff\_TE}}$ is 3.283214 and 3.297138, respectively. Consequently the period Δw_{tr} calculated by using Eq. (2) are 1.51μm and 1.39μm, which are close to those read from Fig. 5(a)-5(b).

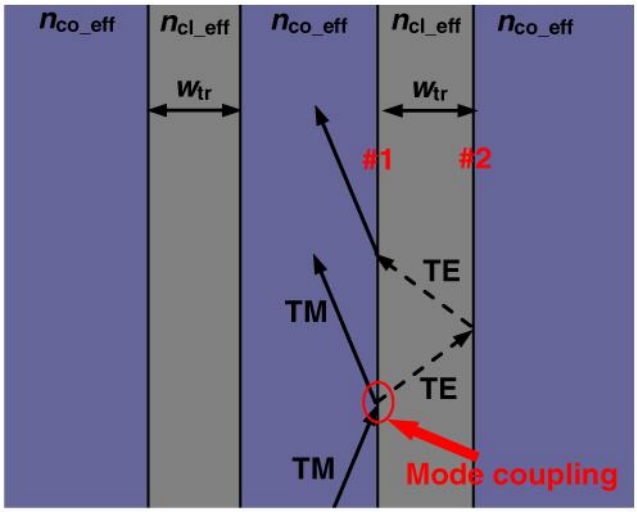

Fig. 6. The equivalent five-layer slab waveguide for the SOI ridge waveguide.

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Figure 7(a) and 7(b) show the calculated leakage losses at 1550nm for TE and TM polarizations as the core width w_{co} ranges from 3μm to 0.8μm. In this calculation, we choose the trench width w_{tr} = 2, 3, 4, and 5μm. For TE polarization, it can be seen that the leakage loss is very low when choosing a relatively large trench with. For TM polarization, as shown in Fig. 7(b), one sees that the leakage loss increases significantly when the core width decreases to about 2μm or less. The trench width also plays an important role for the leakage loss. According to the mode analyses above, one can realize a polarizer with a high extinction ratio by utilizing the huge polarization dependent loss of the shallowly-etched SOI ridge waveguide. For example, the theoretical extinction ratio is over 60dB when using a 1mm-long straight waveguide with w_{tr} = 3μm and w_{co} = 1.1μm.

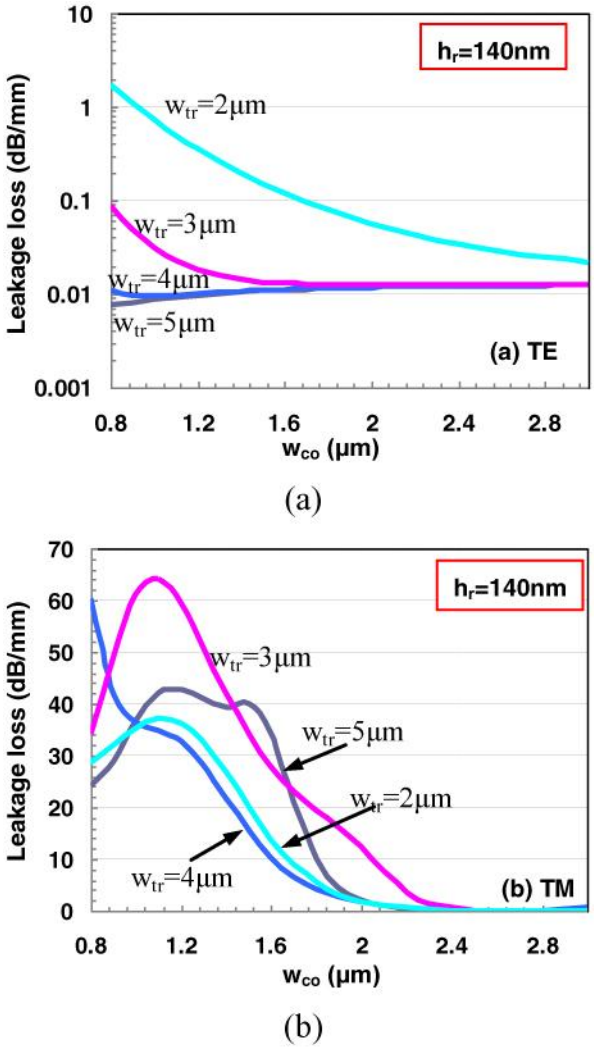

Fig. 7. The leakage loss for TE (a) and TM (b) polarizations for a shallowly-etched SOI ridge waveguide (the rib height h_r = 140nm).

