



Resonant Second Harmonic Generation of Mid-infrared Radiation in InAs/AISb Coupled Quantum Wells



Hunil Cha¹, Darius Morris¹, Junichiro Kono¹, Alexey A. Belyanin², Shigehiko Sasa³, Masataka Inoue³

¹Department of Electrical and Computer Engineering, Rice University, ²Texas A&M University, ³Osaka Institute of Technology
 Contact Author: Hunil Cha, 2300 W Alabama ST #95 Houston, TX 77098, Lamar High School, criss5946@yahoo.com

Introduction

As a high school student, I got an opportunity to work with Dr. Kono's group as an intern. Darius has been my mentor throughout this project and I am thankful to all the others who have given me lots of help.

The fundamental resonant frequencies of many molecules are located in the mid-IR range. These frequencies make trace gas detection possible. For these sensory systems, adequate sources and detectors are needed. This project focuses on developing materials for appropriate mid-IR sources. Engineers have used bandgap engineering to produce coupled quantum well (CQW) structures that have distinct electron states with controllable energies and symmetry which can be used for resonantly enhanced frequency transformation therefore producing second harmonic generation (SHG) into the mid-IR range. (Figure 1-a)

Research Problem

6.1-angstrom III-V semiconductor quantum wells (Figure 1-b), consisting of InAs, GaSb, and AISb, would be an ideal candidate for our research.

- Large conduction band offsets (~2.1 eV in InAs/AISb)
- Unique band alignment
- Large nonparabolicity
- Small effective mass

Figure 1-a

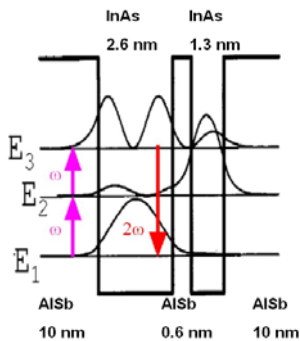
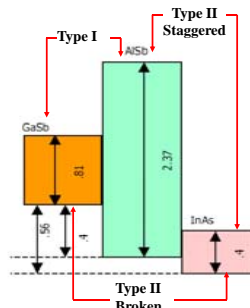


Figure 1-b



Methods

• MBE (Molecular Beam Epitaxy)

- Used to create 6.1-angstrom III-V semiconductor quantum wells
- MBE allows us to grow samples in one epitaxial layers at a time
- With its slow deposition ability, MBE enables us to create samples with more precision and control

• Geometry for ISBT (Intersubband Transition)

- 45 degree parallelogram geometry (Figure 2-a)
- Allows for multiple bounces inside of the sample
- Only the component perpendicular to the quantum wells is active (i.e. Ez component, when the sample is grown in the Z direction)
- We divide the p-polarized spectra (active) by the s-polarized spectra (inactive) to normalize our data
- Surface reflection of light is the same for both polarizations

• Geometry for IBT (Interband Transition)

- Only s-polarization for hh-e transitions; both polarizations for lh-e transitions
- Thus, the incident light can be normal to the sample (Figure 2-b)

Figure 2-a

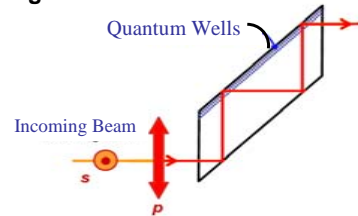
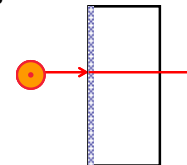


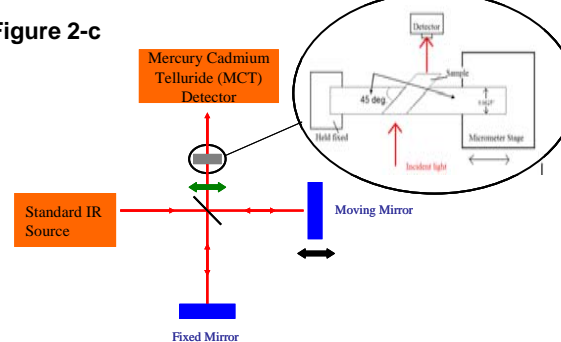
Figure 2-b



• FTIR

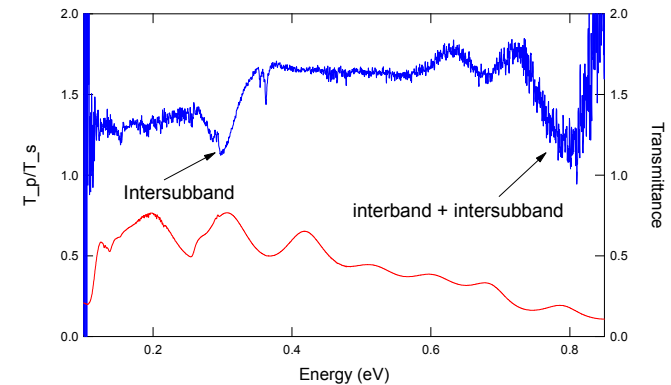
- We have used Fourier-transform infrared spectroscopy (Figure 2-c) to measure the absorption spectra of our quantum well structures.

Figure 2-c



Results

FTIR Spectroscopy of InAs/AISb Coupled Double Quantum Wells



- **Parallelogram Geometry (ratio of p- to s-polarized transmittance)**
 - Intersubband absorption at 0.28 eV
 - Mixed interband/intersubband absorption above 0.8 eV
- **Normal Incidence (s-polarized transmittance)**
 - Descending plot matches interband absorption shown on ISBT

Conclusions

- Learned how to measure intersubband and interband transitions using FTIR
- Able to determine the appropriate light source and detector (FTIR) for collecting data
- Analyze data efficiently with using different programs like Igor and Excel
- Learned to experiment with the well-adjusted settings
 - polishing samples into sufficient geometry
 - purging in order to attain more reliable results
- Learned to work as a team and interact skillfully (Group meetings, Presentations)

Future Goals

- Observe ISBTs in coupled QW structures with desired transition energies and splitting (experiment and theory agreement)
- Observe Resonantly enhanced SHG at observed transition energies
- Replace the OPA with conventional QCL, to create a QCL that can efficiently convert 6 μm light to 3 μm light

