



Silicon-based optoelectronics: progress towards large scale optoelectronic integration and applications

Dingshan Gao¹ · Zhiping Zhou²

Received: 7 March 2022
© The Author(s) 2022

In the past half century, silicon-based microelectronics and optical fiber communication have triggered a far-reaching information technology revolution, which has moved human society into a high-speed information age. The demand for communication capacity and speed is growing exponentially. On the other hand, data center and high-performance computing are facing bottlenecks of speed, bandwidth, and energy consumption of electrical interconnections. Silicon-based optoelectronics has become the key technology to break through these bottlenecks. Thanks to the advantages of high refractive index, capable in small active components, and CMOS compatible process, silicon can achieve a large-scale optoelectronic integration on a micro-chip with low cost and low energy consumption. This has become a hot alternative for the chip industry. In addition, silicon-based optoelectronics has enabled a series of new study fields such as mid-infrared communication, microwave optoelectronics, lab-on-chip, quantum communication, optoelectronic computing, and chip scale lidar.

This special issue on “Recent Advances in Silicon Photonics” encompasses the recent developments in the devices and applications in the field. With five review papers and four original research articles included, this special issue focuses on key devices and their applications in data center coherent interconnections, optoelectronic computing, integrated quantum circuit, and silicon-based optoelectronic hybrid integration.

✉ Dingshan Gao
dsgao@hust.edu.cn

✉ Zhiping Zhou
zjzhou@pku.edu.cn

¹ Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan 430074, China

² State Key Laboratory of Advanced Optical Communication Systems and Networks, School of Electronics, Peking University, Beijing 100871, China

Liu et al. [1] reviewed the state-of-art of thermo-optic phase shifters on SOI substrate. Seiler et al. [2] evaluated and compared the performances of silicon-based optoelectronic components for coherent O-band data center interconnections. Qiu et al. [3] summarized the developing trend of integrated optical directed logic operations in which the operands are electrons, and the operation results are photons. Adcock et al. [4] explored the prospects of dynamic quantum circuits on hybrid thin-film lithium niobate on silicon (TFLN/Si) photonics. Tan et al. [5] identified the key building blocks for the integrated circuits for electronics-photonics convergence and reviewed their recent advances. Cheng et al. [6] proposed a systematic solution to extend the matrix computation of micro-ring array from real-valued field to complex-valued field, and from small scale to large scale matrix computation. Georgieva et al. [7] reported polarization combining 2D grating couplers (2D GCs) on amorphous Si:H, fabricated in the backend of a line of a photonic BiCMOS platform. Tao et al. [8] demonstrated an ultra-compact, low-loss, slot-strip converter with polarization insensitivity based on the multimode interference effect. Ma et al. [9] introduced a method to obtain complete photonic bandgap (CPBG) in a silicon nitride (Si_3N_4) photonic crystal slab.

The nine papers in this special issue comprise only the partial progress in the field of silicon-based optoelectronics. We believe that this special issue will provide the readers with the latest research trends in this field and around their strong interest in this subject matter, further stimulating more cutting-edge research in the future.

Author contributions DG drafted the manuscript. ZZ participated in the manuscript drafting and revising. All authors read and approved the final manuscript.

Declarations

Competing interests The authors declare that they have no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

1. Liu, S.P., Feng, J.B., Tian, Y., Zhao, H., Jin, L., Ouyang, B.L., Zhu, J.G., Guo, J.: Thermo-optic phase shifters based on silicon-on-insulator platform: state-of-the-art and a review. *Front. Optoelectron.* **15**(1), 9 (2022)
2. Seiler, P.M., Georgieva, G., Winzer, G., Peczek, A., Voigt, K., Lischke, S., Fatemi, A., Zimmermann, L.: Toward coherent O-band data center interconnects. *Front. Optoelectron.* **14**(4), 414–425 (2021)
3. Qiu, C.Y., Xiao, H.F., Wang, L.H., Tian, Y.H.: Recent advances in integrated optical directed logic operations for high performance optical computing: a review. *Front. Optoelectron.* **15**(1), 1 (2022)
4. Adcock, J.C., Ding, Y.H.: Quantum prospects for hybrid thin-film lithium niobate on silicon photonics. *Front. Optoelectron.* **15**(1), 7 (2022)
5. Tan, M., Wang, Y.H., Wang, X.Z., Yu, Y., Zhang, X.L.: Circuit-level convergence of electronics and photonics: basic concepts and recent advances. *Front. Optoelectron.* **15**(1), 16 (2022)
6. Cheng, J.W., Zhao, Y.H., Zhang, W.K., Zhou, H.L., Huang, D.M., Dong, J.J., Zhang, X.L.: A small microring array that performs large complex-valued matrix-vector multiplication. *Front. Optoelectron.* **15**(1), 15 (2022)
7. Georgieva, G., Mai, C., Seiler, P.M., Peczek, A., Zimmermann, L.: Dual-polarization multiplexing amorphous Si:H grating couplers for silicon photonic transmitters in the photonic BiCMOS backend of line. *Front. Optoelectron.* **15**(1), 13 (2022)
8. Tao, Z.H., Wang, B., Bai, B.W., Chen, R.X., Shu, H.W., Zhang, X.G., Wang, X.J.: An ultra-compact polarization-insensitive slot-strip mode converter. *Front. Optoelectron.* **15**(1), 5 (2022)
9. Ma, C., Hou, J., Yang, C.Y., Shi, M., Chen, S.P.: Complete photonic bandgap in a silicon nitride slab by utilizing the effective index difference between polarizations. *Front. Optoelectron.* **15**(1), 20 (2022)



Dingshan Gao received his doctorate from Institute of Semiconductors, Chinese Academy of Sciences, China in 2004. Now he is a professor at Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, China. He has been engaged in silicon-based optoelectronics and integrated optics for 20 years. He is currently one of the Chinese coordinators of the Sino-French "PHOTONET" joint research network. His research interests include silicon photonics, nano-optics and quantum optics. He has published more than 90 papers in the international journals. He is also a reviewer of the journals of *Photonics Research*, *Optics Express*, *Optics Letters*, etc.



Zhiping Zhou received his Ph.D. (EE) degree from Georgia Institute of Technology (GT), USA in 1993. From 1993 to 2005, he was with the Microelectronics Research Center at GT, where he engaged research and development in the areas of silicon-based optoelectronics, ultra-fast optical communications, integrated optoelectronics, semiconductor devices and sensors, and nanotechnology. He is now a Professor at Peking University, China. He has been credited for over 650 technical papers, presentations,

and patents. He is a Fellow of OPTICA, SPIE, and IET. He serves as Honorary Director of Chinese Optical Society (COS) and Managing Director of Chinese Society for Optical Engineering (CSOE), the founding Editor-in-Chief of *Photonics Research*. He was founding Chair of IEEE Wuhan Section, 2007–2008, Director of IEEE Atlanta Section, 2001–2003. He also chaired, co-chaired, and served on many program committees for various conferences of IEEE Photonics Society, OPTICA, SPIE, COS, and CSOE.