



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS

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Thesis Title: Engineering Broadband Response in Active and Passive Terahertz Metamaterials Using Planar and Multilayer Configurations

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**SHORT ABSTRACT**

The terahertz (THz) region, between microwave and infrared, offers great potential for advanced technologies like high-speed communication, security screening, and medical imaging. Metamaterials, with engineered subwavelength structures, provide tailored electromagnetic properties that surpass conventional materials. While narrowband metamaterials have been studied for high-Q factor filtering, the need for high-performance THz devices has led to the development of broadband designs, essential for spectroscopy, imaging, and wireless communication.

This thesis explores broadband THz metamaterials, focusing on planar and multistacked resonator configurations. Planar metamaterials, including coupled and radiative resonators, were enhanced with a novel bending-strip resonator, achieving a 350 GHz bandwidth. However, increasing resonator density led to trade-offs in resonance strength. To address this, multistacked resonator metamaterials were developed, achieving a 500 GHz bandwidth by superimposing resonances from stacked layers.

Active tunability, crucial for modulators and filters, was integrated using phase-transition semiconductors like vanadium dioxide ( $\text{VO}_2$ ), enabling tunable modulation. A novel transfer-and-peel-off fabrication method ensured reliable band-pass filter functionality. Hybrid metamaterials exhibited tunable performance with a full-width at half-maximum (FWHM) of 1.02 THz and a modulation depth of 55% at varying temperatures.

Due to the complexity of subwavelength interactions, traditional design methods are time-consuming. Machine learning techniques, such as random forests and neural networks, were employed to accelerate design and optimization, reducing simulation reliance.

This thesis presents a framework for broadband THz metamaterials, integrating tunable designs, advanced fabrication, and machine learning optimization, paving the way for next-generation THz technologies in communication, sensing, and imaging.