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Advances of dispersion-engineered metamaterials

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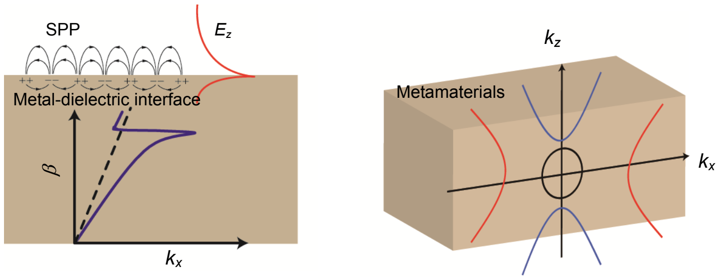

Typical plasmonic structures and their meta-dispersion engineering abilities.

Abstract: Since it was firstly illustrated by the pronounced prism experiment of Isaac Newton, the chromatic dispersions in light matter interaction have been extensively explored. It is generally thought that the dispersion of materials introduces a significant wavelength dependence of the group velocity, leading to undesired signal distortion in communications system, chromatic aberration in imaging system and limited bandwidth of optical devices. However, if dispersions can be properly controlled, they will play a significant role in many applications. For example, dispersion management will suppress the nonlinearities of fiber dense wavelength division multiplexing (DWDM) system and the soliton propagation. Chromatic aberration can be corrected approximately by using materials that exhibit complementary dispersion. Nevertheless, because the dispersion of natural materials is determined by the electronic and molecular energy levels, traditional dispersion management technologies are cumbersome and cannot be required in integrated optics.

With the development of advanced fabrication technology and material science in recent years, the interactions between electromagnetic waves and the matter in subwavelength scale have attracted tremendous interests. In this scale, the metamaterials composed of subwavelength resonant structures exhibit extraordinary dispersion properties. The macroscopic electromagnetic properties of MMs are decided by the specific geometry and arrangement of artificial molecules and thus offering unprecedented flexibility and superiority for dispersion engineering. Consequently, the associated permittivity and permeability can be tuned from positive to zero and negative over the entire electromagnetic range, which is concerned with a surprisingly rich set of exotic optical phenomena.

Meanwhile, the excitations of SPP in metallic structures open an avenue to manipulation electromagnetic wave in nano-scale. The unique dispersion properties of SPP make it with a shrinking wavelength and the ability of local phase modulation. On one hand, the shrinking wavelength property can be utilized to achieve sub-diffraction imaging and super-resolution lithography. On the other hand, inspired by the local phase modulation ability of SPP, we can break the traditional refraction and reflection laws and manipulate electromagnetic wave in a prescribed and highly integrated manner. By introducing subwavelength apertures or antennas along the metal surface, one can harness the propagation and resonance of the SPP with specific frequency. Furthermore, the hybrid and coupling effect among pattern metallic films also increase the tenability of dispersion.

In summary, the interaction between electromagnetic wave and the matter become more diverse and complex in subwavelength scale. Understanding the principle and approaches of dispersion engineering in metamaterials is helpful to design more satisfying optical devices and enhance the electromagnetic manipulation abilities. From this viewpoint, this review manuscript will summarize the recent advances in the theories, approaches and typical applications of dispersion engineering of metamaterials. An outlook of the challenges and future directions in this fascinating area of nanophotonics is also presented at the end of the manuscript.

Keywords: metamaterials; dispersion engineering; local phase modulation; planar optical devices

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