photonics

Editorial

Special Issue "Novel Specialty Optical Fibers and Applications": An Overview

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Citation: Hu, D.J.J.; Humbert, G. Special Issue "Novel Specialty Optical Fibers and Applications": An Overview. *Photonics* **2022**, *9*, 497. https://doi.org/10.3390/photonics9070497

Received: 2 June 2022
Accepted: 14 July 2022
Published: 15 July 2022

Novel specialty optical fibers refer to optical fibers that have been engineered in terms of design, material and structure, and have been post-processed for novel functionalities and applications. The optical properties in novel specialty optical fibers can be manipulated to achieve optimum performance, resulting in numerous important applications. In this Special Issue, the recent advancements in specialty fiber technology are highlighted and reviewed, with a focus on design, development, and application, as well as future challenges and emerging opportunities.

Eight review papers and seven original research papers are published in this Special Issue, "Novel Specialty Optical Fibers and Applications". A brief overview of the published work is presented in this section.

Specialty fibers composed of special materials introduce new functionalities and open up new spectral windows for applications due to the presence of special materials. Chalcogenide glass (ChG) microfibers (MFs) have introduced wide opportunities in the mid-infrared (mid-IR) spectral range due to their broadband transparency, high optical nonlinearity, and hospitality to rare-earth dopants. The emerging and fast-growing field of ChG MFs in mid-IR optics and applications is reviewed in [1]. Bismuth-doped fiber power amplifier is developed to cover the spectral range of 1650–1700 nm, which is unavailable with rare-earth-doped fibers, enabling applications in optical telecommunication and optical-based methane sensing [2].

The original properties offered by light propagation within hollow-core fibers leads to novel opportunities in light generation, fiber sensing, communication, and light manipulation. W. Pei et al. report here the development of an all-fiber laser operating at the 1.6–1.7 μm band based on deuterium-filled hollow-core photonic crystal fibers [3]. This all-fiber structure enhances the Raman scattering of deuterium gas, offering tunable laser operating from 1643 nm to 1656 nm. An all-fiber gas cavity based on anti-resonant hollow-core fibers is fabricated and experimentally demonstrated with the stable and efficient pump coupling of 78.1% at a maximum injecting laser power of 260 W [4]. This work demonstrates a feasible and simple method for an all-fiber gas cavity for the development of high-power fiber gas lasers. The opportunities offered by hollow-core fibers for sensing are reviewed in these two contributions. Recent developments related to all-fiber online Raman sensors with hollow-core fibers are reviewed in [5], and their applicability in relation to reusability, easiness to clean, rapid detection for safety inspections, food detection, water quality detection, etc., is emphasized. The development of anti-resonant hollow-core fiber (AR-HCF)-based sensing applications is reviewed in [6]. This novel class of hollow-core fiber offers a unique sensing platform to achieve highly accurate and ultra-compact fiber optic sensors with large measurement ranges.

Different strategies exploiting the functionalization of specialty optical fibers with liquids or metals and/or specific fiber designs, such D-shape multicore fibers, have been investigated for developing more sensitive fiber sensors. Thereby, the refractive index sensing performance of functionalized fiber can be significantly enhanced with gold film (and a thin layer of titanium dioxide) deposited on a D-shaped honeycomb-microstructure optical fiber. This novel fiber design, proposed in [7], is expected to achieve an ultra-high wavelength sensitivity of 20,100 nm/RIU and a minimum resolution as low as 4.98×10^{-7} RIU (from numerical studies). The functionalization of fiber tips with an array of metallic nanodots is experimentally demonstrated to achieve substantially improved large-angle light-collection performance at multiple wavelengths [8]. This concept paves the way for high-performance fiber-based optical devices and is particularly relevant within the context of endoscopic-type applications in life science and light collection within quantum technology.

In addition to metal functionalization, structural engineering in specialty fibers has resulted in the greater flexibility and controllability of optical properties and thus led to versatile applications for physical and biomedical sensing and communications. Multicore fibers that were initially introduced as a promising platform to realize spatial division multiplexed transmission have been attracting growing interest in sensing applications, as reviewed in [9]. Finally, the specific guiding properties at the critical wavelength (CWL) in Mach–Zehnder-based interferometers (MZIs) have been exploited through different designs of few-mode special optical fibers and microfibers for various sensing applications. The recent development of such a configuration, as reviewed in [10], offers desirable sensing advantages, such as large measurement range, high sensitivity, and multi-parameter sensing.

Specialty fibers for distributed fiber sensor technologies are reported in two review papers in the Special Issue. The recent development of specialty fiber-based Brillouin optical time domain analysis (BOTDA) is reviewed in [11]. These specialty fibers present many opportunities for BOTDA systems, including breakthroughs in Brillouin gains, the discriminative sensing of temperature and strains, multiplexed sensing systems, and the distributed sensing of parameters such as curvature, pressure and salinity. In addition, scattering-enhanced specialty-fiber-based distributed acoustic sensing (DAS) systems are reviewed in [12]. These specialty scattering-enhanced optical fibers enable practical applications for DAS systems in many fields, including geological and resource exploration, structural health monitoring, and hydroacoustic exploration.

