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EDITORIAL

Preface to the special issue on "Recent Advances in Optical Metasurfaces"

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Optical metasurfaces, composed of planar arrays of sub-wavelength dielectric or metallic structures that collectively mimic the operation of conventional bulk optical elements, have revolutionized the field of optics by their potential in constructing high-efficiency and multi-functional optoelectronic systems with a compact form factor. By engineering the geometry, placement, and alignment of its constituent elements, an optical metasurface arbitrarily controls the magnitude, polarization, phase, angular momentum, or dispersion of incident light. The study of metasurface now spans various multidisciplinary fields in both fundamental research on light-matter interaction [1–3], and emerging applications from solid-state LiDAR [4,5] to compact imaging, spectroscopy, and quantum optical devices [6–11]. High-performance metasurface devices have been experimentally demonstrated over the entire optical spectrum from the deep ultraviolet to the terahertz (THz) [12–16], and have been employed to manipulate optical waves in both spatial and temporal domains [17–21].

This special issue on "Recent Advances in Optical Metasurfaces" includes five review articles and five research articles, covering various topics ranging from metasurface design to practical applications. Qiu et al. [22] provide a comprehensive review of the fundamentals and applications of spin-decoupled Pancharatnam–Berry (PB) metasurfaces. Different from traditional PB-phase-based metasurfaces which impinge phase modulations with opposite signs onto the left-handed and right-handed circularly polarized light, the spin-decoupled PB metasurfaces release the above spin-locked limitation and allow independent and arbitrary control over orthogonal circular polarizations. The recent development of bianisotropic metasurfaces has allowed versatile control over the state of polarization and propagation direction of light. Xiong et al. [23] discuss the electromagnetic properties of photonic bianisotropic structures using the finite element method. The authors show that the vector wave equation with the presence of bianisotropy is self-adjoint under the scalar inner product and propose a balanced formulation of weak form in the practical implementation that outperforms the standard formulation in finite element modeling. Realizing active devices with adjustable functionalities is of great interest to the metasurface research community. Bi et al. [24] review the physical mechanisms and device applications of magnetically controllable metasurfaces. Magnetic field manipulation has advantages of ultra-fast response, non-contact and continuous adjustment, thus paving the way toward realizing multi-functional and dynamic metasurface-based devices and systems.

Several typical as well as emerging applications of the metasurface technology, are covered by this special issue. Fu et al. [25] give a comprehensive review of metalenses, tiny planar imaging devices enabled by metasurface technology. The article covers the basic phase modulation techniques, design principles, characterization methods, and functional applications of metalenses. Although a metalens might not fully compete with a conventional lens in terms of imaging quality at the current stage, it possesses unique advantages in terms of multi-dimensional and multi-degree-of-freedom control over an incident light, thus facilitating novel functionalities that are extremely difficult or even impossible to implement using conventional technology. The electromagnetic absorber is another typical application of metasurface technology. Gandhi et al. [26] propose a polarization-insensitive metasurface absorber

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operating in the THz regime. The device consists of metal-dielectric-metal resonators and exhibits absorption greater than 90% over the 2.54 to 5.54 THz range. In recent years, edge detection using metasurfaces has raised a significant interest and could find promising applications in all-optical computing and artificial intelligence. Wan et al. [27] review the development of dielectric metasurfaces for spatial differentiation and edge detection. The article focuses on the underlying principles of dielectric metasurfaces as first- or second-order spatial differentiators and their applications in biological imaging and machine vision.

Non-diffractive beams are highly desired for a number of applications, including biomedical imaging, particle manipulation, and material processing. Liu et al. [28] investigate dual non-diffractive THz beam generation using dielectric metasurfaces. The authors design and experimentally implement Bessel beams and abruptly autofocusing beams, two representative kinds of non-diffractive beams with dramatically opposite focusing properties. With its compact footprint and multiple functionalities, metasurface offers new possibilities in constructing high-performance optical sensors. Ye et al. [29] introduce an ultra-sensitive optical sensing platform based on the parity-time-reciprocal scaling (PTX)-symmetric non-Hermitian metasurfaces. Such devices leverage exotic singularities, such as the exceptional point and the coherent perfect absorber-laser point, to significantly enhance the sensitivity and detectability of photonic sensors. Ren et al. [30] propose a U-shaped THz metamaterial with polarization-sensitive and actively-controllable electromagnetically induced transparency, which could find useful applications in tunable integrated devices such as biosensors, filters, and THz modulators. Realizing large-scale and low-cost fabrication of metasurface could greatly facilitate the technology's practical applications. Oh et al. [31] review the development of nanoimprint lithography for high-throughput fabrication of optical metasurfaces. The authors elaborate various imprint methods for scalable fabrication of metasurfaces and share their perspectives on the technology's future development.

We hope that this special issue on "Recent Advances in Optical Metasurfaces" could provide useful information for metasurface researchers and inspire new ideas for their future exploration. We thank all authors for their contribution to this special issue, and reviewers for their valuable comments. In the end, we would like to express sincere gratitude to the editors of *Frontiers of Optoelectronics* for providing us such an excellent opportunity to put together this special issue and their invaluable assistance along the way.

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