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Editorial

Nanophotonics Pioneer: Prof. Dr. Dieter Bimberg "*Green Photonic Network: From VCSELs to Nanophotonics*"

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Citation: Shi, J.-W.; Lu, T.-C.; Koyama, F. Nanophotonics Pioneer: Prof. Dr. Dieter Bimberg "*Green Photonic Network: From VCSELs to Nanophotonics*". *Photonics* **2023**, *10*, 976. https://doi.org/10.3390/photonics10090976

Received: 23 August 2023
Accepted: 25 August 2023
Published: 27 August 2023

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We would like to celebrate Prof. Bimberg's 80th birthday, 10 July 2022, through the publication of this Special Issue. Prof. Bimberg is one of the great pioneers, having contributed decisively over many decades to the nanomaterials and nanophotonics community. His work stands for remarkable discoveries on the growth and physics behind nanostructures. Based on these fundamental discoveries, he developed many novel concepts for photonic and electronic devices, including high-speed QD- and QW-based VCSELs that have significantly improved the energy efficiency of data communication.

In a world first, he and his research team demonstrated in 2011 that VCSELs can have an extremely low energy-to-data ratio (50 fJ/bit) in terms of their application to data communication. This unprecedented breakthrough led to the resurgence of the use of VCSELs emitting in the near-infrared. In this Special Issue, we highlight recent progress in the application of ultra-high-speed VCSELs to advanced data/telecommunications. Prof. Si-Cong Tian et al. reviewed the progress in short-wavelength (850 nm) energy-efficient high-speed vertical-cavity surface-emitting lasers for data communication [1]. In addition, by combining these state-of-the-art high-speed 850 nm VCSELs with high-performance pre-distorted laser driving circuits for advanced modulation formats, Dr. Urs Hecht et al. have demonstrated high-quality >100 Gbit/sec transmissions per channel [2]. In order to further enhance the bit-rate-distance product of VCSEL-based transmitters, increasing the lasing wavelength from 850 to 1550 nm is the most obvious means to achieve this goal. Prof. Andrey Babichev et al. reviewed the recent progress in long-wavelength (1550 nm) high-speed VCSELs with single-mode performance for data communications [3]. Moreover, he and his team have demonstrated a novel type of wafer-fused high-speed VCSEL with excellent performances at 1550 nm [4]. In contrast to VCSELs that use traditional distributed Bragg reflector (DBR) mirrors, the use of high-contrast grating (HCG) structures as the top mirror is an alternative solution in high-speed VCSELs. Recently, HCG VCSELs have shown significant potential in terms of further suppressing relative-intensity noise (RIN) and benefiting the high-speed transmission of VCSELs. Here, Prof. Anjin Liu et al. demonstrated that surface-emitting lasers with surface metastructures could attain this goal [5].

In addition to the use of for high-speed VCSELs in data transmission, high-power VCSELs are emerging as killer applications in relation to sensing, such as in the case of structured light and time-of-flight LiDAR. Due to the small cavity length and DBRs, VCSELs exhibit much smaller wavelength drifts in the case of temperature variations. Compared with their edge-emitting counterparts, VCSELs can be tested on wafers and be directly integrated with driver circuits. Here, Dr. Takashi Kondo et al. demonstrated an all-monolithically integrated self-scanning addressable VCSEL array with a compact module size and excellent performance in 3D sensing applications [6]. In addition, Dr.

Ching-Yao Liu et al. demonstrated a high-peak-power pulsed laser diode driver based on advanced GaN HEMT technology [7]. In addition, further pushing VCSEL lasing wavelengths to blue and UV regimes will definitely lead to novel applications for sensing, visible light communication, and data storage. Prof. Tatsushi Hamaguchi reviewed the recent progress in GaN-Based VCSELs with the example of a monolithic curved mirror with excellent characteristics [8]. Moreover, Dr. Nathan C. Palmquist et al. demonstrated such a GaN-based VCSEL with the capability of CW lasing under room-temperature operation with a narrow divergence angle of its far-field patterns [9].

The exploration of new active layers of semiconductor lasers is, of course, one of the most important ways to fundamentally improve laser performance. Recently, lasers that use QD as the active layer have shown superior dynamic and static performances to those that use QW active layers under high-temperature operation (around 85 °C or even higher). In addition, QD lasers are more resistant to dislocation defects QW lasers when used as a reference on the Silicon photonic platform. Here, Kaiyin Feng et al. demonstrated a QD laser directly grown on 300 mm silicon wafers with high yield and reliable results ready for commercialization and scaled production [10]. In addition, Fedor Zubov et al. demonstrated a novel microring laser with a dot-in-a-well active layer design to improve the gain of traditional QD active layers [11]. Due to the smaller density of states in the QD active layer than those in QW examples, some potentially abnormal behaviors have been observed in QD lasers with the promise of some novel applications. Here, Dr. Ivan Makhov et al. demonstrated two-state lasing using microdisk laser diodes with QD used as the active region [12].

