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Principles and applications of metasurfaces with phase modulation

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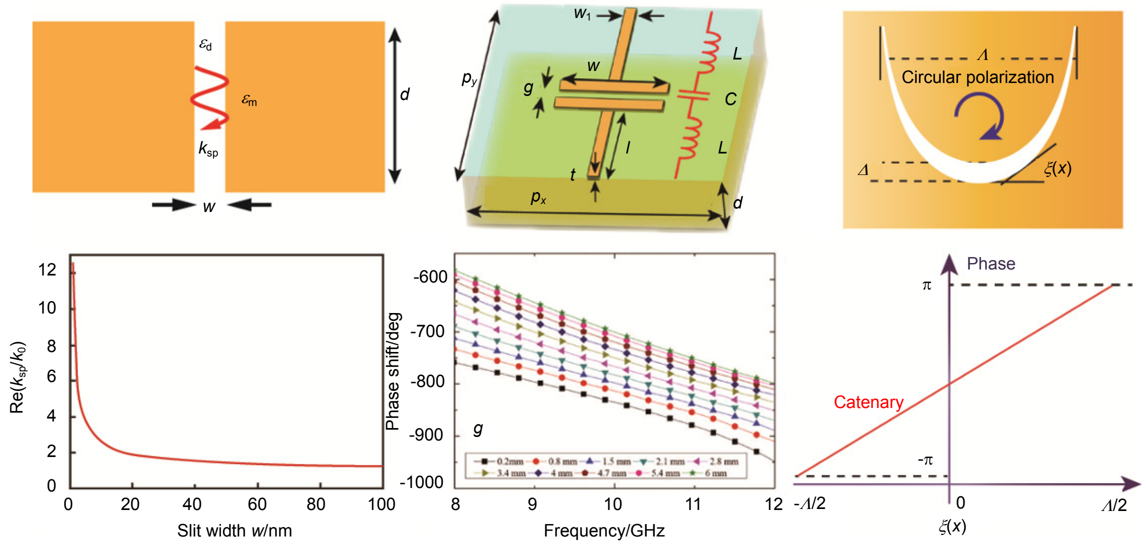

Typical meta-atoms and the corresponding phase modulation in metasurfaces.

Abstract: Conventional refractive optical components such as lenses and prism modifying the wavefronts rely on light propagation over distances much larger than the wavelength, which makes them bulky and weighty. To address this issue, binary optics was proposed in the end of 1980s. Secondary waves created by binary optical components such as holograms diffract in free space and interfere in the far-field to form complex optical patterns. The phase of the secondary waves is modulated through propagation delay in a discrete and planar way. However, the chromatism in diffraction and the limited field of view due to the relatively large scale of phase modulation, limit the applications of the binary optical components. Recently, a type of flat, ultrathin optical components called 'metasurfaces' was proposed. Metasurfaces, seen as the two-dimensional equivalents of metamaterials, are thin-film functional devices constructed by subwavelength structures. Benefiting from their simplified fabrication process of planar profiles and low electromagnetic energy loss compared to metamaterials, metasurfaces are promising for integration with on-chip nanophotonic devices. Abrupt phase changes can be obtained in the planar metasurface structures over the scale of the wavelength, which provide a new avenue to enable a variety of applications including large scale planar imaging, electromagnetic virtual shaping and holographic display in larger field of view. The arbitrary modulation abilities of phase, amplitude and polarization at the subwavelength scale, also the integratable and conformable design make the metasurfaces very attractive. The devices based on metasurface can be designed to possess many required properties replacing bulky optical components. In this paper, we give a brief introduction of the development of the metasurface in an historical perspective. We focus on recent developments of the flat, ultrathin optical and electromagnetic components based on metasurfaces. The physical mechanism of the phase modulation in metasurfaces is analyzed and classified. These types of phase modulation in metasurface, i.e., transmission phase modulation, circuit-type phase modulation, and geometric (or Pancharatnam- Berry) phase modulation, are comprehensively introduced. The unique properties and the applications of each type of metasurface are detailedly discussed. We also review some newly designed novel metasurfaces which make use of merging phase modulation. Furthermore, the magnitude modulation, and the polarization modulation accompanied in the phase modulation of metasurfaces are introduced. At last, we summarize the challenges faced by metasurfaces with an eye toward the promising future directions in this field.

Keywords: metasurface; metamaterials; phase; amplitude; Snell's law

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