INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Planar Terahertz Metamaterial Based Efficient Polarization Devices and Sensors

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SHORT ABSTRACT

The advent of metamaterials has made it possible to control and manipulate light at will through strong light-matter interactions at the subwavelength scale. In the last two decades, research in this area has grown rapidly owing to its immense potential in developing next-generation devices and components. In view of the increasing demand for high-speed communication and bandwidth, the development of photonic components at terahertz frequencies is crucial. In this thesis work, we have examined metamaterial structures of various shapes and sizes in different planar configurations to demonstrate the polarization conversion, modulation, thin-film sensing, and slow light phenomenon at terahertz frequencies.

For polarization conversion, we have proposed a coupled planar metamaterial geometry comprising two identical circular split-ring resonators (SRRs). The geometry is capable of providing a gradual change in polarization of incident terahertz with respect to change in near-field coupling between the resonators. When one resonator is rotated with respect to the other, the cross-polarization signal changes from minimum to maximum for orthogonal rotation and again back to a minimum on complete rotation through 180^0 angle. Further, we have explored the possibility of ultra-wideband terahertz polarization conversion in a planar metamaterial geometry. In a carefully designed metamaterial C-shaped resonator, we have investigated the co-and cross-polarization transmission by rotating the structure with respect to the incident terahertz at different angles. The cross-polarization conversion of nearly 40% is experimentally demonstrated which is highest in the frequency range of 1.22 THz to 2.75 THz, to the best of our knowledge. Further, we have shown that the transmission window can be shifted to the higher frequency range by changing the dimensions of the resonators, which gives the possibility to design polarization conversion devices in the desired frequency window.

Metamaterial structures exhibit strong localization of electromagnetic fields and therefore, provide an excellent platform for sensing analytes with greater sensitivity. Researchers have shown that metamaterials can exhibit electromagnetically induced transparency effect (EIT), a classical analog of a quantum phenomenon that has potential in sensing. It has been a challenging task to develop polarization-insensitive sensors in EIT metamaterials.

We have addressed this challenge in this thesis. We have shown that a planar-coupled metamaterial geometry comprising of four carefully designed C-shaped resonators placed symmetrically on both sides of a cross-wire can exhibit polarization-independent response of the dual-band EIT effect for two orthogonal polarizations of incident light. We have investigated the potential of the metamaterial configuration in thin-film sensing at terahertz.

Several applications require independent control of EIT windows for constructing frequency-selective devices and filters. In this context, we have experimentally demonstrated independent modulation of individual transparency windows through a novel planar-coupled metamaterial configuration comprising a cut-wire (CW) and a pair of double C-resonators (DCRs). By displacing one resonator with respect to the CW, while keeping the other fixed at its position the independent modulation of each transparency window is achieved. In EIT, the dispersion properties undergo a sudden change within the transparency window. This is accompanied by a sharp decline in group velocity of the incident terahertz. This property is significant to the slow light phenomenon. We have shown how steep dispersion change results in the slowing down of transmitted terahertz. This study is significant to the construction of buffers, slow light devices, modulators, etc.

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