INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

The terahertz (THz) range of frequencies has become an important field of research in recent times, with the advent of electromagnetic metasurface technologies. This thesis focuses on the study of the excotic toroidal excitations in metasurfaces and their applications in terahertz frequencies. The toroidal dipole excitations, dominated over by electric and magnetic dipole excitations in natural materials, can be examined and utilzed in carefully designed metasurfaces. This thesis examines, both numerically and experimentally, the excitation of toroidal resonances in metasurfaces, their modulation and electromagnetically induced transparency effects in a toroidal metasurfaces. Further, the thesis discusses the applications of toroidal metasurfaces for broadband terahertz polarization conversion and in exciting polarization independent resonances via a lattice-coupled toroidal mode. In this thesis, the toroidal excitation has been discussed in carefully designed metamaterials with special toroidal symmetries in the terahertz range. The bilayer near-field oupling between two toroidal resonators was analysed and the passive modulation of he dual toroidal resonance has been discussed. In an effort to explore the possibility of active modulation in terahertz metasurfaces, the active tuning of toroidal resonances in a graphene based metasurface has been studied in this thesis. Further, several concepts and applications for the study of toroidal resonances in metasurfaces were examined. A study has been made on the excitation of single and dual-band electromagnetically induced transparency (EIT) via near-field coupled toroidal metasurfaces in this thesis. Such toroidal dual-band EIT could be impactful in the study of slow light systems. The thesis also examines the possibility of terahertz polarization conversion using toroidal excitations in a metasurface. Through the rotation of the meta-atom, nearly 40% cross-polarization conversion was achieved for a 45 degree rotation angle of the meta-atom. The thesis has also examined the possibility of further enchancement of the quality factor of a toroidal resonance by exploring the effect of coupling the toroidal excitation to the first-order lattice mode of the metasurface. The coupling between a toroidal mode and a first-order lattice mode resulted in the enhancement of quality factor in a simple metasurface geometry. The designed metasurface ensures polarization independence, such that the sharp toroidal mode is excited for both the orthogonal polarizations of incident THz radiation. The toroidal excitation and its applications, as discussed in this thesis, can have immense significance in high speed terahertz components for low-loss communication devices.