In addition to spectroscopy and sensing applications, one review paper and two regular papers report specialty fibers for communication applications. Stable orbital angular momentum (OAM) mode generation and transmission in novel fibers are reviewed in [13]. It is worth noting that improvements in fabrication techniques, such as ensuring the uniformity of the longitudinal hollow structures of the novel fibers, remains a critical challenge for OAM mode stability. Through design optimization and simulation investigation, a gold-coated photonic crystal fiber design is proposed to achieve a high loss ratio for polarization filtering at 1550 and 1310 nm [14]. In addition, a dual-core photonic crystal fiber with a liquid–crystal infiltration-based polarization beam splitter is proposed to achieve a splitting bandwidth of 349 nm, covering the entire E + S + C + L + U communication bands [15].

Funding: This research received no external funding.

Acknowledgments: The guest editors would like to thank all authors for their contributions to this Special Issue. We would like to thank all reviewers for providing constructive review comments and recommendations. In particular, we would like to thank editors of *Photonics* journal for the excellent support to this Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Cai, D.; Xie, Y.; Guo, X.; Wang, P.; Tong, L. Chalcogenide Glass Microfibers for Mid-Infrared Optics. *Photonics* **2021**, *8*, 497. [CrossRef]
2. Gomółka, G.; Krajewska, M.; Kaleta, M.; Khegai, A.M.; Alyshev, S.V.; Lobanov, A.S.; Firstov, S.V.; Nikodem, M. Operation of a Single-Frequency Bismuth-Doped Fiber Power Amplifier near 1.65 µm. *Photonics* **2020**, *7*, 128. [CrossRef]
3. Pei, W.; Li, H.; Huang, W.; Wang, M.; Wang, Z. All-Fiber Gas Raman Laser by D2-Filled Hollow-Core Photonic Crystal Fibers. *Photonics* **2021**, *8*, 382. [CrossRef]

4. Shi, J.; Ye, X.; Cui, Y.; Huang, W.; Li, H.; Zhou, Z.; Wang, M.; Chen, Z.; Wang, Z. All-Fiber Gas Cavity Based on Anti-Resonant Hollow-Core Fibers Fabricated by Splicing with End Caps. *Photonics* **2021**, *8*, 371. [CrossRef]
5. Ding, H.; Hu, D.J.J.; Yu, X.; Liu, X.; Zhu, Y.; Wang, G. Review on All-Fiber Online Raman Sensor with Hollow Core Microstructured Optical Fiber. *Photonics* **2022**, *9*, 134. [CrossRef]
6. Ni, W.; Yang, C.; Luo, Y.; Xia, R.; Lu, P.; Hu, D.; Danto, S.; Shum, P.; Wei, L. Recent Advancement of Anti-Resonant Hollow-Core Fibers for Sensing Applications. *Photonics* **2021**, *8*, 128. [CrossRef]
7. Bu, W.; Wu, Z.; Shum, P.P.; Shao, X.; Pu, J. Sensitivity Enhanced Refractive Index Fiber Sensor Based on Long-Range Surface Plasmon Resonance in SiO_2-Au-TiO_2 Heterostructure. *Photonics* **2021**, *8*, 379. [CrossRef]
8. Wang, N.; Zeisberger, M.; Hübner, U.; Schmidt, M. Nanograting-Enhanced Optical Fibers for Visible and Infrared Light Collection at Large Input Angles. *Photonics* **2021**, *8*, 295. [CrossRef]
9. Zhao, Z.; Dang, Y.; Tang, M. Advances in Multicore Fiber Grating Sensors. *Photonics* **2022**, *9*, 381. [CrossRef]
10. Lu, C.; Dong, X.; Wu, C. Characteristics of Critical-Wavelength-Existed Fiber-Optic Mach–Zehnder Interferometers and Their Sensing Applications. *Photonics* **2022**, *9*, 378. [CrossRef]
11. Hu, D.J.J.; Humbert, G.; Dong, H.; Zhang, H.; Hao, J.; Sun, Q. Review of Specialty Fiber Based Brillouin Optical Time Domain Analysis Technology. *Photonics* **2021**, *8*, 421. [CrossRef]
12. Sun, Y.; Li, H.; Fan, C.; Yan, B.; Chen, J.; Yan, Z.; Sun, Q. Review of a Specialty Fiber for Distributed Acoustic Sensing Technology. *Photonics* **2022**, *9*, 277. [CrossRef]
13. Wang, Z.; Tu, J.; Gao, S.; Li, Z.; Yu, C.; Lu, C. Transmission and Generation of Orbital ANGULAR Momentum Modes in Optical Fibers. *Photonics* **2021**, *8*, 246. [CrossRef]
14. Wang, C.; Zhang, G.; Wu, Z.; Zhang, Y.; Zhang, Y.; Jiang, L.; Bi, W. A Broadband Gold-Coated Photonic Crystal Fiber Polarization Filter with a High Loss Ratio of Both Polarizations at 1550 and 1310 nm. *Photonics* **2021**, *8*, 488. [CrossRef]
15. Qu, Y.; Han, Y.; Yuan, J.; Zhou, X.; Yan, B.; Wang, K.; Sang, X.; Yu, C. A Novel Liquid Crystal-Filled, Dual-Core Photonic Crystal Fiber Polarization Beam Splitter Covering the E + S + C + L + U Communication Band. *Photonics* **2021**, *8*, 461. [CrossRef]