Editorial

Special Issue on Advanced Technique and Future Perspective for Next Generation Optical Fiber Communications

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Optical communication refers to the communication mode with optical signal as a carrier. With the development of laser and optical fiber, optical communication has also made great progress and has penetrated into every aspect of our daily life. However, the continuous growth of bandwidth and high-quality service demand has brought unprecedented challenges to optical communication network; thus, it is imperative to find new solutions to meet the new challenges. Due to its powerful computing power, artificial intelligence (AI) is applied in optical communication to improve its performance [1,2]. The combination of artificial intelligence technology and optical communication technology may promise great potential and start a new stage of optical communication and optical network.

This Special Issue aims to discuss advanced analytical tools and new technologies for next-generation fiber optical communication systems and networks. It focuses on the latest advances and future prospects from basic theory to applications, as well as devices, subsystems, and networks. Topics covered include nonlinear fiber optics, advanced devices, AI and deep learning applications in optical fiber communication, and optical network control and management, etc. Seven research articles and one communication paper are included in this Special Issue.

More specifically, passive optical networks are discuss. Zehri, M. et al. proposed a dynamic bandwidth allocation (DBA) algorithm [3]. In time- and wavelength-division multiplexing (TWDM) technology, the laser tuning time (LTT) delay is often ignored when evaluating the performance of dynamic bandwidth allocation (DBA) mechanisms. The DBA algorithm takes LTT into account and is capable of dynamically processing bandwidth and converting the laser wavelength of an optical network unit. By introducing the longest processing time, the first scheduling discipline (LPT) algorithm can reduce the queue delay by 73% compared to interleaved polling with an adaptive cycle time (IPACT) and 33% compared to the WFQ algorithm, which has high practical significance.

Free-space optical communication (FSOC) has the advantages of fast communication speed, strong anti-interference ability, and high security. The use of a FSOC system on unmanned aerial vehicle (UAVs) will help improve communication capabilities and eliminate its strict requirements for electromagnetic environment. Zhang, Y. et al. established an electromagnetic immune FSOC system for UAV control link [4]. The system has great anti-turbulence, anti-vibration, and anti-flight interference performance. Moreover, it achieves the goal of miniaturization without using a gimbal mirror system, a beacon camera system, and a four-quadrant photodetector (QPD), allowing the system to be used in

situations where small FSOC devices are required, such as satellite–submarine communication.

In the field of improving optical communication performance, Yin, H. et al. proposed a method to realize frame synchronization based on Hough transform (HT) methods [5]. Hough transform, a classical method for line detection in digital image processing, is applied to fringe detection in intercept matrix. Simulation results in a 56 Gbps QPSK coherent optical transmission system show that the proposed algorithm can achieve frame synchronization, even with high bit error rate of 0.3. In order to improve the transmission power efficiency, Sampath, K.I.A. et al. validated three previously proposed methods for reducing the peak-to-average power ratio (PAPR) of OSSB-SC signals: peak folding, peak clipping, and high-pass Hilbert transform methods [6]. In this study, he numerically compared the results of the three methods in a 10 Gbit/s non-return-to-zero (NRZ)-coded 100 km-single channel transmission link. The self-phase modulation (SPM) threshold induced by peak folding and peak clipping increased by 2.40 dB and 2.63 dB due to the decrease in the peak-to-average ratio, while the SPM threshold induced by high-pass Hilbert transform increased by 9.86 dB. Moreover, peak folding can suppress the driving signal noise. These methods bring a new development direction to improve the transmission power efficiency of OSSB-SC. Additionally, Hayal, M.R. et al. proposed a model of passive optical network (PON) wavelength division multiplexing (WDM) technology based on hybrid fiber FSO (HFFSO) link, which has shown great transmission performance under the condition of 20 gbit/s-4000 m [7]. In this design, M-ary DPPM-M-PAPM modulation greatly improves performance since it can offer extra information bits. They also studied the influence caused by the turbulence effect on the proposed system based on OOK-M-ary PAPM-DMPP modulation. Simulation results confirm that OOK/M-ary DPPM-M-PAPM hybrid optical modulation technique can be applied in the DWDM-FSO hybrid links for optical wireless and fiber-optic communication systems to improve efficiency significantly, as well as reduce the effect of AT, ICC, and ASE noise.

When discussing the combination of artificial intelligence technology and optical communication, Chang, S. H. took the technical network of machine learning in optical communication as the research object to explore the key technologies and application development of machine learning in optical communication [8]. Through patent analysis, he built a network model that can predict technology development trends, which provided a reference for industry development.