For a polarizer, it is usually desirable to have low loss for the through polarization (e.g., TE polarization for the present case) as well as a compact length. In order to get the optimal design, we consider the requirements of L_{TE}<0.1dB and l<0.1cm, where L_{TE} is the loss for TE polarization and l is the length of the polarizer. For the requirement of L_{TE}<0.1dB, the polarizer length l should satisfy $l < l_{max} = 0.1/L_{TE0}$ where is the loss for TE polarization per

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unit length (dB/mm). Combining with the condition of l<1mm, the length of the polarizer is then given by l = **min**(1mm, 0.1/L_{TE0}). With this length, the extinction ratio of the polarizer is shown in Fig. 8. Theoretically speaking, it is possible to obtain a very high extinction ratio, i.e., >64dB when w_{tr} = 3μm and w_{co} = 1.1μm. Figure 9 shows the wavelength dependence of the leakage loss for TE and TM polarizations of the designed 1mm-long polarizer with w_{tr} = 3μm and w_{co} = 1.1μm. One sees that this polarizer has a very broad-band (1450~1650nm) as well as a high extinction ratio (>50dB).

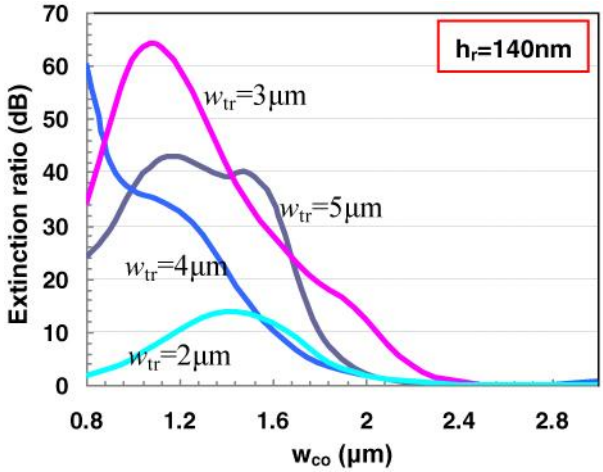

Fig. 8. The extinction ratio for a 1mm-long polarizer with the requirement of L_{TE}≤0.1dB and l≤1mm. Here l = **min**(1mm, 0.1/L_{TE0}).

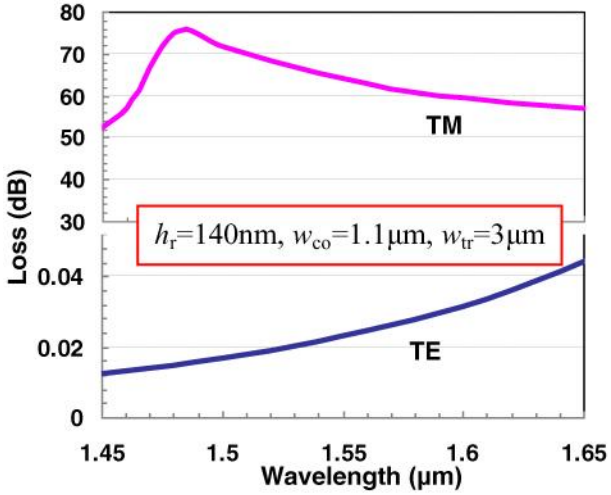

Fig. 9. The wavelength dependence of the leakage loss for TE and TM polarizations for a shallowly-etched SOI ridge waveguide with h_r = 140nm, w_{co} = 1.1μm, and w_{tr} = 3μm.

3. Fabrication and measurement

Figure 10 shows a schematic configuration of the present polarizer, which consists of a straight waveguide defined by two trenches. The two trenches are tapered to be wider at both ends. We use standard processes (including UV lithography, ICP etching, etc.) for the fabrication of the present SOI polarizer. In order to characterize the fabricated devices, we use the measurement setup shown in Fig. 11, which includes a free-space optical system for

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polarization-controlling to have a polarized input light with a high extinction ratio. The extinction ratio of input polarized light at the input side is up to 40dB.

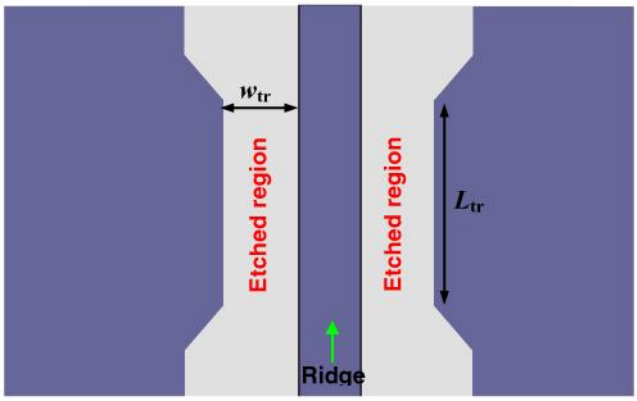

Fig. 10. The schematic configuration of the present SOI polarizer based on a straight waveguide.

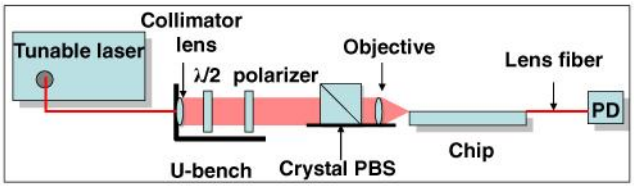

Fig. 11. The measurement setup.

