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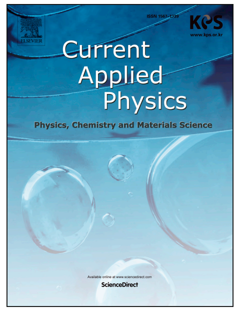

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Highly directional waveguide grating antenna for optical phased array

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Abstract: A highly directional waveguide grating antenna by patterning top cladding has been proposed. Spatial separation of the grating structure from the waveguide reduces the strength of perturbation to achieve a millimeter-scale emission. The optimized grating structure offers above 70% directionality with 800 nm waveguide width. The vertical field-of-view of 15° is achieved with 100 nm wavelength bandwidth. Thanks to the its simple structure and large critical dimension, the proposed structure is suitable for manufacturing in CMOS foundries with DUV lithography.

Key words: LIDAR; optical phased array; diffraction grating; integrated optical devices

1. Introduction

Optical phased array (OPA) has drawn great attention due to the growing needs of LiDAR (Light Detection And Ranging) for autonomous driving and unmanned aerial vehicle. Instead of mechanical steering from the conventional LiDAR, OPA steers its beam emission by modulating optical phases. Thanks to the development in integrated photonics, LiDAR can be manufactured by CMOS semiconductor foundries as a compact size integrated photonic chip [1–11].

One of the key elements of the OPA is the waveguide grating antenna (WGA) based on the diffraction grating, which couples light between the chip and free-space. Diffraction gratings have been extensively studied over decades in the field of integrated photonics. However, most of efforts have been focused on relatively short length of radiation such as fiber grating couplers. WGA for OPA requires the radiation length at least in the order of millimeter for narrowing a far-field divergence angle [1,12]. Therefore, a new diffraction grating structure for WGA is required to increase the radiation length, or equivalently reduce perturbation strength. Previous WGAs rely on the strategy of making smaller structural perturbations on either width or thickness of the waveguide to achieve longer radiation. Inevitable consequence of making small structures is increased difficulties in fabrication for CMOS foundries with DUV lithography. In addition, WGA suffers from undesirable downward radiation which is reflected back toward top causing the Fabry-Perot interference [12,13]. Since the interference affects relationship between reflected and transmitted intensity, it may increase or decrease efficiency of the device. Recently, the double layer waveguide structure was reported to enhance the upward radiation [12]. However, the fabrication of the double layer structure requires many lithography and etch steps, and the double layer structure is not compatible with the conventional integrated photonic devices. In this paper, we propose the highly directional waveguide grating antenna by patterning the top cladding above the waveguide. Spatial separation of the grating structure from the waveguide offers the reduced perturbation strength for millimeter-scale emission without reducing the grating size. The high directionality is also obtained without any additional overlay by optimizing structural parameters. The proposed idea is suitable for manufacturing in CMOS foundries due to its simple structure, such as singly etched grating, large critical dimension (~300 nm), misalignment robustness, and silicon-on-insulator (SOI) compatible dimensions.

Operation of OPA is started by splitting an input power into multiple waveguide elements with either cascaded multi-mode interference (MMI) coupler [8,11], or star-coupler [1,7]. The phases of antenna elements are modulated in such a way that their phase distribution forms the beam front with a desired emission angle. WGA emits the optical power into free-space. Figure 1(a) shows the side view of the proposed WGA structure, the structure is based on the silicon-on-insulator (SOI) platform. Silicon and silicon dioxide are colored as yellow and grey, respectively. The thickness of the bottom cladding (t_{bottom}) is fixed at 2 μm. The waveguide thickness (t_{wg}) is set as a variable. The top cladding thickness (t_{top}) is also set as a variable, and the cladding is partially etched with a depth (t_e). The remained thickness (t_r) is the distance between the waveguide and the top grating. A fundamental quasi-TE mode is launched as input mode along the x-axis. Figure 1(b) is the tilted view showing that the waveguide width (w_{wg}) and thickness are kept constant along the x-axis. The grating grooves are patterned along the y-axis and extended across waveguides. Since the grating structure is separated from the waveguide and located on the top cladding, the strength of the modal perturbation is reduced, compared to the direct perturbation on the waveguide. This separation is also beneficial because it gives additional degree of

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