Optical Engineering

GUEST EDITORIAL

Special Section Guest Editorial: Fiber-Optic Sensors for Environmental Health Monitoring

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Our modern society confronts a myriad of environmental health challenges arising from a combination of industrialization, climate change, population growth, and urbanization. These factors not only directly impact our natural environments and human health but also influence the social infrastructure around us. Extensive attention and effort have been devoted to guiding our society toward a sustainable future. Before taking corrective actions, however, one has to start with the accurate measurement and understanding of our environment and infrastructures. These pressing needs create immense space for sensing technologies, including fiber-optic sensing (FOS).

After decades of advancement, FOS continues to undergo rapid evolution, owing to its exceptional sensitivity, distributed measurement capability, potential for remote monitoring, and immunity to electromagnetic interference. An often overlooked aspect of fiber-optic sensors is their versatility in both operating physics and sensor construction. Whether using the fiber as the sensing element or simply as a light conduit to a sensor head, it creates a plethora of possibilities in a wide spectrum of applications. This flexibility perfectly matches the diverse need for environmental sensing, and in the past decade has been key to the significant growth of FOS beyond the traditional industrial application, extending into the characterization of the world around us.

Environmental health monitoring using fiber-optic sensors encompasses the measurement, tracking and analysis of various environmental factors that may impact human health and well-being. Examples include air and water quality, biomedicine, greenhouse gases, electric systems, structural health, oil and gas production, earthquakes, climate patterns, and many more. Across these diverse fields, FOS is a robust solution provider, and will remain significant in the foreseeable future. The recent rise of deep learning for FOS signal processing further enhances its capabilities. It is important to recognize, however, that the comprehensive monitoring of our environmental health demands the integration of multiple sensing technologies, where FOS can play a critical role.

This special section does not aim to compile a comprehensive collection of recent research. Instead, it highlights emerging techniques that can potentially advance the state of the art. Equally important is our hope to raise awareness about this important subject matter.

In this special section, Lyu et al. provide a comprehensive review of optical fiber sensors for water and air quality monitoring, categorized by operating principles as well as chemicals of interest. Most of the results were published in the past five years, reflecting the current trend in this area. Liu et al. describe a signal processing algorithm for high finesse Fabry-Perot (FP) sensors. The algorithm utilizes Buneman frequency estimation and the full-phase information of the harmonics in Fourier domain and could benefit the popular group of FP interferometric sensors. Lv et al. propose the use of fiber Bragg gratings (FBG) for dynamic humidity monitoring within hydrogen fuel cell stacks. The compact size and light weight of the sensor play a critical role in its performance. The work by Chen et al. is also on signal processing, proposing a transformer neural network with a frequency domain attention mechanism. It is used to analyze the vibration data from a distributed ultra-weak FBG sensing system for defect monitoring of

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subway track bed. Fu et al. explore forward stimulated Brillouin scattering (FSBS) as a platform for acoustic impedance measurement external to the fiber. Aluminum-coated fibers ensure mechanical strength and enhance FSBS waveform propagation, making it more suitable for high humidity or liquid environments. Yaras et al. demonstrate an electric field sensor for time domain measurement compatible with magnetic resonance imaging (MRI). The sensor is based on a phase-shifted FBG actuated by a piezoelectric transducer. Finally, Liu et al. developed a chirped FBG sensor for quantifying the wear on sliding bear in marine environment, where the system will support the monitoring of ship propulsion system.

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