Li, C. et al. proposed and theoretically proved the internal dynamics of complex dissipative soliton-bound states using deep convolution networks (DCNs) [9]. They demonstrated the results via VGG, ResNets, and DenseNets, and achieved high-precision results. They extracted phase evolution information of more complex soliton molecules from time-stretch-dispersive Fourier transform (TS-DFT) spectral data by modifying the network structure. When extracting the dynamics information of complex five-soliton molecules from TS-DFT data, the 48-layer DenseNet obtained a mean Pearson correlation coefficient (MPCC) of 0.9975, which showed the best performance. ResNet and VGG have MPCCs of 0.9906 and 0.9739, respectively. It can be seen from the results that these methods are universal in extracting the internal information of complex soliton molecules with high accuracy. Additionally, Zhang, L. et al. proposed a new architecture combining time lenses and optical neural networks (TLs-ONNs) based on the optical space–time duality [10]. Time lenses were applied to the neural network to achieve imaging of time signals by controlling the phase information of time lens. The performance of the network is tested by simulation, and the accuracy of speech recognition is 95.35%. By fusing the ONN with the photon time stretching test system, not only can real-time data processing be achieved, but also the power and cost consumption can be reduced. This architecture is expected to make a breakthrough in initial screening of cancer cells and can find widespread application in high-throughput data processing.

The continuous development of cloud computing, Big Data, Internet of Things, and other emerging businesses has brought about the explosive growth of data volume, which

has created new development challenges in optical fiber communication. In order to meet the demand of a large amount of data processing, the existing communication system needs to improve the stability and transmission efficiency. In addition, emerging technologies, such as artificial intelligence (AI), can also provide a new development direction for optical fiber optic communication. Artificial intelligence technology in optical communication and optical network is still in its infancy, but has made some progress in deep convolution networks (DCN) and time lens–optical neural networks (TL-ONNs). Whether we continue to improve the performance of traditional optical fiber communication systems or combine emerging technologies to find new bases, the next generation of optical fiber communication system will develop towards the direction of high speed, high stability, high transmission efficiency, and intelligence.

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

References

1. Wu, X.; Hu, F.; Zou, P.; Lu, X.; Chi, N. The performance improvement of visible light communication systems under strong nonlinearities based on Gaussian mixture mode. *Microw. Opt. Technol. Lett.* **2020**, *62*, 547–554.
2. Chi, N.; Zhao, Y.; Shi, M.; Zou, P.; Lu, X. Gaussian kernel-aided deep neural network equalizer utilized in underwater PAM8 visible light communication system. *Opt. Express* **2018**, *26*, 26700–26712.
3. Zehri, M.; Haastrup, A.; Rincón, D.; Piney, J.R.; Sallent, S.; Bazzi, A. A QoS-Aware Dynamic Bandwidth Allocation Algorithm for Passive Optical Networks with Non-Zero Laser Tuning Time. *Photonics* **2021**, *8*, 159.
4. Zhang, Y.; Wang, Y.; Deng, Y.; Du, A.; Liu, J. Design of a Free Space Optical Communication System for an Unmanned Aerial Vehicle Command and Control Link. *Photonics* **2021**, *8*, 163.
5. Yin, H.; Li, S.; Huang, Z.; Chen, J. A Novel Data-Aided Frame Synchronization Method Based on Hough Transform for Optical Communications. *Photonics* **2020**, *7*, 65.
6. Sampath, K.I.A.; Takano, K.; Maeda, J. Peak-to-Average Power Ratio Reduction of Carrier-Suppressed Optical SSB Modulation: Performance Comparison of Three Methods. *Photonics* **2021**,*8*, 67.
7. Hayal, M.R.; Yousif, B.B.; Azim, M.A. Performance Enhancement of DWDM-FSO Optical Fiber Communication Systems Based on Hybrid Modulation Techniques under Atmospheric Turbulence Channel. *Photonics* **2021**, *8*, 464.
8. Chang, S.-H. Patent Technology Network Analysis of Machine-Learning Technologies and Applications in Optical Communications. *Photonics* **2020**, *7*, 131.
9. Li, C.; He, J.; Liu, Y.; Yue, Y.; Zhang, L.; Zhu, L.; Zhou, M.; Liu, C.; Zhu, K.; Wang, Z. Comparing Performance of Deep Convolution Networks in Reconstructing Soliton Molecules Dynamics from Real-Time Spectral Interference. *Photonics* **2021**, *8*, 51.
10. Zhang, L.; Li, C.; He, J.; Liu, Y.; Zhao, J.; Guo, H.; Zhu, L.; Zhou, M.; Zhu, K.; Liu, C.; et al. Optical Machine Learning Using Time-Lens Deep Neural NetWorks. *Photonics* **2021**, *8*, 78.