Development of Bipolar Cascade Laser with an Emission Wavelength of 0.98 μm

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Bipolar Cascade Lasers (BCLs) differ from typical semiconductor laser diodes by its ability to potentially produce more than one photon for every carrier injected into the device. This ability to achieve a quantum efficiency greater than 100% is accomplished by electrically and optically connecting more than one active region in series. Within MIT, gas source molecular beam epitaxy technology is used to deposit the epilayers necessary to create a BCL on GaAs substrates. These lasers contain two active regions that are connected in series by a tunnel junction, in which each active region contains an 8 nm thick $In_{0.2}Ga_{0.8}As$ quantum well with GaAs barriers. The tunnel junction consists of a highly doped p-n junction placed in reverse bias with respect to the overall laser structure. The BCL operates by first injecting a carrier into the first quantum well, where it experiences a radiative interband transition. The carrier then tunnels from the first active region to the second active region, where it undergoes another radiative interband transition. Hence, a single injected carrier experiences multiple radiative transitions, thereby achieving greater than 100% quantum efficiency.

The tunneling event in the laser is critical to its operation. The probability of tunneling is proportional to the bandgap of the semiconductor material used in the junction. A cascade laser has already been demonstrated using a GaAs tunnel junction. The incorporation of indium into the tunnel junction will lower the bandgap of the material and should increase the tunneling probability, as the carriers now face a smaller tunneling energy barrier. Several tunnel junctions with different indium compositions are being studied to better understand this relationship.

Optical communication requirements make it highly desirable to have single mode lasers. A novel laser structure is being studied which combines the cascade laser design with an antiresonant cavity to produce single mode emission. The Antiresonant Reflecting Optical Waveguide Bipolar Cascade Laser (ARROW-BCL) has been studied theoretically and is moving towards the realization of an actual device structure. An ARROW-BCL laser could be used to effectively couple to an optical fiber while producing net optical gain, making the structure desirable for communications applications.