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# Special issue on meta-lenses

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About a decade ago, the unveiling of generalized Snell's laws heralded a significant advancement in nanophotonics, leading to the emergence of metasurfaces[1−6]. This revolutionary milestone has set the stage for the development of advanced optical devices, particularly meta-lens[7−11]. Researchers are already well-versed in the fundamental principles and functions of meta-lenses, which exemplify the concept of phase discontinuities with clarity. However, the exploration of meta-lenses is far from over. To harness their full potential, a thorough and precise examination of each step in the research process is imperative. In this special issue, we have presented five noteworthy research articles that delve into the domain of meta-lenses, spanning topics from optimized design strategies and advanced fabrication methods to a variety of application contexts.

Designing a meta-lens involves building up a meta-atom library, a pivotal step that is often deeply contingent upon the researchers' expertise. For meta-lenses with complex functionalities, the design of appropriate meta-atoms and a comprehensive exploration of their geometric parameters are indispensable. This process, while essential, can be notably laborious and time-consuming. To accelerate it, various optimization methods have been introduced[12]. Zhang et al.[13] demonstrated an efficient genetic algorithm-assisted method to optimize meta-atoms for high-performance meta-optics. This methodology is adept at addressing both single and multi-objective device designs. They first used the method to create a geometric phase-based meta-lens with an average focusing efficiency of over 80% in the visible spectrum. Additionally, the authors constructed multi-objective meta-devices, such as spin-multiplexed structural beam generators and meta-holograms, to validate the algorithm's versatility.

Beyond the genetic algorithm, the particle swarm optimization (PSO) algorithm stands as a potent alternative for tackling multivariate and multi-objective challenges. Zhu et al.[14] enhanced the standard PSO algorithm by incorporating a physical-assisted (PA) strategy to improve performance with limited computational resources. Using the PA-PSO algorithm, the team achieved optimal performance for a meta-lens in the Ka-band at a remarkable sixfold increase in speed compared to the conventional PSO algorithm.

To optimize meta-lenses, it is essential to consider both the design methodologies and the fabrication processes. A variety of fabrication techniques[15−17] are well-suited to different operational bands and materials. For meta-lenses in the long-wave infrared region, although silicon has been widely used, its inherent material losses are a factor that cannot be overlooked. Shen et al.[18] utilized

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chalcogenide glasses to fabricate meta-lenses, which have demonstrated superior performance compared to silicon. To avoid the impact of the soft mechanical properties of the glasses, they refined the deep etching process to fabricate high-aspect-ratio structures. This optimization meets the necessary phase distribution and transmission requirements, offering a promising approach for manufacturing direct and scalable planar infrared optical systems.

In contrast to conventionally optimizing the fabrication process of meta-lens, research by Teng et al.[19] exhibited that meta-lenses can enhance fabrication strategies. They have successfully utilized aluminum nitride (AlN) to create a supercritical meta-lens operating at 405 nm (h-line), which outperforms traditional Fresnel zone lenses in high-resolution direct laser writing. This is due to its smaller focal spot and greater depth of focus. The implications of this approach extend beyond the current scope, suggesting potential applications in ultraviolet (UV) and deep UV lithography.

So far, meta-lenses have demonstrated their utility in series of applications[20] such as light-field sensing[21], particle image velocimetry[22], and facial recognition[23]. In the cover article of this special issue, Chen et al.[24] explored additional possibilities for meta-lenses in the visible spectrum. They innovatively harnessed binocular meta-lens to enhance depth perception through the generation of a stereo-image pair that highlights edge details and exhibits perceptible disparities. When combined with a stereo-matching neural network, this system can effectively eliminate ill-posed regions and deliver rapid responses in less than 0.15 seconds, enabling precise 3D scene reconstruction.

At last, we believe that this special issue provides an in-depth and holistic examination of the latest advancements in the design, fabrication, and application of meta-lenses. It heralds a new era of opportunities for both research and industry. Our heartfelt gratitude goes to the authors, reviewers, and editors for their invaluable contributions. We wholeheartedly hope that readers from diverse fields will derive as much pleasure and inspiration from this issue as we have experienced in curating it.

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## Competing interests

The authors declare no competing financial interests.