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Special Topic: Novel Optoelectronic Devices

Preface: special topic on novel optoelectronic devices

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The research and development (R&D) in silicon or III/V photonics are booming and emerging as the mainstream platforms for large-scale photonic integration circuits, which offer the well-established advantages of scalable chip-wise integration with low cost at high volume and high yield, following the standard complementary metal oxide semiconductor fabrication processes in the microelectronics industry. However, the co-integration of electronics with photonics is critical for fully exploiting the high bandwidth, reducing power consumption, as well as achieving more compact footprint and lower cost. Optoelectronic devices with novel co-integration schemes and new materials with further improved functionalities are urgently needed to push beyond the limitations posed by the intrinsic material capabilities and speed restrictions at the electro-optical interfaces. Recently, considerable breakthroughs revived our understanding of these fields, providing both opportunities and challenges in this exciting area.

Here we organize a special topic on “Novel Optoelectronic Devices” in *National Science Open* (NSO), including the contributions of six groups of researchers in these fields. We aim to cover the state-of-the-art R&D highlights and directions of the novel optoelectronic devices from both physics and application perspectives.

With the end of Moore’s Law, deep learning has flourished in different areas, such as computer vision and natural language processing, but it suffers from the high computing power consumption. In this special topic, we have one perspective paper from Yang *et al*. [1] that discusses the massive and efficient training strategies for optical neural networks (ONNs), which are regarded as the next-generation application-specific integrated circuit for artificial intelligence. They propose three research directions that may bring ONNs into reality, including understanding the mechanism to quickly obtain internal information from ONNs without extra loss during training, software-hardware co-design, and co-integration technologies for electronic and photonic devices.

A memristor is a promising candidate of new electronic synaptic devices for neuromorphic computing, while traditional memristors often exhibit complex device structures, cumbersome manufacturing processes, and high energy consumption. Here we have one original research article from Chen *et al*. [2] that reports a lateral memristor with reduced graphene oxide (rGO) and Pt as electrodes and graphene oxide (GO) as the building materials with direct laser writing technology. Ultra-low energy consumption of 200 nW and typical synaptic behaviors of digital recognition with a high accuracy of 95.74% have been achieved. This work provides a simple and low-cost preparation method for the massive production of artificial synapses with low energy consumption, which may greatly facilitate the development of neural network computing hardware platforms.

Unitary operators are powerful tools in quantum information processing for both investigating non-classical phenomena and exploring quantum computational resources. We have another original research article from Li *et al*. [3] that proposes and demonstrates a scalable and efficient scheme for programmable unitary operations in orbital angular momentum domain. Arbitrary matrix operators can be implemented only by diagonal matrices alternately acting on orbital angular momentum domain and azimuthal angle domain. Proof of principle experiments have been performed on path domain with the same matrix decomposition method, and an average fidelity of 0.97 is evaluated through 80 experimental results with dimensionality of 3×3.

Semiconductor mode-locked lasers (MLLs) can provide coherent optical frequency combs (OFCs) with high repetition rates and output power, which have been recognized as potential multi-wavelength sources used in optical communication field due to their compactness, high-efficiency, and low-cost properties. We have one review contribution from Wei *et al*. [4] that has thoroughly detailed the recent development of semiconductor MLL-based OFCs based on a variety of material platforms, with special focus of III-V semiconductor MLLs on Si substrates for the applications in integrated silicon photonics.

Heterogeneous optoelectronic integrated circuits (OEICs) are attracting significant attention as an alternative approach to construct smaller-sized transistors in the post-Moore era. Two-dimensional (2D) materials offering a range of intriguing optoelectronic properties as semiconductors, semimetals, and insulators, provide great potential for developing next-generation heterogeneous OEICs. Hence we have two relevant reviews in this special topic. Cheng *et al*. [5] review the history, status and trend of the use of 2D materials for waveguide-integrated lasers, modulators and photodetectors to provide a better understanding of the importance of the optical properties of chip-integrated optoelectronics with 2D materials. Qiu *et al*. [6] focus on the graphene-based optical modulators and provide a review from the concept and principle to performance in detail; the challenges and opportunities of the graphene-based optical modulators are also discussed, with a wide range of applications including telecom, interconnects, computing, quantum information processing and beam steering.

We sincerely hope that this special topic could shed some light on the novel optoelectronic devices, provide valuable information and perspective to the research community working on this topic, and inspire many more researchers to enter the related fields. We would like to thank all the authors who have contributed the high-quality peer-reviewed articles to this special topic. We are also grateful to the editorial and production staff of NSO for their high-quality assistance.

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