photonics

Editorial

Special Issue "Photonics for Emerging Applications in Communication and Sensing"

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Photonics has emerged as a crucial enabler for various emerging applications in communication and sensing, revolutionizing industries such as data centers, autonomous driving, 5G wireless networks, cloud computing, the IoT, and virtual reality. This Special Issue aims to present recent advancements and address future challenges in photonics technologies, focusing on performance monitoring in optical networks, photonic sensors and devices, optical signal processing subsystems, and digital signal processing for future optical transmission systems. This collection of research consists of thirteen articles highlighting the transformative potential of photonics in supporting and enabling the advancement of emerging technologies in communication and sensing. By exploring these frontiers, we strive to uncover innovative solutions that will shape the future of communication and sensing.

In optical networks, it is essential to estimate the quality of transmission (QoT) of light paths and monitor the performance of each wavelength channel. Y. Zhou et al. presented a self-attention mechanism-based multi-channel QoT estimator for optical networks. Based on the previous QoT estimation scheme using an artificial neural network (ANN), a self-attention mechanism was introduced to dynamically assign weights to the interfering channels to improve the estimation accuracy and scalability. Specifically, the maximal absolute error achieved by SA-QoT-E was reduced from 4.21 to 1.13 dB in the Japan network (Jnet) and from 3.46 to 0.84 dB in the National Science Foundation network (NSFnet) [1]. To efficiently monitor the optical performance in wavelength division (WDM) networks with low implementation costs, T. Yang et al. introduced optical labels encoded in differential phase-shift keying (DPSK) to enable simultaneous monitoring of all wavelength channels using a single low-bandwidth photodetector (PD) and designed digital signal processing (DSP) algorithms. Less than 1 dB error was achieved after 20-span WDM transmission, verifying the feasibility and efficiency of the proposed scheme [2]. To enhance the physical layer security of optical networks, the signal-to-noise ratio (SNR) of the optical channel can be extracted and used as the basis of key generation. X. Wang et al. proposed a cost-effective key distribution scheme using the extracted SNR as a key for secured communication with promising metrics such as a key generation rate of 25 kbps and a key consistency rate of 98% [3].

Plasmonic sensors are photonics-based devices that exploit the interaction between light and plasmons and the collective oscillations of electrons to detect and analyze changes in local electromagnetic fields. J. Liu et al. investigated the optical extinction spectra of a silver nanocube driven by an ultrashort carrier-envelope phase (CEP)-locked laser pulse. They revealed five localized surface plasmon resonance (LSPR) modes and their physical origin, demonstrating the modulation capability of CEP in selectively exciting LSPR modes.

This research provides insights into controlling and optimizing the optical properties of metal nanoparticles for sensing and detection applications [4]. While traditionally associated with noble metals like gold and silver, plasmonic sensors can also be implemented by using alternative materials such as aluminum nitride (AlN). S. Tang et al. explored a dielectric-grating-assisted plasmonic sensor utilizing the bound states in the continuum (BIC) effect for narrow line widths and high sensitivity in refractive index sensing. This approach addresses the limitations of plasmonic sensors and opens possibilities for improved sensing technologies [5].

Emerging materials such as silicon-based compounds, metasurfaces, and phase-change materials have enabled exciting advancements in photonic devices for optical signal processing. Y. Hong et al. presented an optimized approach using the 3D finite element method to achieve flat and low dispersion profiles in silicon nitride waveguides for efficient four-wave mixing (FWM). Their work results in near-zero dispersion values and high conversion efficiencies with low pump power, enhancing the performance of optical signal processing applications based on FWM [6]. X. Tian et al. introduced a hybrid phase-change metasurface carpet cloak using a novel phase-change material (GSST). This metasurface offers wideband indiscernibility, polarization-immune cloaking, and reversible functionality, providing potential applications in electromagnetic camouflage and illusion [7].

Optical signal processing subsystems play a pivotal role in optical communication, focusing on developing innovative techniques to manipulate, analyze, and enhance optical signals, enabling efficient transmission, detection, and processing of information in optical transmission systems. Y. Liu et al. proposed an optical analog-to-digital converter (OADC) scheme using a multimode interference (MMI) coupler for enhanced bit resolution. Their approach achieved 20 quantization levels with only 6 channels, demonstrating robustness and integration potential [8]. A. Chiba et al. achieved 60 GHz separation optical two-tone signal generation at arbitrary C-band wavelengths without complicated optical wavelength filtering. Their method selectively suppresses undesired low-order optical sidebands using a polarizer, resulting in more than 20 dB suppression over a 40 nm wavelength range [9]. Z. Liu et al. demonstrated a high-resolution 1×6 programmable photonics spectral processor (PSP) using low-cost, compact spatial light paths. This processor allows independent manipulation of filtering bandwidth and power attenuation for each wavelength channel, offering potential benefits for WDM systems [10].

DSP plays a crucial role in extracting, decoding, and enhancing optical signals, ensuring reliable transmission, coherent detection, and efficient utilization of the available optical bandwidth in both coherent and intensity-modulation direct-detection (IMDD) optical communication systems. It encompasses a wide range of techniques and algorithms that enable the optimization of signal quality, advanced modulation formats, error correction, and compensation of impairments. T. Yang et al. proposed a low-complexity scheme for accurate chromatic dispersion (CD) estimation in faster-than-Nyquist (FTN) coherent optical transmission systems. Their scheme achieves high CD estimation accuracy (65 ps/nm) with reduced computational complexity (3%) compared to conventional methods, making it suitable for practical FTN systems [11]. Y. Zhang et al. proposed a parallel distribution matcher scheme for probabilistic-shaped coherent optical fiber communication. The SNR can be enhanced by 0.12 dB, and the block length can be reduced by 40% compared to the conventional scheme using a constant composition distribution matcher (CCDM) [12]. Y. Liu et al. investigated signal pre-processing schemes for SNR equalization in short-reach probabilistically shaped discrete multitone (DMT) transmission systems. The proposed fast Walsh–Hadamard transform (WHT)-based pre-distortion scheme offers a receiver sensitivity gain of 1 dB [13].

This Special Issue on photonics technologies showcases remarkable advancements and prospects in the field. The featured research articles highlight innovative solutions and address key challenges in various topics, such as optical performance monitoring, photonic sensors, photonic devices for optical signal processing, optical signal processing subsystems, and digital signal processing. The continued development of photonics for emerging applications in communication and sensing holds great promise for the future.

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

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