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# Special Issue on Advanced Ultra-High Speed Optoelectronic Devices

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The data communication market has recently experienced a boom. Compared with the traditional telecommunication market, the required linking distance for data communication is much shorter (<2 km), which thus allows the direct transmission of high-speed data over fibers without serious limitations to the maximum data rate from chromatic dispersion and propagation loss. From 2016 to the present day, the data rate of the Ethernet has increased dramatically from 40 to 100 and subsequently to over 400 Gbit/s. This has been a strong driver of the development of high-speed light sources and detectors for emerging applications. In addition, these ultra-fast optoelectronic devices have come to play an important role in the development of next-generation millimeter wave (MMW) wireless communication systems. The radio-over-fiber (RoF) technique can be used to replace the lossy and bulky MMW waveguides or coaxial cables by optical fibers.

In this Special Issue, we highlight recent progress in the application of ultra-high speed optical transmitters, photoreceivers, optical modulators, and integrated optoelectronics devices to advanced data/tele-communications over optical fibers, radio-over-fiber communications, and terahertz communications. The details are given below. Hao-Tien Cheng et al. develop high-speed 850 nm VCSELs with excellent performance for very-short reach (VSR < 25 m) and >400 Gbps data communication [1]. In addition, Nikolaos Panteleimon et al. demonstrate a high-speed 1310 nm membrane DFB laser with state-of-the-art dynamic performance (Sub-pJ/bit) for 100 Gbps transmission (per lane) capable of extending the linking distance to 2 km [2]. When the linking distance for inter-data center communications becomes longer (>40 km), the electro-optics (E-O) Mach-Zehnder modulator (MZM) is highly desirable as having much less chirp than that of directly modulated lasers (DML). Here, Tetsuya Kawanishi successfully shows that the extinction ratio and data transmission can be greatly enhanced by precisely balancing the optical power between different arms of the MZM [3]. In order to overcome the fundamental trade-off between speed and driving voltage in the E-O MZM, though, new materials with strong E-O coefficients are highly desired. Eun-Su Lee et al. thus develop a novel MZM based on fluorinated polyimide with excellent thermal stability performance [4].

With regard to the receiving ends in the data communication system, they are usually required to simultaneously have high-speed, high-sensitivity, and a wide dynamic range due to the fact that the variation in receiving optical power may be large when the linking distance ranges from VSR (<25 m) to over 2 km. Masahiro Nada et al. demonstrated the excellent performance of inverted (p-side down) p-i-n photodiodes and avalanche photodiodes in terms of speed and sensitivity for 106 Gbit/sec PAM-4 data transmission (per channel) [5]. Nassem et al. describe a novel high-speed APD structure with a dual multiplication (M) layer design aimed at overcoming the trade-off for a gain-bandwidth (GB) product encountered in traditional APDs [6]. These dual-M APDs achieve a state-of-the-art GB product and saturation current performance. Exploration of the longer



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infrared (IR) wavelengths in modern fiber communication channels is another way to further enhance their bandwidth capacity. Here, Baile Chen et al. review recent progress in high-performance PDs operated at longer IR wavelengths [7].

Aside from high-performance discrete E-O/O-E components, the incorporation of monolithic integrated photonic integrated circuits (PICs) is also desired to downscale the font factor in the modern transreceiver module. The externally modulated DFB laser (EML) serves as one of the most important PIC components. Patrick Runge et al. demonstrate high-performance EML at a 1310 nm wavelength and p-i-n PDs in a InP platform [8]. By using these two key components, they achieve 100 Gbaud data transmission. Lin Jiang et al. present an overall review article, which discusses the aforementioned technologies for data communication with linking distance ranges from VSR to >2 km [9]. The incorporation of the RoF technology in the last mile of high-speed data or telecommunication networks, which can wirelessly distribute the high-speed data to the user end, is desirable. Here, Kazutoshi Kato demonstrates a secured wireless communication system based on the technologies of photonic-assisted THz-wave beam generation and steering [10].

In summary, the development of high-speed active O-E/E-O components is nowadays one of the most competitive research areas among those devoted to advancing the data and tele-communications sector. Continuous improvements in performance promise to aid in increasing the data rate from fiber channels to the user end.

I hope that the present Special Issue may serve not only as a summary of different research lines, but also that it may encourage further work in this exciting field.

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