Designing of a "Double Well" 17µm Wavelength Quantum Cascade Laser without an Injector Region

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Quantum Cascade Lasers can be designed to emit light out of a wide range of frequencies making them a convenient tool for trace gas sensor systems as well as body tissue gas sensing. What allows the wide range of possible lasing wavelengths is the QCL's lasing wafer's layered structure which creates sets of quantum square wells whose energy level separation correspond to the desired wavelength for the emitted light. By putting a voltage across the wafer, electrons flow through the layers relaxing from the higher energy levels to the lower ones, emitting photons or Longitudinal Optical (LO) phonons as they do so. Here, we aim at designing a 17µm laser, with no injector region and with each active region being composed of a double well. The width of the wells and barriers of the double wells determine the frequency of the emitted light. Moreover eliminating the injector region allows for a grater intensity of emitted light because a larger number of active regions can be included in the laser. Models of the well potentials are tested using a Schrödinger solver program which calculates numerically wave functions and energy levels for specific sized wells. To optimize the efficiency of the laser there has to be a net flow of electrons that relax from the higher energy level to the lower one to emit photons; to ensure this, a system of 3 energy levels, can be set up by using 2 wells separated by a small barrier in such a way that the distance between the 1st and 2nd energy level is equivalent to an LO phonon while the distance between the 2nd and 3rd energy level will result in a photon. This is shown in Fig.1. By using such a design a good population inversion process is created where the electrons will fall from the 2nd to the 1st faster then from the 3rd to the 2nd. While, up to now the widths of the wells have been found especially by "trial and error", here we attempted to solve for them analytically. To accomplish this, an expression relating the energy of the double wells and the lengths of the wells and barriers has to be determined and given the desired energies the widths could be solved for.

This research is supported partly by PCCM (NSF-MRSEC) and Mirth(NSF-ERC)

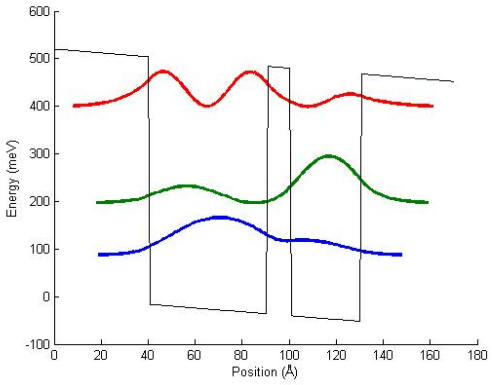

Fig1. Sample of a "double square" well potential with wave functions and energy levels. With the blue energy level being the 1st, green the 2nd and red the 3rd.