Advanced Photonics Congress 2023 (IPR, Networks, NOMA, SOLED, SPPCom) © Optica Publishing Group 2023

A MEMS tunable phase monitor with integrated photodiode read-out for silicon photonic circuits

Pierre Edinger[1], Alain Yuji Takabayashi[2], Cleitus Antony[3], Peter Verheyen[4], Umar Khan[4, 5], Wim Bogaerts[4, 5], Niels Quack[2], and Kristinn B. Gylfason[1]

*[1, *] KTH Royal Institute of Technology, Stockholm, Sweden*
[2] Ecole Polytechnique Fédérale de Lausanne, Switzerland
[3] Tyndall National Institute of Technology, Cork, Ireland
[4] Interuniversity Microelectronics Centre, Leuven, Belgium
[5] Ghent University - IMEC, Dept. of Information Technology, Belgium

[*]edinger@kth.se

Abstract: Electrostatic MEMS provide low power consumption to programmable photonics. However, the scaling of programmable photonics also requires solutions for circuit monitoring. We demonstrate a MEMS tunable phase monitor with integrated read-out on a foundry platform.

1. Introduction

Silicon photonics is the most promising platform for large-scale programmable photonics, where hundreds of phase shifters are used to reconfigure a circuit into multiple functions [1]. However, further improvements are needed to scale the technology: the base phase shifters should have a low power consumption and insertion loss, and the circuits should include photodetectors for on-chip testing, and calibration [2]. Electrostatic Micro-Electro-Mechanical-Systems (MEMS) can provide the low power consumption and insertion loss needed for scaling to circuits with thousands of components [3]. However, no photonic circuit combining MEMS actuators and integrated photodetectors (PDs) has been reported. This is likely due to the low maturity of MEMS technology in silicon photonics, and circuits combining discrete MEMS phase shifters and power taps could be envisioned on platforms with access to both components. Ideally, such monitors should be transparent and not add optical losses to the circuit [4]. Here, we demonstrate a photonic MEMS phase monitor with integrated read-out on IMEC's iSiPP50G platform. The device is transparent when inactive ($>$ 20 dB extinction) and can be used to monitor a single MEMS phase shifter when active.

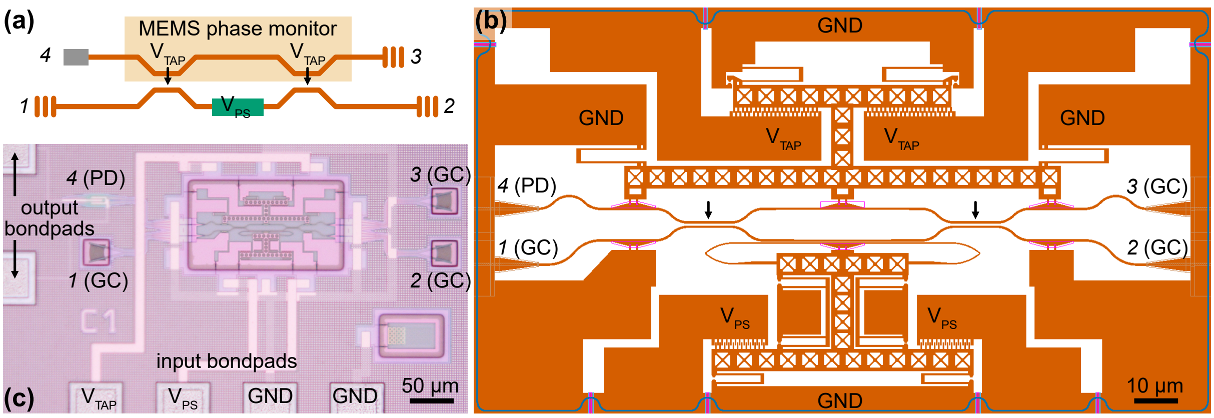

Fig. 1. Electrostatic MEMS tunable phase shifter monitor with integrated photodiode read-out. (a) Conceptual view of the device. (b) The layout of the MEMS phase monitor and the MEMS phase shifter under test. (c) Microscope image of the MEMS phase monitor implemented on IMEC's iSiPP50G platform. GC: grating coupler, PD: photodiode.

2. Device

The demonstrated phase monitor consists of a balanced Mach-Zehnder interferometer (MZI) where the gap of the directional couplers (used as the splitter and the combiner) can be reduced using electrostatic MEMS actuation; see Fig. 1 (a-b). In its passive state, the directional couplers are not coupling any light, and the interferometer does not affect the circuit waveguide. Applying a bias V_{TAP} reduces the air gaps separating the couplers' waveguides. The interferometer becomes active, and phase shifts can be monitored at the output of the tap waveguide. The phase shifter also relies on MEMS actuation but tunes the effective index of a suspended waveguide instead [3]. We used a germanium photodiode from the iSiPP50G library to read the power at the tap waveguide's output.

