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The generalized laws of refraction and reflection

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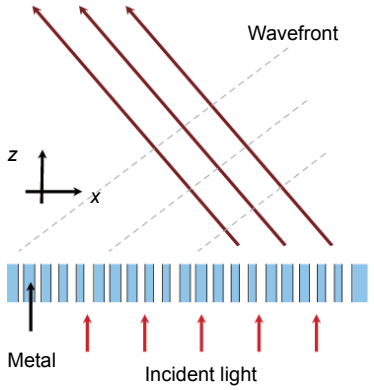

Generalized law of refraction. The local phase shift is introduced by the nanoslits array.

Abstract: The refraction and reflection are basic phenomena in the propagation of all kinds of waves, such as light waves, electromagnetic waves and acoustic waves, when they encounter the interface among different kinds of materials. Because of the rigorous limitation of classical laws, traditional optical components such as spherical lenses and parabolic mirrors must be designed with various non-planar geometric shapes to control the flow of light, which makes these devices bulky and heavy. During the last several hundred years, many efforts have been devoted to make optical components thin and lightweight. One particular example is the diffractive gratings and lenses, where the wavefront can be constructed by locally tuning the transmittance in a two-dimensional space. However, the diffractive devices are suffering from the low diffraction efficiency and large chromatic dispersion, making them difficult to be used in practical optical systems.

Recently, it is discovered that the traditional optical laws regarding refraction and reflection can be rewritten when artificially designed subwavelength arrays are fabricated on the interfaces, which are termed metasurfaces or two-dimensional metamaterials. Different from the 3D metamaterials, metasurfaces-based devices are much thinner and easier to fabricate, thus forming a natural candidate for planar optics. The revised laws in the subwavelength structured flat surfaces provide promising alternatives to achieve imaging, multi-physics decoupling, and holographic display. In particular, metasurface-based imaging is considered as the third generation of imaging techniques (the first and second generations are the refractive and diffractive approaches, respectively).

In this paper, we review the recent progresses in this emerging topic, including the refraction and reflection behavior of light in various materials configurations, the fundamental theories and practical applications. We show that plasmonic elements with local phase modulation ability have provided a crucial candidate to realize the generalized laws of refraction and reflection. Based on the short-wavelength effect of surface plasmon, these flat lenses can be much thinner than the vacuum wavelength. Besides the arbitrary refraction and reflection, it is shown that the new optical laws ensure that the wavefront can be arbitrarily tuned, which are critical to achieve beam shaping, stealth and high-purity holography. At the end of this review, the shortcomings of current researches are analyzed based on our recent results, with a look towards the future trends of the overall area.

Keywords: plasmonics; metamaterial; metasurface; generalized laws of refraction/reflection

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