The objective of this project was to develop a purely solid-state based, thus miniaturized, far-infrared (FIR) (also known as terahertz (THz)) wave source using III-V semiconductor nanostructures for biomolecular detection and sensing. Many biomolecules, such as DNA and proteins, have distinct spectroscopic features in the FIR wavelength range as a result of vibration-rotation-tunneling motions and various inter- and intra-molecule collective motions. Spectroscopic characterization of such molecules requires narrow linewidth, sufficiently high power, tunable (in wavelength), and coherent FIR sources. Unfortunately, the FIR frequency is one of the least technologically developed ranges in the electromagnetic spectrum. Currently available FIR sources based on non-solid state technology are bulky, inefficient, and very often incoherent.

In this project we investigated antimonide based compound semiconductor (ABCS) nanostructures as the active medium to generate FIR radiation. The final goal of this project was to demonstrate a semiconductor THz source integrated with a pumping diode laser module to achieve a compact system for biomolecular applications.

Major accomplishments are summarized below:

1) We grew high-quality InAs quantum wells with AlSb barriers with well widths ranging from 2 nm to 10 nm and observed intersubband transitions (ISBTs) in all samples and photoluminescence in narrow wells. We then systematically studied the ISBT energy, intensity, and linewidth vs. well width and temperature and compared with theory. The results were published in *Applied Physics Letters*. 
2) We also grew coupled double quantum wells and observed THz splitting in ISBTs in the coupled wells, whose magnitude was consistent with theoretical simulations.

3) We obtained THz quantum cascade lasers from the University of Neuchatel and used them for cyclotron resonance studies of ABCS structures. This work represents the first successful spectroscopic application of THz quantum cascade lasers and was published in *Optics Letters*.

4) Extensive computer modeling capabilities have been developed for narrow band semiconductors, including the antimonide quantum wells and superlattices. These capabilities are centered on the 8-band k.p band structure theory based on envelope function approximations. A set of finite-difference-based numerical computer simulation programs was developed and tested extensively. This set of programs now forms the basic tools for antimonide-based quantum well designs. The programs can deal with self-consistent coupling of Schroedinger equations with Poisson equations and are very generic and flexible to deal with a variety of heterostructures.

5) Close interactions between the experiments and theoretical modeling have been established and resulted in significant progress in the understanding of electronic and optical properties of antimonide-based semiconductor structures. This understanding includes optical absorption spectra of InAs/AlSb quantum wells as well as the parameter-dependence of absorption spectrum.

6) The project has resulted in publication of journal papers and conference presentations listed in the following. As part of the report, the publications are attached.

**Publications:**


Presentations:


