

Next Generation Silicon Photonics

(Invited paper)

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ABSTRACT

In the past decade, silicon photonics has been shown as a platform for high-performance massively integrated optical devices that can be integrated with state-of-the-art microelectronics. The toolbox of integrated nanophotonics today is rich: from the ability to modulate, guide and amplify at GHz bandwidths, to opto-mechanical and nonlinear devices. The explosion of silicon photonics enabled components with high performance and opened the door to a variety of applications. Recently new atomically thin materials integrated on silicon photonics platform as a post-process have shown the ability to tailor optical properties of integrated devices by simultaneously tailoring the geometry of the device structures and the intrinsic electronic excitations of the material.

Keywords: Silicon photonics, integrated optics

INTRODUCTION

We are now experiencing a revolution in optical technologies, where one can print optical circuits with hundreds of thousands of optical elements on a silicon wafer. These optical circuits can be modified on demand—one can now control the optical properties of hundreds of different optical paths defined in a mm-sized chip. This revolution is ongoing—new materials and technologies are emerging that can manipulate the flow of light in unprecedented ways.

EMERGING APPLICATIONS OF SILICON PHOTONICS PLATFORM

The revolution in optical technologies is opening the door to applications that only a decade ago were unimaginable. Extremely complex systems based on silicon photonics can now be implemented. We have recently demonstrated the largest array of independently controllable silicon waveguides on a chip for Solid-state beam steering applications[1]. Solid-state beam steering using large-scale optical phased arrays is of great interest for LIDAR and free-space communication systems, enabling wide-angle, long distance ranging or transmission of data in a robust platform [2-5]. Ideally, a widely steerable narrow output beam that can reach to long distances requires a large aperture containing a large number of independently phase-controlled elements while remaining at a reasonable total power consumption. Applications at distances of tens to hundreds of meters require element-counts of several thousands, such that independent phase control overwhelmingly dominates power consumption and has prohibited larger element-count demonstrations thus far. We demonstrate the highest yet-reported element count in an actively steered optical phased array while simultaneously achieving record low power consumption of less than 1.8W for the whole array. The array shows steering in two dimensions over a 70 degree by 14 degree field of view while pumped by an InP/silicon laser fabricated on the same platform.

INTEGRATION OF ATOMICALLY THIN MATERIALS ON SILICON PHOTONICS PLATFORM

Recently new atomically thin materials integrated on silicon photonics platform post-processing have shown the ability to tailor optical properties of integrated devices by simultaneously tailoring their geometry and their intrinsic electronic excitations. These materials could enable unprecedented scalability of silicon photonics systems that are bandwidth and/or power limited. Similarly to Graphene, that has already been integrated on photonic waveguides [6] we have shown recently that 2D materials such as monolayer transition-metal dichalcogenides (TMD) can be used to tune drastically the optical properties of waveguides without affecting its absorption properties, therefore providing electro-optic properties to traditionally passive optical materials. Recently discovered TMDs are atomically thin semiconductors with unique electrical and optical properties [7]. These materials enable strong light–matter coupling, with optical absorption around 10–20% in layers as thin as 0.6 nm [8] at visible wavelengths and extremely efficient Coulomb interactions, as manifested in the exciton binding energies on the order of 0.5 eV [9]. In [10] we show a giant index change beyond 60% in monolayer

WS₂ index under applied voltage. Figure 1a shows a fabricated Mach Zender Interferometer consisting of Si₃N₄ waveguides clad with WS₂ 2D TMD material. Figure 1b shows the transmission response of device for different applied voltages. One can see that the transmission spectra shift drastically due to the change in the real part of the dielectric.

CONCLUSION

Silicon photonics is continuing to evolve. New materials that can be integrated on silicon photonics post-process are emerging, as well as a plethora of new applications that reach beyond data communications.

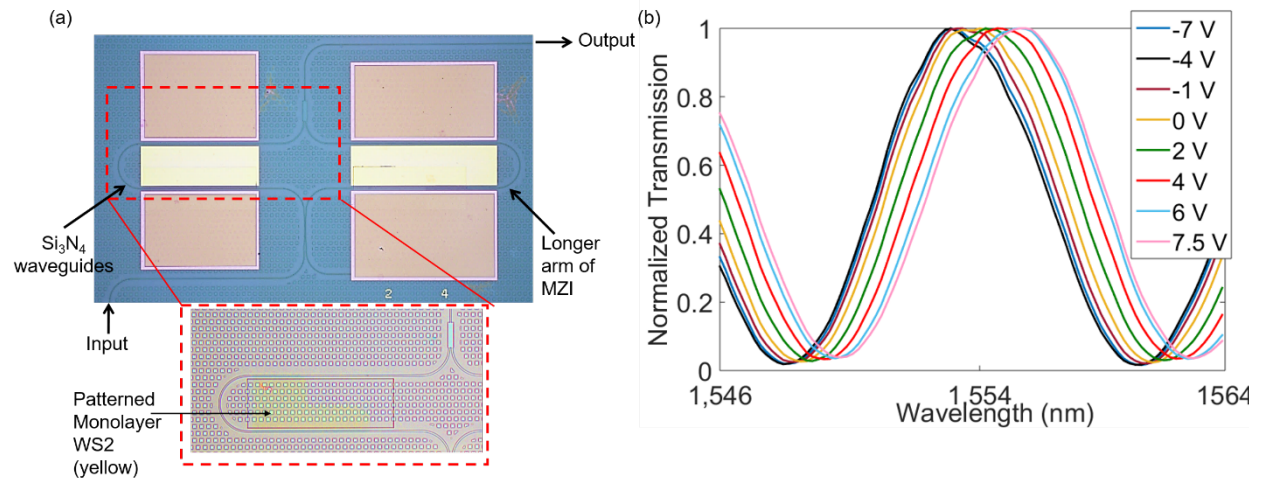


Fig. 1: (a) Optical micrograph of the fabricated MZI with Si₃N₄ waveguides (b) Transmission response of device showing MZI fringes at different voltages

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