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Plasmonics and nonlinear metasurfaces for optical applications



Plasmonic and metamaterial systems are enabling to many relevant technologies. Detecting optical signals in the mid and long wave infrared, and the generation, detection and conversion of single photons for quantum information applications are significant to a range of Air Force technologies and drive the research to increase performance and functionality. We will discuss two metamaterial inspired systems for that have the potential to enable new applications. Both spectral and spatial information is obtained in hyperspectral images. Compressive sensing may allow for the acquisition of more efficient data with higher information content, while preserving functionality. Our research^{1,2} develops a combined method to integrate plasmonic filters and microoptical elements onto detector structures which can both improve their performance and provide a means to introduce compressive sensing methods. By coupling a variety of simulation environments which cover the optical, plasmonic, and electronic domains, we can efficiently comprehensively detector function and performance for a wide range of designs and incorporate compressive sensing into the design loop. We will present the results of several design studies and experimental verification of the modeled device performance. In the second section, we explore how nonlinear properties of metasurfaces can be engineered for quantum information applications. We show that nonlinear multipole interference allows both a non-reciprocal and unidirectional nonlinear generation from nanoelements or their periodic arrangement, with the direction of nonlinear generation preserved with respect to a fixed laboratory coordinate system when reversing the direction of the fundamental field. Alternatively, it can ensure a directionally selective inhibition of the nonlinear response for certain respective directions of the fundamental beams². We attribute the presented phenomena to the existence of the common (electric or magnetic) pathways inducing the electric and magnetic Mie resonances via a nonlinear interaction, such that switching the phase of one (electric or magnetic) of the vectors of the fundamental field can change simultaneously the phase of all (electric and magnetic) nonlinearly generated multipoles³. Furthermore, the interference can occur between various effective hyperpolarizability terms within the electric and magnetic (nonlinearly produced) dipolar modes themselves. Both cases are example where the engineering of materials response through structure to achieve desired optical properties can enable new potential technologies.