OEE | Overview

DOI: 10.3969/j.issn.1003-501X.2017.08.001

From super-oscillatory lens to super-critical lens: surpassing the diffraction limit via light field modulation

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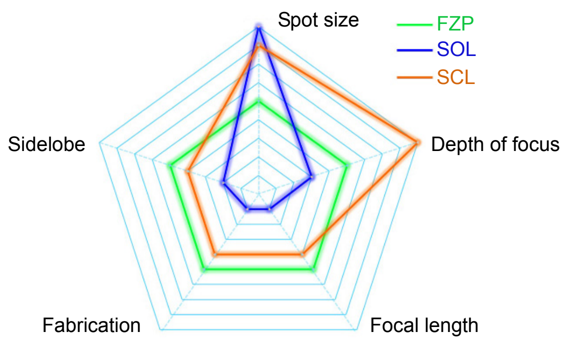

Win or loss: comparison between three typical diffractive lenses.

Abstract: Improving the imaging resolution has always been one of the most important topics since the invention of optical microscope. Due to the fundamental laws of wave optics, the focusing and imaging resolution of traditional refraction and diffraction lenses are subject to the Rayleigh Criterion ($0.61\lambda/NA$), and the spatial resolution of optical microscopy is restricted to ~200 nm at visible light. Tremendous efforts have been made to fight against the diffraction limit in the past decades, and several novel approaches have been invented which could be categorized as near-field and far-field modes. For the near-field techniques, such as NSOM, superlens, hyperlens, microsphere lens, they always suffer from the challenges of near-field operation and small field of view, which make them not meet some requirements of practical applications. Although very high imaging resolution in far-field could be achieved by the fluorescence-based approaches, all these techniques have a common feature that is quite limited to biological domain because of the requirement to put dyes and fluorescence into objects. Therefore, the label-free technique for super-resolution imaging in far field is very important for general applications. Recent advance in this field is the development of planar metalens which could achieve sub-diffractive focusing and imaging in far field by means of light field modulation. Super-oscillatory lens (SOL) and super-critical lens (SCL) are the typical representatives of planar metalens. Through precisely modulating the interference effect of each diffractive unit, the focal spot size in a certain region of the target plane is controllable in lateral and longitudinal directions. Combined with the confocal technique, the label-free superresolution imaging could be realized in far field with purely non-invasive manners. Compared with the traditional optical lens, the planar metalens is much more attractive due to its distinct advantages of powerful focusing capabilities, compact configuration, higher design freedom and the integratable properties, etc. In this review, we briefly introduce the field modulation mechanism and design principle of the planar metalens. The research progress of the super-oscillatory lens and super-critical lens, as well as their applications in far-field label-free super-resolution imaging, is presented in detail. The advantages and limitations of that planar lens are compared and briefly discussed. A perspective about the future outlook of planar metalens is summarized. Since the planar metalens has a powerful capability in manipulating the light field, the rapid development in various applications would be gradually realized in the near future.

Keywords: super-oscillatory lens; super-critical lens; super-resolution imaging; diffractive optics

Citation: Qin Fei, Li Xiangping, Hong Minghui. From super-osciallatory lens to super-critical lens: surpassing the diffraction limit via light field modulation[J]. *Opto-Electronic Engineering*, 2017, **44**(8): 757–771.

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