Properties of Silicon-Germanium Terahertz Devices

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Silicon Germanium (SiGe) optoelectronic devices are attractive because of compatibility with silicon integration and fabrication techniques. Silicon based optoelectronic devices for use in the terahertz (THz) region of the electromagnetic spectrum exhibit lower free-carrier and reststrahlen-band absorption than in III-V compound semiconductors. Because the nature of the bandgap is irrelevant for quantum well devices utilizing intersubband transitions, these transitions can be applied to fabrication of THz emitting and detecting SiGe quantum well devices. THz quantum well emitters based on intersubband transitions have the advantage of good coupling between the neighboring stages of the device. The quantum efficiency and output power scale with the number of active stages employed.

Current pumped THz emitting devices have been fabricated based on intersubband transitions in SiGe quantum wells. The SiGe layers were grown by Molecular Beam Epitaxy (MBE) on silicon substrates. The spectral lines occurred in a range from 5 to 12 THz depending on the quantum well width, Ge concentration in the well, and device temperature. By a calibration carried out using the known spectral emission from a blackbody radiator, a time-averaged power of 15 nW was extracted from a 16 period SiGe/Si superlattice with quantum wells 22 Å thick, at a device temperature of 30 K and a drive current of 550 mA. A net quantum efficiency of approximately 3 x 10^{-4} was calculated from the power and drive current, 30 times higher than reported for comparable quantum cascades utilizing heavy-hole to heavy-hole transitions and, taking into account the number of quantum well periods, approximately four times larger than for electroluminescence reported previously from a device utilizing light-hole to heavy-hole transitions. Emitters and detectors based on SiGe intersubband transitions open up a new range of THz frequencies, and the time averaged power emitted from these devices can be increased by using optimized structures which can provide the basis for a SiGe intersubband quantum cascade laser.

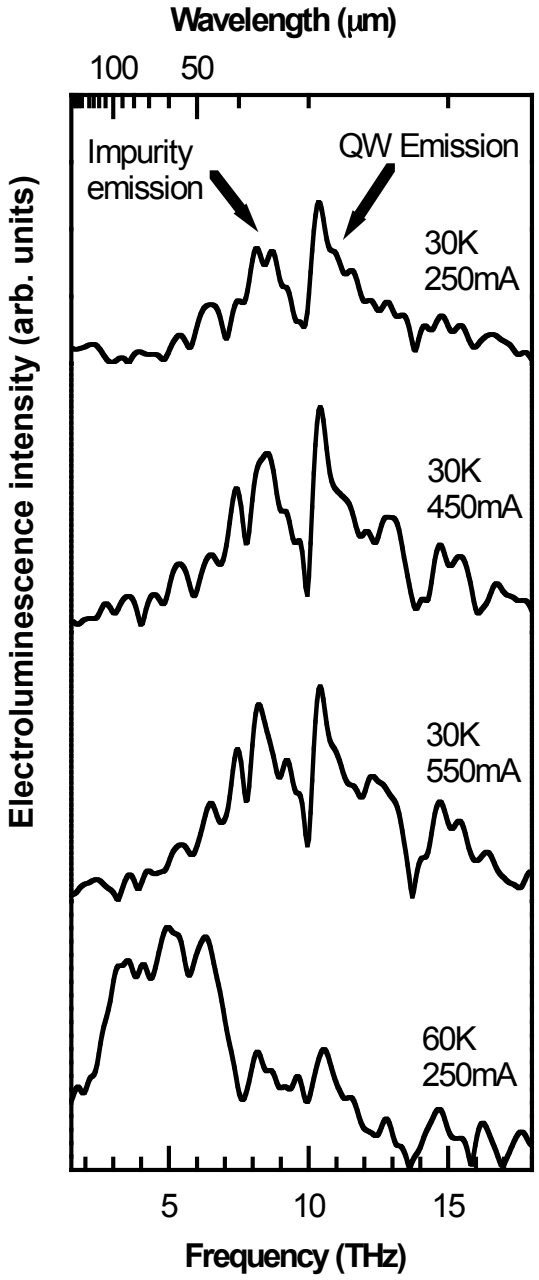

Fig 1. Electroluminescence observed in top-emission geometry at two different temperatures and various drive currents. Quantum well emission can be observed separately from impurity emission in the first 3 curves at 30 K.