Abstract

Despite considerable interest in the terahertz (THz) frequency range of the electromagnetic spectrum, the technological developments in terms of devices such as high-speed modulators and highly sensitive sensors are lagging, which are essential to cater to the need of the increasing population. The artificially designed plasmonics and metamaterial structures have the potential to realize such devices through careful arrangements of its constituents. They strongly interact with terahertz radiation and manipulate them in the desired fashion to realize photonic devices for THz applications, ultimately filling the technological gap in this region. In this thesis, the primary focus has been to investigate terahertz plasmonic and metamaterial structures for applications in highly sensitive sensors and high-speed modulators.

We propose a planar plasmonic terahertz waveguide comprising of one-dimensional array of periodically arranged subwavelength scale pyramidal corrugations. The waveguide supports highly confined modes along with the corrugated pattern. We investigate the refractive index sensor capability of the terahertz surface plasmon modes supported by the waveguide. We also analyze the dispersion properties and quality factors of the fundamental as well as higher-order modes of the waveguide and examine the significance in thin film sensing at terahertz frequencies.

In terahertz plasmonic waveguide, we also investigate near field coupling between modes of the waveguide comprising asymmetric resonators placed

in close proximity. The waveguide is designed to support surface plasmon polaritons (SPPs) at two distinct terahertz frequencies, which are near to each other. This is accomplished by carefully designing the unit cell comprising of two resonators with slightly different sizes. The resonators in the form of rectangular apertures are placed along the transverse direction in the near field regime. The role of near field coupling between resonators and their potential in modulating terahertz is comprehensively discussed.

We further investigate a double slot waveguide configuration to explore the actively tunable plasmon induced transparency (PIT) effect in the terahertz regime. One of the slot structures is filled with a dielectric material of certain refractive index which causes a slight shift in its resonance frequency as compared to the unfilled slot. The two slightly different frequencies results in PIT effect due to the destructive interference of the modes. The electric field profiles clearly indicate the emergence of the PIT effect. The observed transparency window is found to varying with the change in refractive index of the dielectric material, which promises an active and tunable control of the effect without changing the physical dimensions. Further, we examine the possibility of switching the transparency effect by incorporating a thin silicon layer between the grooves, by varying its conductivity.

The potential of metamaterials in building modulators has been widely explored in last few years. The broadband modulation has been a challenging task at terahertz frequencies. We address this limitation by designing a tunable broadband metamaterial absorber comprising frustum shaped dielectric (SiO_2) structures on top of a one-dimensional period array of graphene nanoribbons over the ultrathin metal-backed dielectric. The excitation of plasmons in graphene nanoribbons combined with resonance induced by the graphene-dielectric-metal cavity leads to nearly perfect broadband absorption for the TM polarized radiation. The modulation of the absorption

spectrum has been examined by changing graphene conductivity with the help of its Fermi energy. The figure of merit of our design indicates that it can be very promising to outperform some of the recently reported tunable metamaterial absorbers.