Diode Laser Pumped Far-Infrared Local Oscillator Based on Semiconductor Quantum Wells

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Terahertz Field: A Technology Gap

- Need for compact THz sources
  - Frequency too high for electronics and too low for photonics
  - No mature solid state technology for generation and detection

Existing THz Sources and Shortcomings

- Molecular lasers pumped by another laser (e.g., methanol laser pumped by CO$_2$ laser used in the EOS satellite)
- Free-Electron lasers
- P-Ga lasers under B field
- Parametric generators, photomixers in non-semiconductors
- Ultrastable laser generation of oscillating charge carriers

Shortcomings:
Low output power, low efficiency, low temperature pulse operation, bulky size (need big pump lasers), broadband (not lasers)

Applications of A THz Laser

- Terahertz modulation and switching
- Chemical, biochemical, and astrobiological detection and sensing
- Materials and security inspection
- High bandwidth, secure data link
- ... many more applications

Previous Optical Pumped LW Generations

- CO$_2$ laser pumped GaAs/AlGaAs QWs emitting 15.5mm (Paris-Sud)

Optically Pumped Sb-based Intersubband Generation—— Whys

- Why Intersubband?
  - Long wavelength generation
  - Reduced Auger processes
  - Large transition matrix elements
- Why Sb-QWs? (unique bandedge lineups)
  - Flexibility in wavelength design
  - Deep conduction band wells allowing NIR (diode) laser pumping
Optically Pumped Sb-based Intersubband Generation—— Why

- Why optical pumping?
  - Less reliant on population inversion
  - Utilization of resonant nonlinearities
  - Lower carrier concentration and lower free carrier absorption
  - Absence of heavily doped layers for contacts and injectors
  - Potential integration if diode lasers used as pumps

InGaAs/InP/AlAsSb QWs (Lattice-Matched to InP, 5.9A)

Raman Enhanced Optical Gain

Pump Intensity Dependence of THz Gain

Pump-Probe Interaction Induced Raman Shift

THz Laser Gain in InGaAs/InP/AlAsSb QWs
Diode-Laser Pumped Difference Frequency Generation (InGaAs/InP/AlAsSb QWs)

InAs/GaSb/AlSb Nanostructures

4-Level Laser Scheme  3-Level DFG Scheme

InAs/AISb Double QWs: DFG Scheme

Sb-Based Triple QWs: Laser Scheme

Exciton State Pumped THz Generation

Liu and Ning, In Nonlinear Quantum Materials, Fundamentals, and Applications, OSA Digest, 2000

Liu and Ning, 1999, unpublished