3. Measurements

The MEMS phase tap was designed and implemented on IMEC's iSiPP50G silicon photonics platform (Fig. 1 (c)). The MEMS phase monitor and phase shifter were suspended using hydrofluoric acid vapor [3]. The voltage biases for the MEMS phase tap and the phase shifter under test were applied using a custom-printed circuit board controlled by a microcontroller (Beaglebone). We used a tunable laser (81680A-7, Agilent) to characterize the device over the C-band; see Fig. 2 (a). For the photocurrent measurements, we used a lock-in with a trans-impedance amplifier (HF2LI + HF2TIA, Zurich Instruments); see Fig. 2 (b). The monitor displays an extinction ratio of 20 dB in the passive state, which could be further improved by increasing the passive air gap of the directional couplers. Applying a bias V_{TAP} increases the current read at the PD as expected, which can then be used to monitor the phase shifter. We used a laser power of 500 µW and an amplifier gain of 10^5 V/A for all measurements.

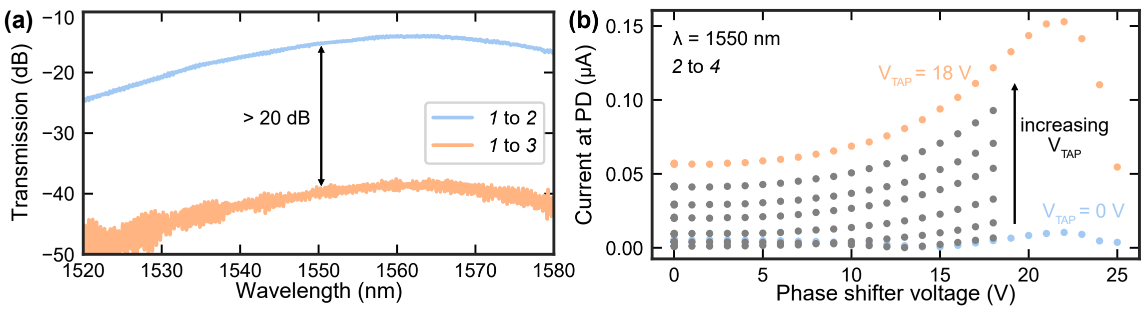

Fig. 2. Characterization of the MEMS tunable phase shifter monitor. (a) Optical transmission in the passive state, displaying a broadband extinction ratio over 20 dB. (b) Measured current through the integrated photodetector versus phase shifter voltage V_{PS} and different tap biases V_{TAP}.

4. Conclusion

We have demonstrated the first integrated phase monitor using electrostatic MEMS actuation. By physically moving one arm of an MZI and reducing the air gap of the directional couplers, the device achieves a passive extinction ratio of over 20 dB. Moreover, we implemented the MEMS actuators on a commercially available photonic foundry platform, enabling integrated photodiode read-out to monitor the phase shifter under test.

Acknowledgments

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.780283 (MORPHIC). We thank Dr. Max Yan for access to measurement equipment.

References

1. W. Bogaerts, D. Pérez, J. Capmany, D. A. B. Miller, J. Poon, D. Englund, F. Morichetti, and A. Melloni, "Programmable photonic circuits," Nature **586**, 207–216 (2020).
2. P. Dumais, D. J. Goodwill, D. Celo, J. Jiang, C. Zhang, F. Zhao, X. Tu, C. Zhang, S. Yan, J. He, M. Li, W. Liu, Y. Wei, D. Geng, H. Mehrvar, and E. Bernier, "Silicon Photonic Switch Subsystem With 900 Monolithically Integrated Calibration Photodiodes and 64-Fiber Package," J. Light. Technol. **36**, 233–238 (2018).
3. P. Edinger, A. Y. Takabayashi, C. Errando-Herranz, U. Khan, H. Sattari, P. Verheyen, W. Bogaerts, N. Quack, and K. B. Gylfason, "Silicon photonic microelectromechanical phase shifters for scalable programmable photonics," Opt. Lett. **46**, 5671–5674 (2021).
4. F. Morichetti, S. Grillanda, M. Carminati, G. Ferrari, M. Sampietro, M. J. Strain, M. Sorel, and A. Melloni, "Non-Invasive On-Chip Light Observation by Contactless Waveguide Conductivity Monitoring," IEEE J. Sel. Top. Quantum Electron. **20**, 292–301 (2014).