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Design of Metamaterials for control of electromagnetic waves

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Metamaterials are artificial effective media supporting propagating waves that derive their properties form the average response of deliberately designed and arranged, usually resonant scatterers with structural length-scales much smaller than the wavelength inside the material. Electromagnetic metamaterials are the most important implementation of metamaterials, which are made from deeply sub-wavelength electric, magnetic and chiral resonators and can be designed to work from radio frequencies all the way to visible light. Metamaterials have been major new development in physics and materials science over the last decade and are still attracting more interest as they enable us to create materials with unique properties like negative refraction, flat and super lenses, impedance matching eliminating reflection, perfect absorbers, deeply sub-wavelength sized wave guides and cavities, tunability, enhanced non-linearity and gain, chirality and huge optical activity, control of Casimir forces, and spontaneous emission, etc. In this talk, I will discuss the design, numerical simulation, and mathematical modeling of metamaterials. I will survey the current state of the art and discuss challenges, possible solutions and perspectives. In particular, the problem of dissipative loss and their possible compensation by incorporating spatially distributed gain in metamaterials. If the gain sub-system is strongly coupled to the sub-wavelength resonators of the metamaterial loss compensation and undamping of the resonant response of the metamaterials can occur. I will explore new, alternative dielectric low loss resonators for metamaterials as well as the potential of new conducting materials such as Graphene to replace metals as the conducting material in resonant metamaterials. Two dimensional metamaterials or metasurfaces, implementations of effective electromagnetic current sheets in which both electric and magnetic sheet conductivities are controlled by the average response of sub-wavelength local resonators, emerge as simpler implementation of many of the unique properties of metamaterials. I will discuss a few novel examples how these metamaterials can be used for dispersion engineering, and beam shaping.