High performance TM-pass polarizer via subwavelength grating bandgap engineering

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***Abstract*—Silicon photonics systems exhibit a strong birefringence which makes polarization management critical. Here we demonstrate, with full 3D-FDTD simulations, a TM-pass polarizer based on tilted subwavelength gratings that reflects the TE_0 mode into the TE_1 mode, which can then be easily eliminated. The polarizer achieves TM mode insertion losses below 0.4dB, reflections into the undesired fundamental TE mode of less than -20 dB, and an extinction ratio above 20 dB, over a 150 nm bandwidth around the wavelength of 1550 nm.**

I. Introduction

Silicon on insulator (SOI) is quickly becoming a mainstream platform for integrated optics. Its high-index contrast along with CMOS-like fabrication processes is enabling low-cost, large-scale production of chips with a high density of devices [1]. However, the large index contrast also leads to a strong birefringence. Therefore, polarization management in SOI becomes of great importance [2]. Different types of devices are employed to fulfill this task. Among them, polarizers are used to achieve high polarization purity for applications such as biosensing [3] or polarization multiplexing for high speed communications [4]. In the standard 220 nm SOI platform, TE-pass polarizers are significantly simpler to design than TM-pass polarizers, since the TE polarization is more confined than the TM polarization. For TM-pass polarizers several solutions have been proposed, but most of them require a complex fabrication process [5] or reflect the fundamental TE mode back into the system [6], which can have detrimental side-effects. Other approaches include using a polarization splitting mechanism with an air cladding, which can be problematic for integration [7], employing a Bragg grating with only 50 nm wide slots to radiate the TE polarization [8], or leveraging a directional coupler comprised of silicon and silicon nitride waveguides to couple only the TM mode [9].

Here, we propose a new TM-pass polarizer design for standard 220 nm silicon that exploits tilted subwavelength structures. This structure enables us to engineer the anisotropy of the structure by only affecting the TE-polarization [10], [11]. In addition, the proposed design can be fabricated with a single etch-step, achieving insertion losses below 0.4 dB, an extinction ratio above 20 dB and keeping the reflections into the undesired fundamental TE mode under -20 dB in the the 150 nm operational bandwidth.

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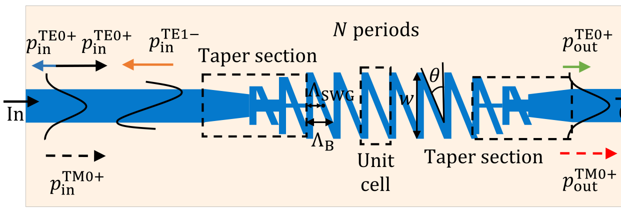

Fig. 1. Schematic of the TM-pass polarizer. For TE polarization the forward propagating fundamental mode is converted into the backward propagating first order mode as the periodic structure behaves as a reflector, whereas for TM polarization the structure behaves as an homogeneous subwavelength metamaterial.

II. Polarizer structure and design

The polarizer is comprised of a periodic structure, as shown in Fig. 1, and input/output taper sections. The device is designed to block the forward propagation TE_0^+ mode, reflecting it into the backward propagating TE_1^- mode, while allowing the forward propagatingTM_0^+ mode to pass through with negligible losses. Each second strips of this structure is tilted an angle θ, yielding a period $\Lambda_\mathrm{B} = 2\Lambda_\mathrm{SWG}$. This periodic perturbation will affect mainly the TE polarization, leaving the TM polarization almost untouched [12]. As a result the device operates as an (anti-symmetric) Bragg grating for TE polarization, and as a subwavelength structure for TM polarization [13].

In order to make the structure reflect the TE_0^+ mode into the TE_1^- mode, the pitch Λ_B must be chosen so that the phase matching condition between the modes is met: $k_0^+ + k_1^- = 2\pi/\Lambda_B$ [14]. Using the MPB software package [15], the pitch of the structure $\Lambda_\mathrm{B} = 440\,\mathrm{nm}$ is calculated to center the phase matching condition at a wavelength of $\lambda = 1550\,\mathrm{nm}$. The remaining geometric parameters of the device are then designed via MEEP [16], a 3D-FDTD open-source simulator, to minimize the insertion losses: $\mathrm{IL[dB]} = -10\log_{10}\left(p_\mathrm{out}^\mathrm{TM0+}\right)$ and the back-reflections into the fundamental mode: $\mathrm{BR0[dB]} = 10\log_{10}\left(p_\mathrm{in}^\mathrm{TE0-}\right)$, while maximizing the extinction ratio: $\mathrm{ER[dB]} = 10\log_{10}\left(p_\mathrm{out}^\mathrm{TM0+}/p_\mathrm{out}^\mathrm{TE0+}\right)$ and the back-reflections into the first order mode: $\mathrm{BR1[dB]} =$