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Broadband and resonant metamaterials for optical to THz frequencies

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Metamaterials are designed materials with sub-wavelength featured constituents with dielectric permittivity (ε) and magnetic permeability (μ) that may not exist in naturally existing materials. They thus offer novel functionalities, as well as a response that is desired. Metamaterials with periodic arrangement of scattering elements or layered structures often exhibit resonant response [1]. While these tend to work for applications at designed resonant frequencies, broadband responsive structures are helpful for light coupling, and for applications that require the same structure to work at multiple frequencies. Broadband metamaterials can be realized by either having multiple scattering elements, to cover different wavelength regions, that are randomly arranged in an array or by having scattering elements arranged in a random array or a quasi-periodic array. Broadband responsive metasurfaces are useful in bio- or chemical sensors with high sensitivity and selectivity. High sensitivity can be achieved by utilizing surface enhanced Raman signal, and selectivity can be achieved by utilizing multiple Raman lines of the analyte molecule instead of a single resonance. Singly resonant metamaterials are useful for highly sensitive biomolecule sensing by combining the resonant enhancement of local field with a technique like differential phase measurement in ellipsometric geometry. I will show demonstration of resonant and broadband responsive structures that are sensitive to single molecules and are also selective [2,3]. Magneto-plasmonic structures, combining metals and ferromagnetic dielectrics, offer enhanced magneto-optical (MO) effects that are of device level. Not just at resonances of the metamaterials, but plasmonic quasicrystal structures enhance MO response over a broad wavelength region or at multiple resonant wavelengths [4,5]. Even in noble metals, carefully designed nanostructures offer MO response offering new functionalities to optoelectronic devices. Non-classical light emitters are other hotly pursued areas of research in the growing quantum technologies. Metamaterials exhibiting hyperbolic dispersion profile and bound states in continuum resonances are often used for non-classical light sources [6]. In the THz frequency region, metamaterials are interesting to realize various components as well as in mimicking two level systems and quantum optical phenomena [7].

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