12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

12E2-2

Silicon Photonic Wire Filter Using Asymmetric Sidewall Long-Period Gratings in a Two-Mode Waveguide

Young-Bo Cho, Jin-Soo Shin, Byung-Ki Yang, Joo-Hyung Lee, Jun-Bo Yoon and Sang-Yung Shin
Dept. of EECS, Korea Advanced Institute of Science and Technology
373-1, Guseong-dong, Yuseong-gu, Daejeon, Republic of Korea
(Phone) 82-42-869-5420, (Fax) 82-42-869-8020 e-mail: whdud@eeinfo.kaist.ac.kr

Abstract

We demonstrate a silicon photonic wire filter using asymmetric sidewall long-period gratings. The period and depth of fabricated grating are 4.3 μm and 5 nm, respectively. The length of long-period grating is 260 μm. The measured maximum attenuation at the center wavelength is about 13 dB. The bandwidth of the transmission dip is 4.5 nm.

1. Introduction

The high refractive index contrast optical waveguide has attracted much attention in recent years. A promising material for high refractive index contrast is silicon because it has a good optical transmission characteristic at infrared optical fiber communication wavelengths. Moreover, it has compatibility with silicon complementary metal-oxide-semiconductor (CMOS) devices [1].

On the other hand, long-period fiber gratings (LPFGs) have been studied and used for various devices in optical communication and optical sensing [2]. They have several advantages such as easy fabrication and low insertion loss. However, one major limitation of LPFG devices is that they need a relatively long device length to achieve desired characteristics. To partially solve this problem, long-period waveguide grating (LPWG) devices have been reported [3,4]. Their device length may be further reduced by employing high index contrast silicon waveguides.

In this paper, we propose and fabricate a silicon photonic wire LPWG device and investigate its characteristics for a filter. It may be applied to realize a polarization splitter.

2. Device structure and operation principle

The proposed LPWG device consists of single mode waveguide sections, taper sections and a two-mode section with asymmetric sidewall LPGs. The structure is schematically shown in Fig 1. Taper sections connect the input and output single-mode waveguides to the two-mode waveguide. The two-mode waveguide supports both E^x_{11} mode (TE_0-like mode) and E^x_{21} mode (TE_1-like mode). The operation of this device is based on the coupling between these two modes by using LPWGs. Because of the horizontal asymmetry of E^x_{21} mode, the LPWG should be asymmetric [5].

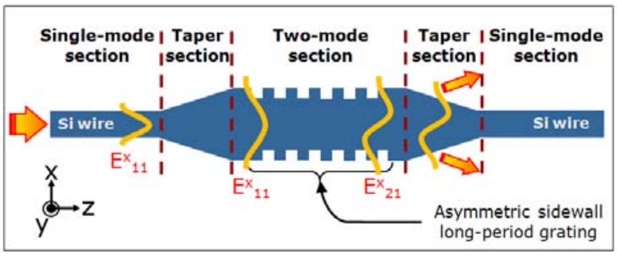

Fig. 1 Structure of the filter

If the E^x_{11} mode is excited in the single-mode waveguide, it evolves to the E^x_{11} mode of two-mode waveguide through the input taper section. At the wavelength satisfying the phase matching condition, the E^x_{11} mode is coupled to the E^x_{21} mode by the asymmetric LPGs on the sidewall of the two-mode waveguide. Since the output taper removes the E^x_{21} mode, we obtain notch filter characteristics at the output single mode section.

The width and height of the single mode waveguide are 450 nm and 230 nm, respectively. To guarantee the two-mode operation, the width of multimode waveguide is chosen to be 1 μm. The numerically calculated electric field profile of each mode is shown in Fig. 2. Based on the coupled mode theory and numerical simulations, we choose the period and depth of LPWGs as 4.3 μm and 5 nm, respectively. The total length of the LPWGs is 260 μm.

