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Large-scale achromatic flat lens by light frequency-domain coherence optimization

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Abstract

Flat lenses, including metalens and diffractive lens, have attracted increasing attention due to their ability to miniaturize the imaging devices. However, realizing a large scale achromatic flat lens with high performance still remains a big challenge. Here, we developed a new framework in designing achromatic multi-level diffractive lenses by light coherence optimization, which enables the implementation of large-scale flat lenses under non-ideal conditions. As results, a series achromatic polymer lenses with diameter from 1 to 10 mm are successfully designed and fabricated. The subsequent optical characterizations substantially validate our theoretical framework and show relatively good performance of the centimeter-scale achromatic multi-level diffractive lenses with a super broad bandwidth in optical wavelengths (400–1100 nm). After comparing with conventional refractive lens, this achromatic lens shows significant advantages in white-light imaging performance, implying a new strategy in developing practical planar optical devices.

Introduction

Conventional refractive lens has achieved great success in the area of imaging, metrology, detection, etc.^{1–2}, but its bulky and heavy characteristics prevent the systems from being compact, lightweight, and miniaturized, which is in high demand for portable and convenient applications³. Metalenses, made of subwavelength nano-unit cells with ultrathin, lightweight, and flat architecture, do provide possible solutions that to some extent overcome the shortcomings of conventional diffractive lens with higher focusing efficiency and weak shadow-effect^{4–7}. However, metalenses still severely suffer from poor imaging quality under broadband illumination due to serious chromatic aberration^{10–13}. Several pioneering works have demonstrated achromatic metalens operating over a broad wavelength range^{14–21}. However, according to the

fundamental limitations of the achromatic flat lens, the diameter of an ideal achromatic metalens (under the diffraction limit) is restricted by its thickness (the max height each nano-unit can achieve)^{18–20,32–34}. As results, the diameters of reported achromatic metalenses with NA ≥ 0.1 in the visible do not exceed 200 μm due to their relatively small thicknesses ($<4\mu\text{m}$) up to date. Such miniaturized metalenses are useful in the micro-nano optics or integrated optics (for example, endoscope⁷). However, millimeter- or centimeter-scale metalenses are necessary when it comes to other fields, such as augmented reality, lens modules in cell phones, landscape cameras and telescopes^{1,15}. Under theoretical estimation, hundred-micron thickness is needed to access the ideal centimeter scale (5–10 mm) achromatic metalens, which requires a very large aspect ratio ($>1000:1$) for the constructing nano-units, while the reported largest one is only about 50:1^{28,34,35}. Therefore, to access an ideal large-scale achromatic metalens based on the common meta-designs seems to be unachievably difficult.

Fortunately, the multi-level diffractive lens provides an alternative strategy to reach the achromatism by

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On The Construction Of Large Achromatic

Thomas Dick



On The Construction Of Large Achromatic:

On the Construction of Large Achromatic Telescopes Alexander Rogers, Sir John Frederick William Herschel, 1828*

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