In summary, the development of high-speed and high-power VCSELs and QD semiconductor lasers are currently competitive research areas. Continuous improvements in the performance of VCSELs and QD lasers promise to aid in increasing the data rate from fiber channels to the end user. We hope that the present Special Issue, which highlights some parts of Prof. Dieter Bimberg's great academic achievements, may not only serve as a summary of different research lines but also be an inspiration for current researchers and those who are just beginning their professional association with these exciting fields.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Tian, S.-C.; Ahamed, M.; Bimberg, D. Progress in Short Wavelength Energy-Efficient High-Speed Vertical-Cavity Surface-Emitting Lasers for Data Communication. *Photonics* **2023**, *10*, 410. [CrossRef]
2. Hecht, U.; Ledentsov, N., Jr.; Ordouei, H.; Kurth, P.; Scholz, P.; Ledentsov, N.; Gerfers, F. Digital Non-Linear Transmitter Equalization for PAM-N-Based VCSEL Links Enabling Robust Data Transmission of 100 Gbit/s and Beyond. *Photonics* **2023**, *10*, 280. [CrossRef]
3. Babichev, A.; Blokhin, S.; Kolodeznyi, E.; Karachinsky, L.; Novikov, I.; Egorov, A.; Tian, S.-C.; Bimberg, D. Long-Wavelength VCSELs: Status and Prospects. *Photonics* **2023**, *10*, 268. [CrossRef]
4. Babichev, A.; Blokhin, S.; Gladyshev, A.; Karachinsky, L.; Novikov, I.; Blokhin, A.; Bobrov, M.; Kovach, Y.; Kuzmenkov, A.; Nevedomsky, V.; et al. Impact of Device Topology on the Performance of High-Speed 1550 nm Wafer-Fused VCSELs. *Photonics* **2023**, *10*, 660. [CrossRef]
5. Liu, A.; Zhang, J.; Hao, C.; Wang, M.; Zheng, W. Surface-Emitting Lasers with Surface Metastructures. *Photonics* **2023**, *10*, 509. [CrossRef]
6. Kondo, T.; Hayakawa, J.; Iguchi, D.; Sakita, T.; Higuchi, T.; Takeyama, K.; Ohno, S.; Murata, M.; Usami, H. All-Monolithically Integrated Self-Scanning Addressable VCSEL Array for 3D Sensing. *Photonics* **2023**, *10*, 304. [CrossRef]
7. Liu, C.-Y.; Wu, C.-C.; Tang, L.-C.; Chieng, W.-H.; Chang, E.-Y.; Peng, C.-Y.; Kuo, H.-C. Design of High Peak Power Pulsed Laser Diode Driver. *Photonics* **2022**, *9*, 652. [CrossRef]
8. Hamaguchi, T. GaN-Based VCSELs with A Monolithic Curved Mirror: Challenges and Prospects. *Photonics* **2023**, *10*, 470. [CrossRef]
9. Palmquist, N.C.; Anderson, R.; Kearns, J.A.; Back, J.; Trageser, E.; Gee, S.; Denbaars, S.P.; Nakamura, S. Long-Cavity M-Plane GaN-Based Vertical-Cavity Surface-Emitting Lasers with a Topside Monolithic Curved Mirror. *Photonics* **2023**, *10*, 646. [CrossRef]
10. Feng, K.; Shang, C.; Hughes, E.; Clark, A.; Koscica, R.; Ludewig, P.; Harame, D.; Bowers, J. Quantum Dot Lasers Directly Grown on 300 mm Si Wafers: Planar and In-Pocket. *Photonics* **2023**, *10*, 534. [CrossRef]

11. Zubov, F.; Moiseev, E.; Maximov, M.; Vorobyev, A.; Mozharov, A.; Shernyakov, Y.; Kalyuzhnyy, N.; Mintairov, S.; Kulagina, M.; Dubrovskii, V.; et al. Half-Ring Microlasers Based on InGaAs Quantum Well-Dots with High Material Gain. *Photonics* **2023**, *10*, 290. [CrossRef]
12. Makhov, I.; Ivanov, K.; Moiseev, E.; Dragunova, A.; Fominykh, N.; Shernyakov, Y.; Maximov, M.; Kryzhanovskaya, N.; Zhukov, A. Two-State Lasing in Microdisk Laser Diodes with Quantum Dot Active Region. *Photonics* **2023**, *10*, 235. [CrossRef]

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