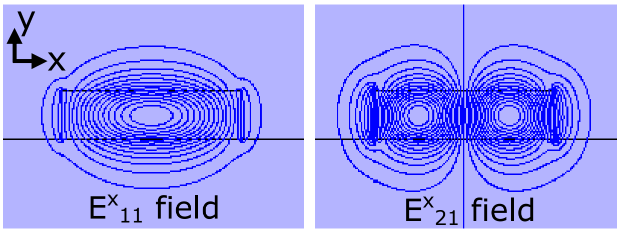

Fig. 2 Electric field profiles of two-mode waveguide

3. Fabrication procedures and experimental results

The LPWG device is fabricated by using conventional processes of semiconductor devices. Fig. 3 shows the steps. First, both LPGs and waveguides are simultaneously formed by using e-beam direct writing and inductively coupled plasma reactive ion etching. As we adopt a sidewall LPG structure, there is no need to carry out another e-beam direct writing and dry etching processes. Furthermore, a precise alignment process between LPGs and waveguides is not necessary. Then, to characterize the device, we fabricated mode size converters[6] at input and output ends of the LPWG filter.

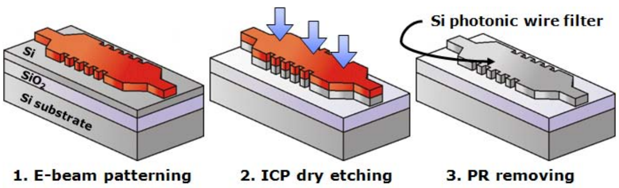

Fig. 3 Fabrication procedure

The measured transmission spectra of the fabricated LPWGs are shown in Fig. 4. If the E^x_{11} mode is exited, we can find that the LPWGs have maximum attenuation level of 13 dB at 1609 nm of the center wavelength. The 3-dB bandwidth of notch filter is about 4.5 nm. On the other hand, if the E^y_{11} mode (TM_0-like mode) is exited, the LPWGs do not reveal any resonance dip. From this result, the filter using sidewall LPGs may be used as polarization splitter at the center wavelength.

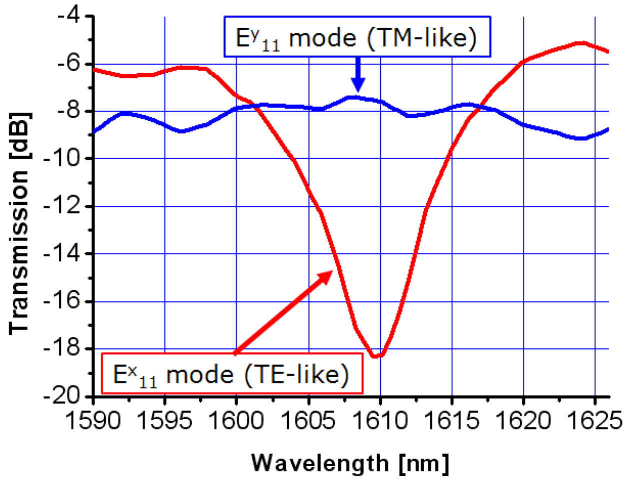

Fig. 4 Transmission spectra of the fabricated LPWGs

4. Conclusion

We have demonstrated a silicon photonic wire filter using asymmetric sidewall LPGs. Its fabrication processes are simplified by adopting a sidewall LPG structure. The total length of the LPWGs is 260 μm. The device has maximum attenuation level of 13 dB and 3-dB bandwidth of 4.5 nm at 1609 nm wavelength. The LPWGs can be used as filter and polarization splitter.

Acknowledgment

This work was supported by the Korea Science and Engineering Foundation(KOSEF) grant funded by the Korea government(MOST) (No. R01-2005-000-11280-0)

References

1 Ling Liao et al., *IEEE J. Quantum Electron*., vol. 41, no. 2, pp. 250, 2005

2 S. W. James et al., *Meas. Sci. Technol*., vol. 14, R49, 2003

3 Vipul Rastogi et al., *Appl. Opt*., vol. 41, no. 30, pp. 6351, 2002

4 Min-Suk Kwon et al., *IEEE J. Lightwave Technol*., vol. 22, no. 8, pp. 1968, 2004

5 Jose M. Castor et al., *Opt. Express*, vol. 13, no. 11, pp.4180, 2005

6 Tai Tsuchizawa et al., *IEEE J. Select. Topics Quantum Electron*., vol. 11, no. 1, pp. 232, 2005