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Research advances of hyperbolic metamaterials and metasurfaces

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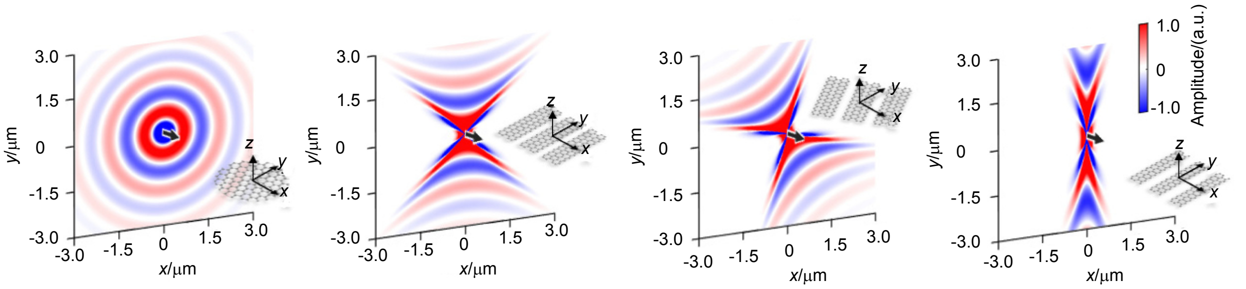

E_z field component of surface plasmons excited by a *z*-oriented electric dipole located above homogeneous metasurfaces defined by various conductivity tensors. The insets show possible realizations of the different metasurface topologies using pristine or nanostructured graphene layers.

Abstract: In recent years, with the continuous progress of micro/nano fabrication technique, the interaction of material and electromagnetic wave in the subwavelength scale has attracted widespread attention. Electromagnetic metamaterial is artificial material composed of building blocks whose feature size is much smaller than the working wavelength, with the electromagnetic properties that does not exist in natural materials. As an important branch of electromagnetic metamaterials, hyperbolic metamaterials become the focus of research for their unique characteristic to control near-field waves. By changing the size and arrangement of the components of hyperbolic metamaterials, the excitation intensity and direction of the surface plasmons (SPs) in them can be modulated, so that the unique dispersion curves can be achieved. Hyperbolic metamaterials have been used in many fields, such as subwavelength imaging, light localization and enhanced spontaneous emission. Hyperbolic metasurface is a new type of planar metamaterials with hyperbolic dispersion relationship and has many similarities in theory and applications with hyperbolic metamaterial. Compared with the bulk hyperbolic matematerials, hyperbolic metasurfaces exhibit more excellent performances because the large reduction in the longitudinal dimension limits the propagation of the electromagnetic waves in the two-dimensional plane.

In this review, starting with hyperbolic metamaterials, we introduce their basic theory of dispersion equation and isofrequency surface, and then describe the method of realizing hyperbolic dispersion from two different structures: metal-dielectric multilayer structure and metal nanowire structure. Effective medium theory to calculate the effective dielectric tensor and the choice of real materials are also presented. At the end of this section, we briefly introduce the typical applications of hyperbolic metamaterials, including optical negative refraction and hyperlens imaging. The latter part of the review is about hyperbolic metasurface and we begin with the introduction of the basic theory and isofrequency curve of hyperbolic metasurface. The difference is that in addition to the introduction of ordinary hyperbolic dispersion, we also stress the special case of near the topological transition point, where the dispersion curve is almost flat and the transmission of electromagnetic wave is almost diffraction-free. Then we list the natural hyperbolic materials that can be used to fabricate hyperbolic metasurface, including uniaxial and two-dimensional materials. The artificial method of using graphene to achieve any topological structure on the plane is illustrated. In analogy with the hyperbolic metamaterial, the negative refraction effect and the hyperlens imaging in hyperbolic metasurface are also introduced. In addition, intriguing properties of hyperbolic metasurfaces and their potential applications are described. Finally, we point out the restrictions of the hyperbolic metamaterials and metasurfaces and the prospect of future applications.

Keywords: hyperbolic metamaterials; hyperbolic metasurfaces; negative refraction; hyperlens

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