Opportunities for Mechanically Actuated Photonics

Pierre Edinger[1], Gaehun Jo[1], August Djuphammar[1], Elena Volkova[2], Carlos Errando-Herranz[2], Cleitus Antony[3], Simon J. Bleiker[1], Wim Bogaerts[4, 5], Niels Quack[6], Frank Niklaus[1], and Kristinn B. Gylfason[1]

(1) KTH Royal Institute of Technology, Stockholm, Sweden, gylfason@kth.se
(2) Delft University of Technology, Delft, the Netherlands
(3) Tyndall National Institute of Technology, Cork, Ireland
(4) Interuniversity Microelectronics Centre, Leuven, Belgium
(5) Ghent University - IMEC, Dept. of Information Technology, Belgium
(6) The University of Sydney, Australia

Abstract *Photonic integrated circuits (PICs) promise to be the optical equivalent of electronic integrated circuits (ICs). However, current PICs cannot match the number of devices per chip of electronic ICs due to active photonic components' large footprint and power consumption. By micromechanical actuation of PICs, we show compact devices with orders of magnitude power reduction compared to thermo-optic counterparts. ©2024 The Author(s)*

Introduction

During the last decade, silicon photonics has delivered on its promise to expand the user base of photonics technology. Today, multiple foundries produce silicon photonics on up to 300 mm wafers, and multi-project wafer (MPW) runs have lowered the barrier of entry to the level required for innovative start-up companies.

Silicon photonics has found its first volume application in pluggable data center transceivers, and recently, a major electronics producer announced serious plans for delivering the long-sought on-chip optical interconnects. With this maturing of the platform, integration density is increasing rapidly and, in the process, exposing an unsolved scaling bottleneck: control of phase and power in large-scale silicon photonic circuits.

The strength of photonics comes from the possibility of coherent information processing at the speed of light. Controlling the phase and amplitude of on-chip optical signals throughout the complex circuit is necessary to leverage this benefit on a large scale. Due to the large thermo-optic coefficient of silicon, this control must be active to compensate for local and global temperature variations during operation. As the photonic-electron integration becomes tighter, this limitation will become increasingly severe due to the significant thermal dissipation of high-performance electronics. The current control solution relying on local heaters will become less efficient as thermal loads increase since heaters can only increase temperature, and their effect relies on a temperature difference to the increasingly hot ambient.

Recently, integrated microelectromechanical actuation has emerged as a uniquely scalable solution for phase and power control in silicon photonics [1]. By leveraging design and processing know-how from the vast silicon microelectromechanical systems (MEMS) field, multiple groups have demonstrated both single devices and larger circuits [2], [3]. Importantly, foundries can integrate MEMS actuators into their existing process flows with only minor adjustments. These demonstrations have set the scene for the rapid growth of silicon photonic MEMS.

Silicon photonic MEMS

By micromechanical actuation of PICs, we show orders of magnitude reduction of power consumption compared to current thermo-optic counterparts [4]. Within the European projects MORPHIC [5] and PHORMIC [6], we have realized our technology in an established silicon photonics foundry platform, IMEC's iSiPP50G, and show complex circuits on a small chip [7]. Furthermore, we show wafer-level vacuum-sealing of the silicon photonic MEMS circuits [8], [9]. We demonstrate our approach by implementing MEMS tunable photonic devices such as phase shifters [10] and monitors [11], couplers [12], [13], and wavelength filters [14]. We have also recently started exploring the non-volatile operation of photonic switches [15], optomechanics [16], and integrated electrical MEMS switches [17].

Conclusions

We address the scaling challenge of photonic integrated circuits by implementing extremely low-power mechanical actuators in an established silicon photonics platform. This technology has the potential to enable large-scale programmable silicon photonics.

ISBN: 978-3-8007-6426-6

Acknowledgements

This project has received funding from the European Union's Horizon research and innovation programme under grant agreements No 780283 (MORPHIC), 871740 (ZeroAMP), and 101070332 (PHORMIC).

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ISBN: 978-3-8007-6426-6