Figure 12(a) and 12(b) show the measurement transmission losses of both TE and TM polarizations for the designs with w_{co} = 1.0μm and 1.2μm, respectively, and the length L_{tr} = 1mm. The trench width is w_{tr} = 2.0μm. Here the coupling loss is excluded. It can be seen that the loss of the TM_0 mode is much higher than the TE_0 mode, as expected from the calculation results shown above. The present polarizer also shows a broad-band response (>100nm). Figure 12(c) shows the extinction ratio for the polarizer with different rib width w_{co}. The solid curve is the calculation result while the circles are the measured one. It can be seen that they agree well with each other qualitatively. Both the calculation and measurement show that there is a maximal extinction ratio around w_{co} = 1.2μm.The measured extinction ratio is lower than the calculated one, which might be because TE polarization has higher scattering than expected. Another possible reason is that TM polarization has some background noise due to the scattering when the TM light leaks and touches the adjacent waveguides in the same wafer.

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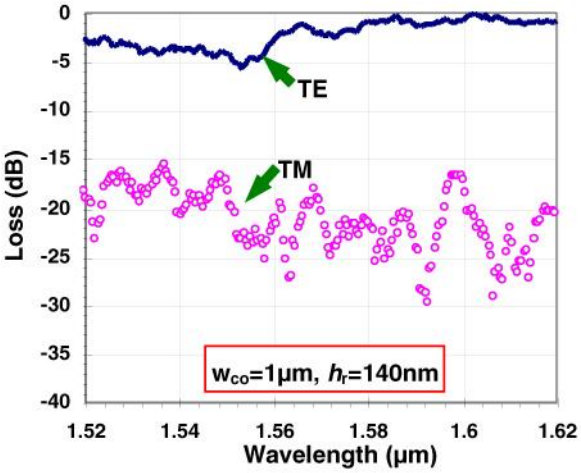
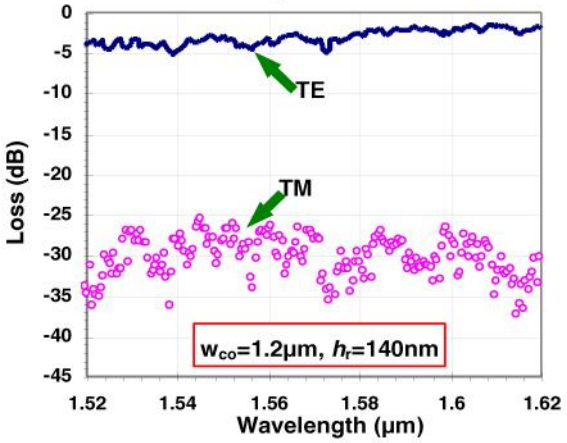
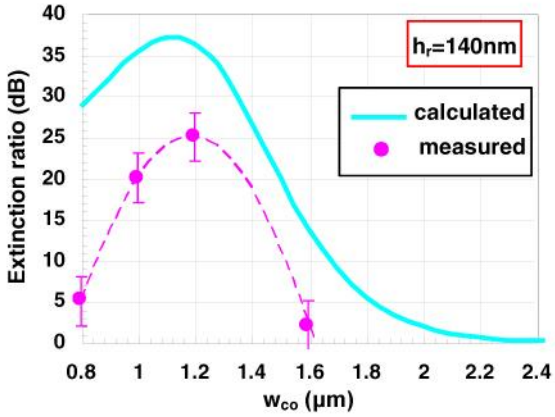


(a)



(b)



(c)

Fig. 12. The measured results for the transmissions of the TE_0 and TM_0 modes when w_{co} = 1μm (a), and w_{co} = 1.2μm (b); (c) the extinction ratio. The trench width is w_{tr} = 2μm and the length L_{tr} = 1mm.

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4. Conclusion

In this paper, we have given a detailed analysis for the mode characteristics of shallowly-etched silicon-on-insulator ridge optical waveguides by using FV-FDM mode solver with a PML boundary treatment. It has been shown that the leakage loss of the present SOI ridge waveguide is very strongly polarization-dependent. The TE fundamental mode can be low loss while the TM fundamental mode has very large leakage loss. More importantly, the leakage loss of the TM fundamental mode changes quasi-periodically as the trench width w_{tr} varies. The formula of the period Δw_{tr} is also given. By utilizing the huge polarization dependent loss of this kind of waveguide, we have proposed a compact and simple optical polarizer based on a straight waveguide. The large dependence of the TM leakage loss on the trench width indicates that one has to choose the trench width optimally to have a maximal extinction ratio. Both the theoretical and experimental results show that the proposed polarizer has very broad bandwidth. The measured extinction ratio is as high as 25dB over a 100nm wavelength range for a 1mm-long polarizer.

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