

Terahertz Microelectronics Transceiver



PI : Mike Wanke • PM: Greg Hebner

Contributors: Ron Allman, Chris Ablett, Christian Arrington, Todd Barrick, Igal Brener, Weng Chow, Mike Cich, Kevin Fortier, Chuck Fuller, Aaron Gin, Albert Grine, Terry Hargett, Roy Jorgenson, Mark Lee, Maytee Lerttamrab, Paul Miller, Chris Nordquist, Michael Pack, John Reno, Adam Rowen, Sally Samora, Eric Shaner, Larry Stephenson, Ines Waldmuller, Mike Watts, and Erik Young

Problem

- THz offers innovative and potentially disruptive capabilities in applications such as:
 - "See-through" imaging for high-resolution concealed object detection & identification
 - Chemical detection & identification via highly distinctive THz absorption/emission signatures
 - High spatial resolution radar / High data rate secure wireless telecommunication
- Unlike microwaves & infrared, THz lacks a solid-state microelectronic technology base
 - Continuous wave THz sources of sufficient power tend to be big, tube-based oscillators
 - Strong atmospheric absorption makes THz signal-to-noise requirements very difficult
- *This project sought to build a foundational integrated microelectronic technology for THz*

Replace big tube technology:



1 m
THz Molecular Gas Tube Laser

with microelectronics:



First Integrated THz Mixer on a Chip

All Solid-State Approach

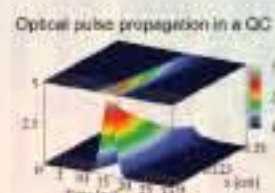


- Compact, reliable, & scalable to high-volume, low marginal cost fabrication
- Multidisciplinary team needed: device physics, rf engineering, mechanical and process engineering, material science ...
- Resource intensive: state-of-art semiconductor growth & microfab, computational modeling & design, rf & optical test...
- Increased degree of integration throughout program
 - discrete component system integration
 - rectangular waveguide integration
 - monolithic integration

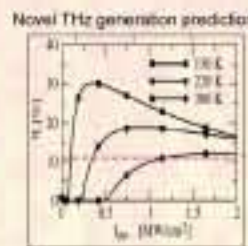


Results

Developed Unique Device-modeling Codes

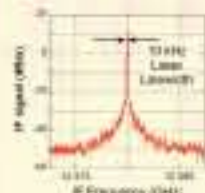


- Developed a multi-threaded, self-consistent design code, combining multiple sets of physics in same code.
 - k.p bandstructure
 - Poisson solver
 - microscopic scattering
 - radiation fields

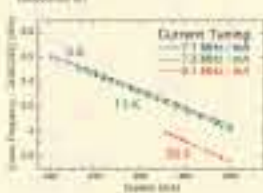
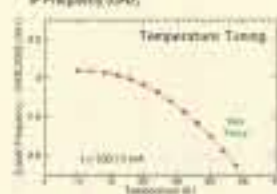


- Modeled THz QCL physics, novel structures for possible high-temperature THz generation, and unexplored quantum coherence effects.
- Created an automatic design tool ideal for creating structures to isolate specific physical mechanisms.

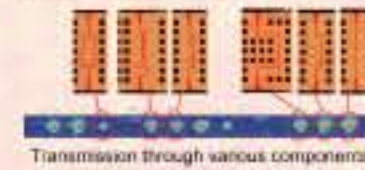
Quantum Cascade Laser Spectroscopy



- Demonstrated high-resolution spectroscopy of molecular vapor using tunable THz QCL.
- Explored laser tuning ranges and spectra-purity.
- Produced 8% gain-bandwidth in THz QCLs, offering the possibility to broadly tune QCLs for molecular identification applications.



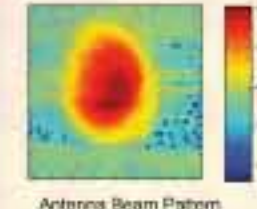
First Demonstration of Surface Metal Micromachining of THz Waveguide Components



SEMs of Waveguides



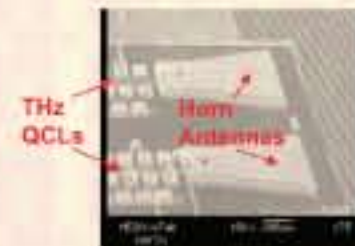
EM modeling of Magic Tee



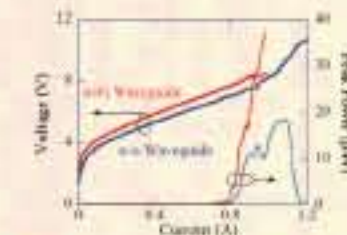
Antenna Beam Pattern

- Demonstrated THz components (waveguides, bends, tees, and couplers) needed for THz integrated circuits.
- Achieved low propagation and bend losses.
 - 1.4 +/- 0.15 dB/mm
 - 0.15 +/- 0.15 dB
- Characterized THz antennas offering path to spatial output-beam mode control.

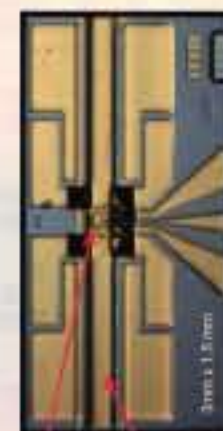
The First Integrated QCL and Rectangular Waveguide



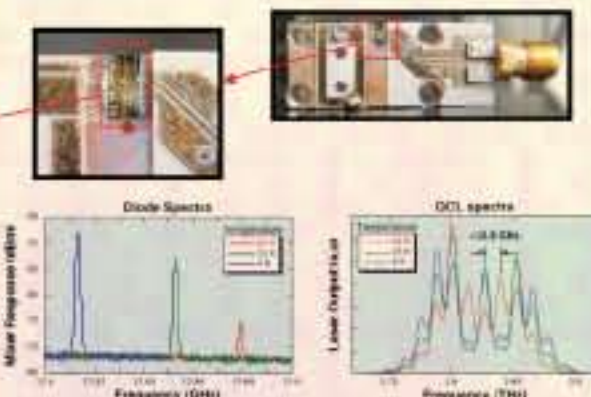
- Combines optical and microwave technology, opening the path for THz integrated circuits.
- THz energy emitting from antenna demonstrates it can be used for a quasi-optical transceiver local oscillator
- Promises enhanced beam quality, improved applicability, and pathway to broadly tunable THz lasers.



The First Integrated THz Mixer Fundamental Goal of THz Grand Challenge



Schottky Diode Mixer
THz Quantum Cascade Laser



- Enables robust, compact THz transceivers
- Opens path to THz heterodyne imaging arrays.
- Removes coupling/alignment difficulties with discrete components.

Significance

THz image of concealed object using QCLs



- TpT will be a core technology making THz practical outside the laboratory
- All solid-state THz technology will improve reliability, reduce size/weight, and reduce cost in future THz systems
- Opens up major new capabilities of interest to Sandia & Sandia customers

