Design, Development and Fabrication of Gallium Nitride (GaN) High Electron Mobility Transistor (HEMT) based terahertz devices for Space Applications

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by

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ABSTRACT

Terahertz (THz) technology has attracted tremendous attention recently due to its promising applications in various domains such as medical, biological, industrial imaging, broadband, safety, communication, radar, space science, etc. Due to non-availability of powerful sources and highly sensitive & efficient detectors, the so called "THz gap" remains largely unfilled. Despite seamless efforts from electronics and photonics technology researchers, the desired level of technology development to fill the THz gap still remains a challenge. In the present thesis, a very new and versatile mechanism for electrical tuning of intersubband transitions (ISBT) is presented in Gallium Nitride (GaN) high electron mobility transistor (HEMT) device. ISBT phenomena is usually demonstrated in the photonic device like quantum cascade laser (QCL). This dissertation is explored the photonics ISBT phenomenon in an electronics GaN HEMT device. Conventional photonic devices are operated at cryogenic temperatures to minimize the thermal effect. The reported maximum operating temperature of THz QCL is in the range of 150-200 K which is too low for general applications. The conduction band tuning through external gate bias makes advantage of HEMT device for room temperature (RT) terahertz applications.

The theoretical models for electrically tuneable plasmonic metamaterials-assisted ISBT have been developed. Experimental demonstration of electrical tuning of ISBT in a GaN HEMT device at room temperature has not only provided a novel mechanism but also discriminates ISBT from other transitions induced by deep-level traps and defects in the 100 nm GaN HEMT device. The intersubband energy levels are extracted by using low temperature Photoluminescence (PL) measurement. The PL emission peaks data are also supported by a simulation based on a self-consistent solution of Schrodinger and Poisson equations. It is possible to tune the subband energy level inside triangular quantum well of GaN HEMT by applying gate voltage. The GaN HEMT device responds toward incident terahertz radiation due to inherent advantage of conduction subband tuning through external bias. The presented novel approach for ISBT in GaN HEMT has the potential possibilities in the context of overcome the THz gap in the electromagnetic spectrum at ambient temperature.